EXAMINING PRE-SERVICE SCIENCE TEACHERS' DEVELOPING PEDAGOGICAL DESIGN CAPACITY FOR PLANNING AND SUPPORTING TASK-BASED CLASSROOM DISCUSSIONS

by

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Teachers face many challenges as we move forward into the age of the *Next Generation Science Standards (NGSS)* (Achieve, Inc., 2013). The *NGSS* aim to develop a population of scientifically literate and talented students who can participate in the "innovation-driven economy" (p. 1). In order to meet these goals, teachers must provide students with opportunities to engage in science and engineering practices (SEPs) and learn core ideas of these disciplines.

This study followed pre-service secondary science teachers as they participated in a secondary science teacher preparation program intended to support the development of their pedagogical design capacity (Brown, 2009) related to planning and supporting whole-class task-based discussions. Teacher educators in this program designed an intervention that aimed in supporting this development. This study examined a particular dimension of PDC – specifically, PSTs effective use of resources to plan science lessons in which students engage in a high demand task, participate in SEPs, and discuss their work in a whole-class setting. In order to examine the effectiveness of the intervention, I had to define PDC *a priori*. I measured PDC by documenting how/whether PSTs engaged in the following instructional planning practices: developing Learning Goals, selecting and/or designing challenging tasks, anticipating student thinking, planning for monitoring student thinking, imagining the discussion storyline, planning questions, and planning marking strategies.

Analyses showed a significant difference between baseline lesson plan scores and Instructional Performance scores. These findings suggest these patterns and changes were directly linked to the teacher preparation program. The mean increase in Instructional Performance scores during the course of the teacher preparation year further supports the effect of the teacher preparation coursework.

Pre-service teachers with high pedagogical design capacity continually integrated the ambitious planning practices they learned in their coursework. In contrast, pre-service teachers with low pedagogical design capacity appeared to appropriate the vocabulary and language they learned in coursework, but did not integrate these practices at a high level. This study suggests that pre-service teachers who receive intensive instruction on ambitious planning practices for task-based discussion effectively develop the pedagogical design capacity to plan for task-based discussion lessons.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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1.0 THE RESEARCH PROBLEM

Teachers will face many challenges as we move forward into the age of the *Next Generation Science Standards (NGSS)* (Achieve, Inc., 2013). The *NGSS* aim to develop a population of scientifically literate and talented students who can participate in the "innovation-driven economy" (p. 1). In order to meet these goals, teachers must provide students with opportunities to engage in science and engineering (SEPs) practices (Figure 1.1) and learn core ideas of these disciplines.

<u>Science and Engineering Practices (SEP) for K-12 Classrooms</u>

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

Figure 1.1: Science and Engineering Practices for K-12 Classrooms. From The Next Generation Science Standards (Achieve, Inc., 2013)

To begin with a clear vision of what instruction that aims to meet the *NGSS* goals might look like, consider the following vignette[1] of Mr. Gates' classroom (from Cartier, Smith, Stein, & Ross, 2013).

[1] The vignette is intended to make salient certain types of teacher-student interactions and the level and type of thinking required to teach with understanding. As such, the vignette is an enhanced composite that highlights specific aspects of instruction.

In Mr. Gates' seventh-grade life science class, the early units of the course focus on natural variation and patterns of growth in organisms. In order to study these patterns and variation, students were gathering data on the growth of Wisconsin Fastplant (*Brassica rapa*). At the end of this lesson arc, Mr. Gates wanted his students to understand three scientific ideas:

1) Natural variation exists in any population of organisms. To identify patterns and correlations, one needs to use mathematical tools that make it possible to describe "typical" growth (including the spread of values that can be considered typical). Typical growth in Fastplants is described by range and shape. This is often the case in populations of organisms.
2) Fastplant growth is characterized by an s-shaped growth curve, where stem length increases slowly for the first 10-12 days and then increases quite steeply for about 7 more days. Following pollination (around Day 18), the stem growth slows considerably.
3) The growth patterns of Fastplants can be explained by considering where the plant is "spending" its energy resources at various stages of its life cycle and how that is advantageous (e.g., following pollination the plant does not invest energy resources in additional flower production or stem growth, but instead uses its energy to nurture the growth of seed pods and seeds).

In preparation for this unit and in consideration of time, Mr. Gates planted Fastplant seeds in containers to allow time for seed germination. He planted 6 plants in each container. On Day 10, the students received individual plant containers. Students decided to measure "growth" of the plants every 2-3 days for 11 days, marking a piece of string to indicate the plant height and then putting the sting on a ruler to get the height in cm. Once students had finished collecting data on the plants, Mr. Gates wanted them to create a representation for their data that would enable them to answer the question: **How would we describe the growth of a typical Fastplant?**

Mr. Gates told his students that they could represent their data any way they wanted. He also told them they could use their raw data (their actual recorded values) or transform their data in some way, which would be depicted in the representation. He emphasized that students needed to be able to explain: 1) what values they plotted; 2) how they got those values; and 3) why their representation helps to answer the question, "How would we describe the growth of a typical Fastplant?" In this first discussion about the Fastplant data, he hoped to focus primarily on learning goals 1 and 2.

As students worked on the task in their groups, Mr. Gates circulated among the 8 groups, made note of the different approaches the students used and asked clarifying questions. In addition, he pressed students to think about what information they needed to create their representations, why they chose to represent their data the way that they did, and how they could describe typical Fastplant growth using their representation.

Mr. Gates noted that the groups were using different approaches to represent their data -- different formats (bar graphs, pictures, line graphs) and measures of central tendency (e.g., mean, range). He thought that group 1 used the most unusual approach of all, choosing to represent their data by creating pots for each plant indicating the length of each plant in the pot at the indicated time points. Mr. Gates noticed that although this approach provided information about plant height, there might be some difficulty in interpreting the representation.

Although he instructed each group to hang their poster on the wall, he quickly decided to focus the discussion on the representations produced by Group 7, Group 1, Group 8 and Group 5. He felt that this set would highlight a range of approaches for representing the data and, he hoped, make clear that some representations provided more insight into typical plant growth than others.

He began by asking *Ryanne from Group 7* to share her group's work with the class. Since three of the groups had produced line graphs, this seemed like a good place to start. Although there were four members of the group, it had been a few days since Ryanne shared ideas during a whole class discussion and Mr. Gates wanted this student to have an opportunity to demonstrate her understanding.

Once Ryanne reached the front of the room, she explained that her group measured the height of each plant and found that from day 13 to 21 the plants grew a lot. So, she explained, they chose to represent their data in a line graph that depicted the growth of all six of their Fastplants in a different color.

Mr. Gates then posed a question to the class asking, "What are some things you notice about the representation *Group 7* has created?" Several students shared their ideas:

Juan: You can easily see the day of measurement and the height of the plants.
Mr. G.: Okay, Juan, where do you see that?
Juan: The graph has axes that are labeled and there is a key so we can tell which plant is which.
Mr. G.: Okay, so the x and y axes allow us to understand what data is represented. Class, do we agree with that?
Trina: I do. You can also see the height of all the plants on any day they were measured.
Mr. G.: Okay, so what does this graph tell you about the plants' growth?
Trina: The plants get taller over time.
Mr. G.: Okay, the plants get taller over time. What else?
David: Some plants are growing faster and taller than others.

Tessa: The plants start out growing slowly, then they really grow a lot, and then they sort of don't grow much.

At this point, Mr. Gates asked the class if they could "see" what Tessa described in the graphs. Marcela, from Group 8, volunteered, "Each of the graphs has the same basic shape that sorta looks like an S." Mr. Gates asked the class whether the line graphs that Groups 2 and 3 had produced (which were displayed for all to see) had this same general appearance. The students all nodded in agreement. Moses, from Group 3, commented, "Yeah, no matter whether it's a tall plant or a short plant, it still has the same shape." Mr. Gates noted, "So, could we say that an s-shaped growth curve is typical for Fastplants?" Many students again nodded their agreement. England added, "You can really see from all the line graphs that the plants have an s-shape growth curve over the time that we measured them." Mr. Gates explained that it was typical for these plants to grow slowly at the beginning of their life cycle followed with a steep increase in growth that can be seen in these graphs. Although the idea *typical growth* had not been specifically raised by the first group, by building on what Tessa had noticed about the plants, Mr. Gates was able to get students to consider an s-shaped growth curve as a way to describe typical growth (p. 34-40[2]).

Mr. Gates' lesson reflects how a teacher might enact the vision of the *NGSS* – specifically, how he might provide and support opportunities for students to engage in science and engineering practices that mirror those in the professions (Figure 1.1). Mr. Gates' students had an opportunity to plan and carry out an investigation (SEP 3) as they measured the Fastplants' growth. During these investigations, students collected and represented data on plant height. As students constructed their representations, they interpreted and analyzed their data (SEP 4) in various ways including using measures of central tendency. Mr. Gates asked the students to construct an explanation (SEP 6) detailing how their representation answered the central question of the investigation. When the whole class discussion began, students communicated their group's findings and Mr. Gates prompted students to critically examine and evaluate the work of their classmates (SEP 8).

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[2] Reprinted with permission from the National Council of Teachers of Mathematics.

In classrooms such as Mr. Gates', where students are engaged in SEPs, teachers face the additional challenge of designing instruction so that students are wrestling with the underlying science ideas at a high level (Engle, 2011; Engle & Conant, 2002; Stein & Smith, 2011). To design instruction in this way, a teacher must first identify key learning goals to focus the lesson and then choose a task that is robust enough to support students' thinking and learning in the discipline. After selecting (or designing) a task, the teacher must then imagine in detail the ways in which his/her students might engage with the task, design appropriate tools and scaffolds to support and direct that engagement, and plan for ways to monitor students' work during the task.

Clearly, this work of instructional design is complex. In this study, I investigated the extent to which pre-service secondary science teachers develop the capacity to design instructional opportunities for students through: (1) collaboratively completing a challenging task that involves participation in one or more SEP, and (2) actively participating in a structured class discussion in order to share ideas and develop consensus understanding of key patterns and/or disciplinary concepts. In the sections that follow, I provide a brief summary of the research base for the proposed study, describe the specific research questions in detail, and discuss the potential contributions and limitations of the work.

1.1 BACKGROUND

1.1.1 Teachers as Instructional Designers

In order for the ambitious vision of science instruction presented by the *NGSS* (Achieve, Inc., 2013) to become a reality in secondary schools, teachers must design instruction with these goals in mind. By using various curriculum resources (e.g. texts, online lesson plans and resources, standards, curriculum materials, etc.), teachers can design instruction that supports students' engagement in SEPs and their sense-making related to key disciplinary phenomena. The ability to navigate through the vast number of these resources and to design instruction appropriate for each group of students is the essence of what Brown (2009) terms *pedagogical design capacity (PDC)*.

Not surprisingly, many teachers rely on curriculum materials as they design their instruction (Ball & Cohen, 1996; Beyer, Delgado, Davis, & Krajcik, 2009). However, many of these curriculum materials do not provide teachers with the needed support to design and teach lessons in which students participate in challenging tasks and have opportunities to engage in the science and engineering practices advocated by the *NGSS*. Moreover, it can be problematic if teachers interact with curriculum materials chiefly by "offloading" (Brown, 2009) responsibility for decision-making (i.e. by following the curriculum materials as written) rather than by critically drawing from the materials during the instructional design process. Often, the materials used are inadequate to support student sense-making through inquiry. Thus, teachers must use the available curriculum materials in critical and strategic ways and also draw upon other resources in order to design instruction that supports students' science engagement at a high level.

This study is situated in the perspective that critical and intentional use of instructional models and curriculum materials may play an important role in teachers' planning of high-level task-based discussions (Brown, 2009; Beyer & Davis, 2009; Cartier et al., 2013; Davis & Smithey, 2009; Remillard, 2005; Zembal-Saul, 2009). More specifically, this study examined pre-service secondary science teachers' (PSTs') developing PDC as they draw on various resources – including texts, online resources, and instructional models presented in their pedagogy courses - to plan for and implement high-level task based discussions. In the sections that follow, I provide background that addresses why this type of instruction is worthy of focus with particular emphasis on the importance of science discourse in classrooms.

1.1.2 The Importance of Science Discourse in Classrooms

Students in today's science classrooms must have opportunities to develop the practices and skills used in science and engineering professions in order to be productive members of our technologically advanced society (Achieve, Inc., 2013; Duschl, 2008). Discourse – or students engaging in talk with one another around disciplinary concepts – is a key component of classrooms where students are engaged productively in SEPs. While discourse is necessary to achieve the *NGSS* goals, it is also a challenge for teachers to orchestrate (Grossman et al., 2009a; Stein, Engle, Smith, & Hughes, 2008).

As teacher educators, our goal is to provide pre-service teachers with conceptual and practical tools to support their learning and teaching (Grossman, Hammerness, & McDonald, 2009b), and we are particularly interested in supporting their skills related to orchestrating productive classroom discussion. Researchers have identified many different pedagogical strategies designed to aid teachers in supporting robust discussions and supporting students in the types of discourse that increase deep understanding. Pedagogical frameworks, such as Investigating and Questioning our World Through Science and Technology (IQWST) (Berland & Reiser, 2008; McNeill, Lizotte, Krajcik, & Marx, 2006), the evaluate-alternatives model (Sampson & Grooms, 2009), the Accountable Talk framework (Michaels, O'Connor, & Resnick, 2008), and the Five Practices model (Smith & Stein, 2011; Stein et al., 2008) provide teachers with strategies and techniques that support student learning through discussion. These frameworks have several features in common. Specifically, each emphasizes the need for teachers to (1) choose appropriate instructional content that promotes discourse, (2) guide and support students through scaffolding, and (3) hold students accountable to classroom and scientific norms.

Of these frameworks, teacher educators at a large urban university in the Midwest selected the Five Practices model to support PSTs as they plan for and design science discussions. Prior to this study, teacher educators spent three years integrating the Five Practices model into pedagogy courses at the university, which is described in greater detail in Chapter Three. This early design work produced evidence that the model can help teachers achieve the goal of designing demanding tasks and supporting students' engagement in them (Cartier et al., 2013).

1.1.3 The Five Practices Model for Orchestrating Productive Discussions

Often, teachers struggle in planning for and implementing whole class task-based discussions (Cartier et al., 2013; Smith & Stein, 2011; Stein et al., 2008). It is difficult for teachers to provide opportunities for students to share their thinking while still maintaining control over the discussion and ensuring that the desired learning goals emerge. Stein et al. (2008) explain that a major challenge for teachers is orchestrating whole-class discussions around instructional tasks; teachers often have difficulty utilizing the variety of student responses to particular tasks and incorporating them into a coherent line of dialogue. In order to aid teachers in effectively using student responses in a whole class discussion, they proposed a model that is designed to make teaching more manageable. By supporting teachers in learning how to *anticipate* student responses, *monitor* student responses to tasks, *select* students to present their responses, purposefully *sequence* the students' responses, and *connect* the ideas through discussion, the model guides teachers through the processes of preparing for and supporting whole class discussions (Smith & Stein, 2011; Stein et al., 2008).

1.1.4 Implementing Discussions Around High-Level Tasks

In order to implement task-based discussions that support students' learning of disciplinary core ideas and SEPs, tasks must be high-level, or cognitively demanding (Smith & Stein, 2011; Cartier et al., 2013). Researchers characterize instructional tasks in many ways. One way to is to identify and describe the level of cognitive demand required of the students (Doyle, 1983; Stein, Grover, & Henningsen, 1996). A high cognitive demand task requires students to invest a significant amount of effort in making sense of the underlying phenomena or concepts being studied (Doyle, 1983).

Teachers can implement high cognitive demand tasks at different points in an arc of lessons and/or can focus on a variety of SEPs. This study focuses on three particular task types that, when used together, provide opportunities for students to participate and engage in all eight science and engineering practices described in the *NGSS*. These three task types are: (1) experimentation, (2) data representation, analysis, and interpretation, and (3) explanation (Cartier et al., 2013). Experimentation tasks are tasks in which students engage in protocol design, critique, and/or follow a protocol to gather data. Data representation, analysis, and interpretation tasks involve students representing data and interpreting patterns. The students in Mr. Gates' class, described in the vignette presented earlier in this chapter, engaged in this second category of science tasks. Finally, during explanation tasks, as the name implies, students provide explanations for patterns and phenomena.

1.1.5 How Teachers Learn

Traditional approaches to teacher education center on teacher learning of theoretical knowledge divorced from the context of classroom practice. In contrast, researchers argue that teacher learning should be situated in the context of practice (Ball, Sleep, Boerst, & Bass, 2009; Feiman-Nemser, 2001; Putnam & Borko, 2000). Ball and Forzani (2009) argue that developing the capacity to implement certain high-leverage practices should be the focus of teachers' professional preparation. Focusing on a set of core, or high-leverage, practices in teacher education allows pre-service teachers to begin to develop a set of necessary skills to successfully support student learning through inquiry (Grossman et al., 2009b). In the secondary science program in which this study was based, teacher educators adopted this practice-based focus in which PSTs participated in the high-leverage practice of designing high-level tasks where students engage in task-based science discussions.

Using the Grossman et al. (2009a) framework, teacher educators provided teachers with opportunities to approximate carefully decomposed high-leverage practices, like orchestrating discussions (Grossman et al., 2009b). In order to support teachers' ability to successfully orchestrate task-based discussions, teacher educators decomposed the Five Practices model to highlight the planning practices necessary to support these discussions. Teacher educators then developed or selected representations that depict the practices and support PSTs in approximations of them.

1.2 THE STUDY

1.2.1 Purpose & Research Questions

Researchers have examined the implementation of the Five Practices model, particularly in mathematics (Eskelson, 2013; Smith, Cartier, Eskelson, & Ross, 2013; Stein et al., 2008). However, PDC in conjunction with implementation of the Five Practices was not a focus of these studies. Additionally, few researchers have studied the development of PDC related to task-based science discussions. Consequently, little is known about the ways in which PSTs use curriculum materials and available resources as they plan for and implement productive whole-class discussions and the types of scaffolds, models, and learning structures that can support them in doing so.

This study followed PSTs as they participated in a secondary science teacher preparation program intended to support the development of their PDC related to planning and supporting whole-class task-based discussions. Teacher educators in this program designed an intervention that aimed in supporting this development. As part of the teacher education program, the PSTs engaged in the following:

- Developed a shared vision of what disciplinary engagement looks like in secondary classrooms.
- Compared/contrasted instructional tasks and identified opportunities for engagement in the SEPs.
- Learned the components of a lesson plan and wrote a lesson plan using those components.

- Planned, taught, and reflected on whole-class task-based discussions in their field placements.

This study examined a particular dimension of PDC – specifically, PSTs' effective use of resources to plan science lessons in which students engage in a high demand task, participate in SEPs, and discuss their work in a whole-class setting. In order to examine the effectiveness of the intervention, I had to define PDC *a priori*. I measured PDC by documenting how/whether PSTs engaged in the following instructional planning practices: developing Learning Goals, selecting and/or designing challenging tasks, anticipating student thinking, planning for monitoring student thinking, imagining the discussion storyline, planning questions, and planning marking strategies. I studied how PSTs use resources during the instructional design process and whether they connect explicitly to these planning practices during reflection following implementation of task-based discussion lessons.

This dissertation study addressed the following research questions:

I. To what extent do PSTs draw on the *Five Practices Model* to support planning of task-based discussion lessons?

Specifically –

i. To what extent do they anticipate students' work on the task?

ii. To what extent do they plan for ways to monitor students' work during the task?

iii. To what extent do they plan specific questions to elicit, challenge, or extend students' thinking?

iv. To what extent do they plan or imagine a storyline for how they want the discussion to unfold?

v. To what extent do they plan to make connections across students' ideas and connect to disciplinary ideas?

vi. To what extent do they plan for specific marking strategies to highlight important ideas?

vii. To what extent do they purposefully select and sequence the ideas they want to emerge during the discussion?

a. What available *curriculum materials*, including texts, online resources, and standards, do PSTs use during planning of these lessons?

b. What other resources or frameworks do PSTs use to plan task-based discussion lessons?

II. To what extent does PSTs' use of various resources and planning strategies support or hinder their ability to create lessons in which students are engaged in a challenging task where they participate in SEPs and engage in discussion?

III. To what extent does PSTs' pedagogical design capacity (PDC) for task-based science discussion lessons change over the course of their teacher preparation program? Are patterns and changes related to specific learning opportunities or elements within the teacher preparation program?

1.2.2 Significance

This study addressed a number of important issues under the broader umbrella of PDC. First, few researchers have explored the development of PDC specifically related to designing high cognitive demand tasks where students engage in discussion (Beyer, 2009; Beyer & Davis, 2009; Eskelson, 2013; Forbes, 2009; Forbes & Davis, 2008; Smith et al., 2013). In the next chapter, I describe the research related to PDC and instructional design. In this study, using descriptive methods, I drew on data from PSTs in a secondary science teacher education program. I examined how the PSTs use the available curriculum materials, resources, and instructional models to plan for their instruction. Specifically, I focused on the types of curriculum materials and resources used as well as the adaptations and modifications made to those materials. Additionally, I examined the PSTs' use of the Five Practices model and other tools introduced during their coursework, as they plan for and reflect on their instruction. From this study, teacher educators can gain insight into how the Five Practice model supports the development of PDC in PSTs. Furthermore, this study provides insights and practical suggestions regarding how to design experiences for PSTs that support their developing PDC as science teachers. This study offers insight into how teacher educators might design learning contexts to support PSTs' planning for more authentic science practices.

Finally, this dissertation study contributes to the existing literature regarding the PSTs' use and adaptation of curriculum materials (Beyer & Davis, 2009; Forbes, 2009), as well as literature on supporting the development of teachers' PDC (Brown, 2009; Brown & Edelson, 2003; Forbes, 2011; Forbes & Davis, 2010). In addition, this study aims to design learning contexts for PSTs to equip them with the tools to design particular learning opportunities for their students where discussions are the principle learning structure and identify characteristics of successful design.

1.2.3 Limitations

This study investigated a small number (N=15) of PSTs in a single teacher education program. All participants in this study were enrolled in a graduate teacher preparation program at a large urban university in the Midwestern United States that culminated in a 7-12 certification in a content area science and Master of Arts in Teaching degree. In order to be accepted into this program, applicants must have an undergraduate science degree with a minimum 3.0 GPA. Thus, these PSTs may not be representative of all PSTs in the country.

Furthermore, the PSTs selected for this study were a sample of convenience. As such, these PSTs were not a representative sample of all PSTs and the findings are not generalizable to all PSTs or teacher education programs. However, the findings provide some evidence of the potential influence and usefulness of an intervention of this type and could be used as a guide for further research in teacher education. This study focused exclusively on planning practices and capturing PDC, but did not connect PDC with instructional practice. This study measured the instructional design capacity of PSTs, but did not address instructional efficacy or impact.

Additionally, during the 2013-2014 school year, I served as a co-instructor for the secondary science methods courses and as a clinical field supervisor. As such, I co-planned, instructed, and provided feedback to the PSTs on the various course assignments throughout the year, in addition to supporting the development of the PSTs during their clinical experiences. During the dissertation study, I served as a co-instructor for the secondary science methods course and as principal researcher for this study. Assuming both roles, it is essential that I define each. As instructor, I co-planned and facilitated class discussions, provided support for PSTs' use of the Five Practices model, and provided feedback on written assignments. However, I did not teach the all sections of the course related to lesson planning, nor did I provide feedback on the all lesson plans and assignments PSTs complete during the course. As principal researcher, I obtained consent at the start of the semester so that I could use the PSTs' work in my study. I also obtained additional consent from a small sample of PSTs so that I could interview them at various points during study. Serving as course instructor and principal researcher might limit the degree to which the PSTs remain open and honest in their answers, which is why the interviews were conducted after the completion of the fall and spring terms.

1.3 OVERVIEW

In the chapters that follow, I provide justification for and detailed information about the design of the study. In Chapter Two, I provide a thorough discussion of the research that informs this study and the theoretical framework on which it is based. Chapter Three details the context of the study itself, and the methods used to address the research questions. I describe the data sources and present the methods of collecting, coding, and analyzing the data. The results of the analyses described in Chapter Three are presented in Chapter Four. Chapter Five summarizes the results found in Chapter Four and discusses the implications of these results and possible explanations for them as well as provides recommendations for further study.

2.0 LITERATURE REVIEW

In establishing the groundwork for this study, I first explore research on providing learning opportunities for teachers through the relationship between teachers and curriculum materials and their role as instructional designers. I then describe learning contexts for professional practice. Third, I discuss the instructional tools and resources that support teachers' design of lessons that supports student engagement in the SEPs described in the *NGSS* (Achieve, Inc., 2013). Finally, I provide a description of the high-level tasks and resources to help beginning teachers learn to draw from curriculum materials and resources to enact the planned curriculum in their classrooms.

2.1 UNDERSTANDING TEACHERS' USE OF CURRICULUM MATERIALS

Curriculum materials and the ways in which teachers use those materials play an important role in their professional practice. Teachers' beliefs, knowledge, and resources impact their planning in a variety of ways. There is a growing line of research in education that examines the ways in which teachers use curriculum materials to engage in the work of teaching (Beyer, 2009; Beyer & Davis, 2009; Brown & Edelson, 2003; Davis & Krajcik, 2005; Drake & Sherin, 2006; Forbes, 2009; Forbes, 2013; Forbes & Davis, 2008; Grossman & Thompson, 2008; Pintó, 2004; Remillard, 2000; 2005). These studies detail the ways in which teachers' beliefs and knowledge about teaching, student learning, and the discipline influence how teachers draw upon and use curriculum materials to engage students in learning.

In the sections that follow, I discuss this research and outline perspectives on the teacher-curriculum relationship. First, I define and provide detail about the term “curriculum materials.” I, next discuss relevant research on teachers’ use of curriculum materials, specifically focused on pre-service teachers. Next, I describe the notion of teachers as instructional designers and pedagogical design capacity. Finally, I detail ways to support teachers as they interact with and use curriculum materials and articulate the frameworks used in this study to support teachers’ learning.

2.1.1 Defining Curriculum Materials

Curriculum materials take a variety of forms. Researchers use the term “curriculum materials” to describe the resources teachers use to design lessons that support students’ learning. Those materials include, but are not limited to, standards, lesson plans, textbooks, laboratory manuals and guides, curriculum programs, teacher-created materials, and professional publications (Grossman & Thompson, 2008), which Shulman (1987) describes as “tools of the trade for teachers” (p. 8). Typically teachers draw on these materials in order to plan lessons that promote students’ learning of canonical ideas (Remillard, 2005). In doing so, teachers create lesson plans that are refined and revised from year to year as they reflect on student learning and the emergence of new curriculum materials. Therefore, curriculum materials not only support student learning but also support teachers’ learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). Because researchers and educators interpret the term curriculum materials very broadly to include all the resources a teacher might use as they design instruction, it is important to note that I use the term here to describe the standards, textbooks, and other resources designed for teacher use as they design instruction that meets the goals set forth by the *NGSS* (Achieve, Inc., 2013).

2.1.2 The Relationship Between Teachers and Curriculum Materials

The relationship between teachers and curriculum materials is a dynamic one in which teachers critique, adapt, draw on, and enact curriculum materials while at the same time considering their needs and the needs of their students. Remillard (2005) describes curriculum use as "how individual teachers interact with, draw on, refer to, and are influenced by material resources designed to guide instruction" (p. 212). Using the available curriculum materials as a guide, teachers engage in a variety of design practices before, during, and after instruction. The ability of a teacher to select a task, modify, omit, or add to existing materials is dependent upon the quality of the curriculum materials and the teacher's own content knowledge (Brown, 2009). The teacher's capacity to analyze the available materials and craft instruction can often lead to lessons and tasks that do not meet the needs of students and/or are not robust learning experiences built around science concepts and practices (Beyer, 2009; Beyer & Davis, 2009; Brown, 2009; Brown & Edelson, 2003; Davis & Smithey, 2009; Forbes, 2009; Forbes & Davis, 2008).

2.1.2.1 Teachers' participation with curriculum materials

Curriculum research has focused on mathematics teachers' use of curriculum materials (Collopy, 2003; Lloyd, 1999; Remillard, 1999; 2000; Stein & Kim, 2009), and science teachers' use of curriculum materials, particularly elementary science teachers (Beyer & Davis, 2009; Brown, 2002; 2009; Davis & Smithey, 2009; Forbes, 2013; Forbes & Davis, 2008; Pinto, 2004; Schwarz et al., 2008). These studies described and examined teachers as actively participating with their curriculum materials to design instruction (Remillard, 2000). Teachers not only use curriculum materials, but also learn from those materials (Grossman & Thompson, 2008). Remillard (2000) described the ways in which two fourth-grade teachers used and learned from mathematics curriculum materials as more than just reading the textbook. She defined the teachers' "curriculum processes" (p. 335) as learning through: "reading the text, reading students, and reading tasks" (p.339). In reading the text, teachers move beyond simply reading the text to interpreting and selecting particular segments of texts to read as they designed tasks. The ways in which the teachers read and interpreted their curriculum materials influenced the selection, design, and/or invention of mathematical tasks. Differences in these two teachers' ideas about mathematics teaching and learning in addition to their teaching contexts and students lead to differences in the ways they used the same curriculum materials and designed varying tasks and learning opportunities for their students.

Stein and Kim (2009) reiterated this notion regarding teachers' participating with curriculum materials. Their study described the importance of supporting teachers to consider the abilities and knowledge of their students as they design tasks. In other words, teachers must critically examine their curriculum materials in an effort to plan learning opportunities for their students where they engage in deep thinking. If teachers simply follow a set of activities provided in the materials without understanding the purpose and underlying learning goals of those activities, they will have difficulty meeting the needs of their own students. Consequently, it is critical for teachers to consider their students' knowledge and preconceptions as they draw upon their curriculum materials to design tasks that support student learning.

Similarly, Brown (2002; 2009) examined middle school teachers' use of an inquiry-based science curriculum. He argued that the relationship between teachers and curriculum materials can be described in one of three ways: offloading, adapting, and improvising (Figure 2.1). When teachers utilized the curriculum materials as is following the tasks and activities without consideration of context, relying heavily on the materials as written, they offload the curriculum onto the learners. In adapting curriculum materials, or what Remillard (1999; 2000) calls invention, teachers modified the existing materials to create a planned curriculum influenced by their own beliefs and knowledge and those of their students. As teachers assumed more authority in their ability, or depending on the context, they crafted instructional episodes based loosely on the content provided in the curriculum materials, or invented their own tasks (Brown, 2002; Remillard, 1999; 2000). Brown (2009) explains that the planned curriculum may look very different for every teacher; a novice teacher may offload instruction because he is unfamiliar with the content, likewise, an expert teacher may offload when she utilizes materials directly from the curriculum because they help support her students in meeting the goals of the task.

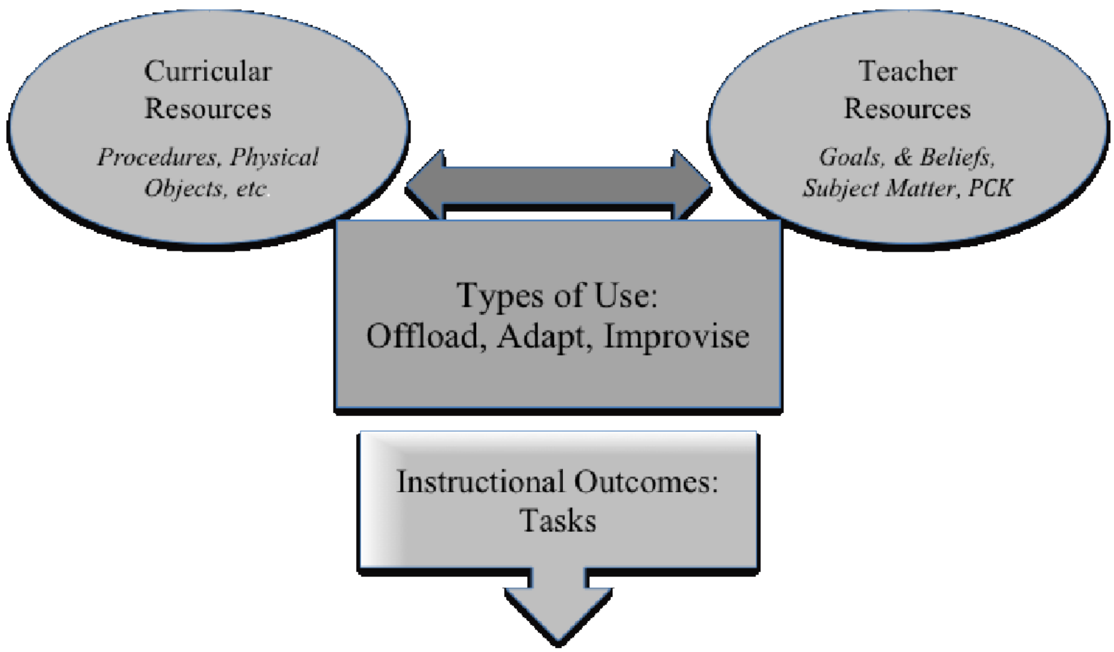


Figure 2.1: Relationship between teacher and curriculum resources in curriculum design (adapted from Brown & Edelson, 2003)

As teachers design instruction with respect to content and context, their goal is to design and plan lessons that will be implemented in their classrooms (Grossman & Thompson, 2008). Remillard (2005) introduces a framework to describe this relationship between the teacher and her curriculum materials (Figure 2.2). This framework details the complexity of the relationship between teachers and curriculum materials as described above. The teacher equipped with her content knowledge for teaching, including pedagogical content knowledge and subject matter knowledge (Ball, Thames, & Phelps, 2008), and her own beliefs and experiences actively participate with the curriculum itself. The curriculum, as described above, can be the variety of representations, tasks, textbooks, and laboratory manuals available for teachers' use.

Through this relationship, the teacher designs the planned curriculum based on particular contextual influences. The planned curriculum reflects the teacher's critical analysis of the available resources with respect to context and includes the selection and design of tasks that meets students where they are and supports the development of their conceptual understanding in the discipline. As the teacher implements the planned curriculum with his students, the enacted curriculum develops. The interactions between the students, teacher, context, and planned curriculum build a curriculum that differs from the planned curriculum. Because the teacher cannot anticipate all student preconceptions about certain canonical ideas, or plan for all events that might happen in any given lesson, she makes in the moment adaptations to the planned curriculum thereby creating the enacted curriculum. The teacher can then use this enacted curriculum as they plan for and build subsequent lessons from year to year.

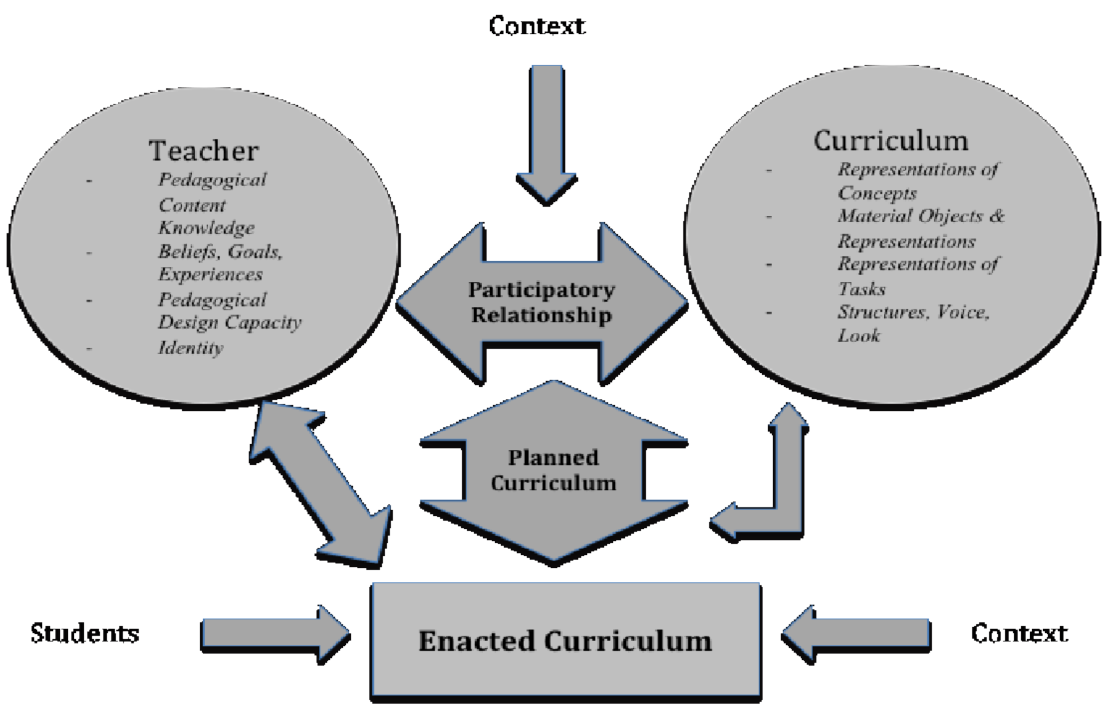


Figure 2.2: Framework describing the participatory relationship between teachers and curriculum materials (adapted from Remillard, 2005)

2.1.3 Teachers as Instructional Designers

The notion of teachers as instructional designers is not new. Contemporary views on the relationship between teachers and curriculum support this notion (Brown, 2002; 2009; Brown & Edelson, 2003; Cartier et al., 2013; Forbes, 2013; Remillard, 1999; 2002; 2005). As teachers engage in this process of instructional design, they "purposefully use curriculum resources; consider students' prior knowledge, experiences, and interests; and carefully select (or design) and sequence of learning opportunities for students" (Cartier et al., 2013, p. 127).

Remillard (2000) describes ways in which teachers engage in instructional design in part through the reading of students, of texts, and of tasks. Reading texts, as described earlier, involves more than just reading the textbook, it involves critical analysis of the available curriculum materials and for teachers to select and sequence tasks and activities in appropriate ways to support student learning (Remillard, 1999). By reading students, the teachers considered students' thinking, ideas, and preconceptions as they designed and enacted their instruction. Anticipating students' thinking and the ways in which teachers can build upon and support student ideas is an important dimension of instructional design (Cartier et al., 2013; Smith & Stein, 2011; Stein et al., 2008). By recognizing students' misconceptions and understandings about disciplinary ideas, teachers can design tasks that build on these understandings.

Similarly, reading tasks involved the same critical analysis of tasks (Remillard, 2000). Solving, completing, and/or considering tasks and the difficulties that students may encounter as they engage in them is another important piece of instructional design. Thinking about the task, or thinking through the lesson, in critical ways can support teachers as they design their planned curriculum (Smith, Bill, & Hughes, 2008). Analyzing tasks through the student lens allows teachers to understand their value in supporting students' learning and support teachers as they build upon individual tasks to create lesson arcs and curriculum units (Remillard, 2000).

2.1.3.1 Pedagogical design capacity

Instructional design involves the incorporation of all components and resources by teachers, which enables them to design appropriate, and conceptually challenging instructional episodes for their students. Organizing and using the available resources in ways that support student learning involves well-developed skills of decision-making and analysis (Brown, 2009). Researchers refer to these skills and the instructional capacity to design robust lessons as *pedagogical design capacity* (PDC) (Brown, 2009; Brown & Edelson, 2003). The skill necessary for teachers' to develop strong PDC is not innate; it is the culmination of experiences, decision-making abilities, and knowledge and beliefs about teaching. By carefully selecting, designing, and sequencing lessons through careful adaptation, offloading, or improvisation, teachers demonstrate their skill in instructional design of tasks, or PDC (Brown, 2002; 2009).

In summary, researchers highlight certain factors that influence the ways in which teachers interact with, draw upon, and use curriculum materials in planning instruction. For example, teacher knowledge, beliefs, and experiences in combination with the available curriculum materials and the context influence the planned and ultimately the enacted curriculum. These factors, while strong and available for experienced teachers to draw upon, are difficult for beginning teachers to draw upon and/or utilize in ways that support student learning effectively. In the next sections, I detail pre-service teachers' participation with curriculum materials and the ways in which teacher education and preparation programs can support pre-service teachers' development of their PDC.

2.1.4 Supporting Teachers' Pedagogical Design Capacity Development

Teachers must learn how to mobilize and assess the vast array of curriculum resources as they learn to design lessons that support student learning (Beyer; 2009; Beyer & Davis, 2009; Brown, 2002; 2009; Forbes, 2009; Forbes & Davis, 2008; Forbes, 2013). Developing PDC can be challenging for many pre-service teachers. To meet these challenges, PSTs use curriculum materials in a variety of ways, often times influenced by their mentor teachers and the context in which they teach (Beyer & Davis, 2009; Forbes, 2013; Thompson, Windschitl, & Braaten, 2013).

2.1.4.1 Pre-service teachers' participation with curriculum materials

Researchers have described the varied ways PSTs interact with and use curriculum materials (Ball & Feiman-Nemser, 1988; Beyer & Davis, 2009; Brown, 2002; Forbes, 2009; 2013, Forbes & Davis, 2008; Grossman & Thompson, 2008; Ross, Lucas-Evans, Cartier, & Forman, 2013). Often times, PSTs develop the conception that instructional design and effective teaching involves inventing tasks and curriculum materials from scratch (Ball & Feiman-Nemser, 1998). Ball and Feiman-Nemser (1998) suggest that the methods courses at the participating universities did not support PSTs in understanding their role as instructional designers. Instead of mobilizing existing resources and adapting or modifying those resources to meet students' needs, the PSTs created tasks and activities on their own. Consequently, these PSTs did not receive the support necessary in their teacher preparation programs to develop their PDC.

In contrast, other studies suggest that PSTs often use curriculum materials as written without critically analyzing their affordances and drawbacks because they do not feel they have the authority or expertise to do so (Beyer & Davis, 2008; Grossman & Thompson, 2008). PSTs utilize curriculum materials in this way for many reasons that can be attributed to the development of their PDC. One reason is they have not had the support or opportunities in their teacher preparation to understand the value and importance of being critical of curriculum materials (Ball & Feiman-Nemser, 1988; Grossman & Thompson, 2008). PSTs' pedagogical content knowledge is often not well developed (Davis, Petish, & Smithey, 2006; Shulman, 1987).

Another reason PSTs might use curriculum materials in uncritical ways is due to their lack of robust experiences as learners, particularly elementary science teachers (Davis et al., 2006). Consequently, teachers who lack science expertise often rely on prepared science curriculum materials as they organize science instruction (Mikeska, Anderson, & Schwarz, 2009). With their science expertise often lacking, science teachers have difficulty selecting and organizing tasks included in available curriculum materials. In fact, teachers often struggle teaching fundamental science concepts even when using curriculum materials. Curriculum materials are often the main means by which these science practices and canonical knowledge are incorporated into lessons (Mikeska et al., 2009). Because many teachers lack robust experiences as science learners, their expertise in science is often lacking (Davis et al., 2006). Consequently, teachers who lack science expertise often rely on prepared science curriculum materials as they organize science instruction (Mikeska et al., 2009). Mikeska and colleagues' (2009) study is situated in the perspective that curriculum materials play an important role in teachers' work (Beyer & Davis, 2009; Brown, 2009; Davis & Smithey, 2009; Remillard, 2005; Schwarz, 2009; Zembal-Saul, 2009). Curriculum materials and the ways in which teachers interact with those materials influence what science concepts teachers choose and how they teach those concepts to students, ultimately contributing to students' learning. Creating learning environments that build upon students' prior knowledge and experiences and support students' participation in SEPs is a goal for teachers as they design and select tasks (Beyer & Davis, 2009). With their science expertise and experience with science inquiry often lacking, beginning teachers have difficulty selecting and organizing tasks included in available curriculum materials.

In contrast, researchers suggest that supporting PSTs in selecting, critiquing, and adapting of curriculum materials aids in their pedagogical content knowledge and development of pedagogical design capacity (Beyer & Davis, 2009; Forbes, 2009; 2013; Forbes & Davis, 2008). In an examination of how PSTs apply educative supports in analysis of curriculum materials and the development of lesson plans, Beyer and Davis (2009) report that without proper educative supports, the PSTs do not identify strengths and weaknesses in curriculum materials and how those materials support students' learning. Moreover, without adequate support in teacher education courses and teacher preparation, PSTs may only focus on the practical and management aspects of teaching, as opposed to supporting student thinking and learning (Behm & Lloyd, 2009; Beyer & Davis, 2009). However, with the proper support and education, PSTs can develop the skills needed to critique and adapt curriculum materials in ways that support student learning and understanding of the discipline (Beyer & Davis, 2009; Davis & Smithey, 2009; Forbes & Davis, 2008). For example, when PSTs are provided with support in critically analyzing curriculum materials for instructional tools to support student inquiry, they are better able and equipped to design instruction and plan questions to elicit and support student thinking (Ross et al., 2013).

2.1.4.2 Teacher education

Supporting the development of PSTs' PDC is an ambitious challenge for teacher education. To prepare and support PSTs, it is necessary for teacher education to provide opportunities for teachers to engage in the practices and work of teaching and build a beginner's repertoire (Feiman-Nemser, 2001). Researchers argue for the organization of teacher education around a core set of practices through which the knowledge, skills, and identity necessary for teaching can develop (Ball & Forzani, 2009; Grossman et al., 2009a; Grossman et al., 2009b). Grossman et al. (2009b) describe characteristics of these core, or high-leverage practices. They are practices that: "occur with high frequency in teaching; novices can enact in classrooms across different curricula or instructional approaches; novices can actually begin to master; allow novices to learn more about students and about teaching; preserve the integrity and complexity of teaching; and are research-based and have the potential to improve student achievement" (p. 277). With support PSTs can begin to appropriate the practices that support the development of their PDC.

2.1.4.3 Teacher learning and engaging in practice

Due to the need in teacher education for better instruction in the high-leverage practices and the development of PDC, the Grossman et al. (2009a) framework provides an opportunity for teacher educators to help develop PSTs' pedagogies of this practice. More specifically, in this Grossman et al. (2009a) model for teacher learning, PSTs learn by engagement in practices that are strategically constructed. The teacher educator structures the practice so that specific elements of practice are foregrounded. Moreover, teacher educators can introduce PSTs to particular tools, models, and frameworks designed to help critique and analyze curriculum materials to plan for and implement tasks that support student learning.

The Grossman et al. (2009a) framework enables teacher educators to decompose and represent various practices with the PSTs engaging in iterations of approximations of those practices with increasing levels of authenticity. By separating complex practices, such as the critique and analysis of curriculum materials and lesson planning, into its component parts, PSTs will feel more comfortable enacting the complex practice in their own classrooms leading to increased use high fidelity implementation in their own classrooms (Grossman et al., 2009a; Stein et al., 2008). What follows is a detailed summary of the Grossman et al (2009a) framework for teaching practice.

Decomposition of Practice. Critiquing and adapting curriculum materials and designing curriculum in any discipline is complex. During this process, teachers employ a variety of moves, tools, and routines to guide students' thinking toward understanding the core ideas of the discipline (Leinhardt & Steele, 2005). In order for PSTs to begin to engage in any high-leverage practice, Grossman et al. (2009b) posit that they may need varying and scaffolded opportunities to recognize, examine, and enact components of these practices. Once the PSTs have built their repertoire and addressed these instructional challenges, they can begin to develop and integrate them in their teaching. When teacher educators *decompose* the particular practice in question, such as selecting and designing high cognitive demand tasks as in this study, they choose particular components essential to successful use of that practice. Once identified, the teacher educators make particular instructional choices to make salient the characteristics for the PSTs.

Representation of Practice. Representations of practice involve the many ways that portions of the planning and enactment of lessons or teacher moves can be used to help PSTs unpack the nuances of said practice (Grossman et al., 2009a). Teacher educators make instructional choices about the ways in which to represent the practice for the PSTs. These representations provide the PSTs with detailed insight into nuances of the practices that might otherwise go unnoticed. Representations vary greatly, but typically, teacher educators provide opportunities for the PSTs to view and unpack representations through written case studies, videos, or expert observations.

Approximation of Practice. Approximations of practice provide the PSTs with opportunities to engage in varying levels of authentic practice from less complete and authentic to more so. Teacher educators scaffold the approximations so that PSTs with little experience engage in less authentic experiences. Ultimately, the multiple scaffolded iterations, the PSTs participate in multiple opportunities to practice, develop, and rehearse important skills as they move through the approximation continuum from less authentic to more authentic (Figure 2.3) (Grossman et al., 2009a). Giving PSTs opportunities to engage in live role-play experiences, facilitate simulated discussions in class, analyze a written case, critique curriculum materials, write lesson plans, and, enact discussions with students allows for learning to occur through experience, their own and others. By making the practice public, PSTs feel more comfortable making mistakes as they are learning in the safety of the classroom because learning from failure helps to lessen the risk of error in the field because nervousness and uncertainty on the part of teacher (Grossman et al., 2009a).

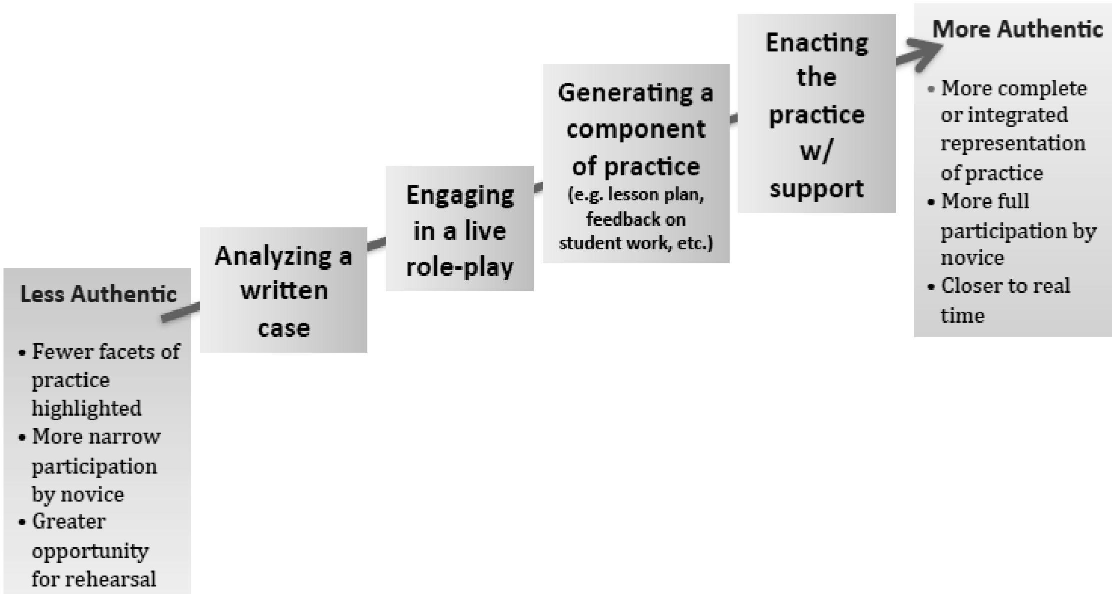


Figure 2.3: The authenticity continuum in approximations of practice described by Grossman et al. (2009a)

To summarize, this section detailed the focus on practice in teacher education. By providing PSTs with opportunities to engage in the work of teachers, they gain the confidence and knowledge to more readily draw upon their learning experiences in the classroom. In the next section, I detail specific tools and resources teachers educators can draw upon as they support PSTs' development of their PDC specifically related to the design of challenging tasks where students engage in the SEPs, a focus of this study.

2.2 SUPPORTING THE DEVELOPMENT OF PEDAGOGICAL DESIGN CAPACITY IN PRE-SERVICE TEACHERS

The *Next Generation Science Standards (NGSS)* (Achieve, Inc., 2013) reflect much of the research on student learning in science over the past several decades. These standards introduce a series of science and engineering practices (SEPs) (see Figure 1.1) around which science education across grade levels should focus. Practices such as planning and carrying out investigations and constructing explanations and designing solutions and the others seek to promote the engagement of students in the work of science inquiry (Stage, Asturias, Cheuk, Daro, & Hampton, 2013).

One of the many challenges teachers, particularly pre-service teachers, face as they work to design instruction to reflect the vision set for in the *NGSS*, is selecting and/or designing curriculum and tasks that support student learning and engagement in these SEPs (Cartier et al., 2013). Because of this challenge, PSTs rely heavily on curriculum materials for support as they design instruction (Davis & Smithey, 2009). However, many curriculum materials provide opportunities for students to complete a task, but often do not provide opportunities for students to engage in the SEPs related to scientific inquiry (Davis & Krajcik, 2005). Without the proper knowledge and tools to analyze curriculum materials productively, teachers may not recognize strengths, and most importantly, weaknesses in those materials resulting in ineffective adaptations in which lessons fail to support student learning and participation in the SEPs (Beyer & Davis, 2009). Therefore, PSTs need support in learning how to critically examine and adapt curriculum materials to design appropriate tasks for their students. Moreover, teacher educators must be concerned with helping PSTs develop the skills and practices related to critiquing curriculum materials and planning lessons. In other words, teacher educators must provide PSTs with conceptual and practical tools to support their learning (Grossman, Hammerness, & McDonald, 2009b).

2.2.1 The Five Practices and Instructional Design

Researchers argue that providing learning environments for students where they can engage in robust discussions about disciplinary ideas and concepts support students' learning (Cartier et al., 2013; Smith & Stein, 2011; Stein et al., 2008). In particular, science lessons that center on discussion provide opportunities for students to engage in the SEPs while learning the core ideas of the discipline (Cartier et al., 2013). However, many teachers continue to focus on teacher-centered pedagogical practices despite the fact that the *NGSS* call for learning environments in which students are actively engaged in scientific work (Duschl, 2008). Moreover, teachers often dominate whole class discussions by leading a fact-based didactic (Lemke, 1990).

Stein et al. (2008) argue that a major challenge for mathematics teachers is orchestrating whole-class discussions around instructional tasks. They explain that teachers often have difficulty utilizing and incorporating the variety of student responses to particular tasks into a coherent line of dialogue. In order to aid teachers in effectively using student responses during a whole class discussion, they propose a model that is designed to make teaching more manageable for teachers. By supporting teachers to focus on anticipating student responses, monitoring student responses to tasks, selecting students to present their responses, purposefully sequencing the students responses, and connecting the ideas through discussion, it is hoped that teachers can more easily orchestrate a conversation that builds on student thinking and engages students in learning. Stein et al. (2008) designed the Five Practices model for teachers to use as they plan for and orchestrate classroom discussions. These practices aim to eliminate much of the improvisation that occurs during a whole class discussion and when utilized together teachers have more time to make instructional decisions. These practices as defined by Smith and Stein (2011) are:

(1) *anticipating* likely student responses to challenging mathematical tasks;

(2) *monitoring* students' actual responses to the tasks (while students work on the task in pairs or small groups);

(3) *selecting* particular students to present their mathematical work during the whole-class discussion;

(4) *sequencing* the student responses that will be displayed in specific order; and

(5) *connecting* different students' responses and connecting the responses to key mathematical ideas (p. 8).

Cartier et al. (2013) argue, "utilizing the Five Practices model and talk moves to plan and support instruction enables students to engage in various science practices while learning core ideas" (p. 127). I discuss each of these practices in depth in the following sections and provide examples of *The Case of Kendra Nichols* (Cartier et al., 2013) who utilizes each of the practices during her science lesson planning and instruction.

Anticipating. The first practice involves a teacher imagining or envisioning how students might approach a task or activity, which occurs prior to the lesson itself. Anticipating requires that teachers assess the difficulty level of the task for students and involves considering possible students' strategies, both correct and incorrect, for completing the task and /or solving the problem. Strategies might include the features or ideas that students might consider, as well as representations, models, and/or protocols that students might produce and how these strategies relate to the learning goals of the lesson (Cartier et al., 2013). An important component of anticipating requires that teachers engage in and/or complete the task themselves in order to identify the approaches students might take. When anticipating teachers can consult various curriculum materials and resources that might include possible misconceptions or ideas that might emerge during classroom discussions (Smith & Stein, 2011; Stein et al., 2008).

Cartier et al. (2013) describe the importance of anticipating and provide an example of how a science teacher anticipates students' stumbling blocks and responses to a task. Ms. Nichols, a middle school science teacher considers students' understandings of molecules at this grade level as she plans for a lesson on the behavior of water molecules. After considering her curriculum materials and other resources, like the National Science Digital Library[3] literacy maps, she determined that students might have issues with concepts of molecule spacing, the role of heat, molecule size, and molecule movement. After considering these ideas, she created a complete and correct representation of the behavior of water molecules in different phases, which she planned to introduce during her discussion. By anticipating these student stumbling blocks and important features she wanted to highlight, Ms. Nichols was better prepared to imagine the storyline of the discussion and facilitate a class discussion that builds on student understandings and allows them to learn key understandings of the discipline.

Monitoring. Similar to anticipating, the teacher engages in the practice of monitoring during discussion planning, yet the actual monitoring occurs during lesson enactment (Smith & Stein, 2011). Monitoring student responses involves attending to students' thinking and strategies as they work on the task. Teachers generally circulate around the classroom while students work either individually or in small groups during monitoring. During this time, they

[3] For more information on the NSDL Digital Library go to http://nsdl.org/.

carefully attend to what students do and say as they work. Teachers then determine which of their anticipations are surfacing during the lesson and helps teachers to redirect and support students in making progress on the task (Stein et al., 2008).

STUDENT GROUP	Features Correctly Represented	Features Missing or Incorrectly Represented	ORDER and NOTES
	__ SPACING __ HEAT __ MOVEMENT __ FORCES __ TYPE & SIZE	__ Incorrect Spacing __ No/Incorrect Heat __ No/Incorrect Movement __ Different-Size Molecules __ Other __ Accurate Representation	
	__ SPACING __ HEAT __ MOVEMENT __ FORCES __ TYPE & SIZE	__ Incorrect Spacing __ No/Incorrect Heat __ No/Incorrect Movement __ Different-Size Molecules __ Other __ Accurate Representation	
	__ SPACING __ HEAT __ MOVEMENT __ FORCES __ TYPE & SIZE	__ Incorrect Spacing __ No/Incorrect Heat __ No/Incorrect Movement __ Different-Size Molecules __ Other __ Accurate Representation	

Figure 2.4: Ms. Nichols' monitoring tool (Cartier et al., 2013, p. 51). Reprinted with permission from National Council of Teachers of Mathematics

A common way for a teacher to prepare for monitoring is, before the lesson, to create a list of anticipated student responses or ideas that will help in accomplishing the lesson goals. Cartier et al. (2013) provide an example of the monitoring tool Ms. Nichols created as she planned her behavior of water lesson (Figure 2.4). Using her anticipations and lesson goals as a guide, Ms. Nichols created a table that identified the key features correct and incorrect that she used to collect data about her students' understandings during their work on the task. She completed the chart as she observed students' engagement in the task and posed strategic questions to students to assess and advance their thinking as they created their representations. Ms. Nichols then used this completed monitoring tool to assist her in planning the storyline and the questions she would ask during the class discussion.

Selecting. After a teacher has anticipated student ideas and monitored students' work, she must select particular students to share their work with the rest of the class in order to have particular ideas emerge, whereby giving teacher more control over the discussion (Smith & Stein, 2011; Stein et al., 2008). Selecting is a very crucial part of the Five Practices because it enables a teacher to decide what ideas are important and when those ideas will emerge during the course of the discussion. A teacher's selection is guided by her lesson's goals, so she selects certain students to present because of the concepts or core ideas represented in their responses and ideas.

Typically, a teacher selects by calling on specific students or groups of students to present their work over the course of the discussion. Alternatively, the teacher might also ask for volunteers, but select particular students from those who volunteer to present their ideas during the discussion. Selecting students to share ideas enhances the quality of the discussion. Stein et al. (2008) explain that by selecting students' ideas the teacher can plan for the emergence of a storyline that meets students' needs and give them the authority to share their ideas and contribute productively in their learning (Engle & Conant, 2002). Making plans for selecting helps the teacher know the particular students and groups to call upon during the discussion as well as helps to support the emergence of the important scientific ideas.

Returning to *The Case of Kendra Nichols*, Ms. Nichols uses her monitoring chart as a tool to support her decision-making during the selection process. After examining the chart, she noted which ideas were common among the students' representations and which were less common. In the interest of time, she makes a conscious choice to only select certain students to present, but plans to include all the students in the discussion (Cartier et al., 2013).

Sequencing. Teachers can also begin to develop the storyline of the discussion by making purposeful choices about the order in which ideas are shared. Smith and Stein (2011) explain, “The method selected must support the storyline that the teacher envisions for the lesson so that the mathematics to be learned emerges in a clear and explicit way” (p. 49). For example, the teacher might want to have an idea common among many students presented before those ideas only a few students share in order to provide access and validate the work of every student (Stein et al., 2008). Again, during planning the teacher can consider the possible ways of sequencing anticipated responses to highlight core ideas key to the lesson. Additionally, the teacher can incorporate unanticipated responses into her final sequence of ideas (Smith & Stein, 2011).

Sequencing is evident in Ms. Nichols’ planning. On her monitoring tool (a segment of the tool can be seen in Figure 2.5), Ms. Nichols took time to select the ideas she wanted to emerge and purposefully selected the order of and who would present these ideas. Ms. Nichols is careful to select students who have not presented their ideas recently to do so in this discussion. Cartier et al. (2013) explains, “By selecting students who had not presented recently, she was giving them the opportunity to demonstrate their competence and to gain confidence in their abilities. Her practice of identifying one member of the group to present was also a way to hold all members accountable for the work of the group” (p. 84).

STUDENT GROUP	Features Correctly Represented	Features Missing or Incorrectly Represented	ORDER and NOTES
A	__ SPACING __ HEAT __ MOVEMENT __ FORCES X TYPE & SIZE	X Incorrect Spacing X No/Incorrect Heat X No/Incorrect Movement __ Different-Size Molecules __ Other __ Accurate Representation	• *Size of the molecules remains the same in all phases* • *Spacing in solid and liquid is inaccurate* • *Heat and movement of molecules isn't represented*
B	__ SPACING X HEAT __ MOVEMENT __ FORCES __ TYPE & SIZE	X Incorrect Spacing __ No/Incorrect Heat X No/Incorrect Movement X Different-Size Molecules __ Other __ Accurate Representation	• *Molecules get bigger from solid to gas instead of changing spacing of molecules, "molecules take up more space"* • *Heat is represented* *Used marbles, but only after prompt
C	__ SPACING __ HEAT X MOVEMENT __ FORCES X TYPE & SIZE	X Incorrect Spacing X No/Incorrect Heat __ No/Incorrect Movement __ Different-Size Molecules __ Other __ Accurate Representation	• *Movement represented – "solid squiggles" / arrows represent movement* • *Gas molecules are farther apart because you could squeeze the gas when the plunger went down*

Figure 2.5: A portion of Ms. Nichols' monitoring tool displaying her effort to select and sequence (Cartier et al., 2013, p. 59). Reprinted with permission from the National Council of Teachers of Mathematics

Connecting. Finally, connecting is the opportunity for the teacher to assist students as they draw connections between their responses, those of their classmates, and the core ideas of the lesson (Smith & Stein, 2011). Different than the traditional presentation where there are separate presentations of how to solve a problem, connecting allows teachers to build students' ideas on each other to develop key conceptual ideas.

Teachers help students form these connections in a variety of ways. For example, the teacher can directly ask students to compare different representations or mark key ideas explicitly for students so that they attend to the important idea (Cartier et al., 2013; Smith & Stein, 2011). Returning to the *Case of Kendra Nichols*, it is evident that her careful planning for anticipating, monitoring, selecting, and sequencing enabled her to easily plan to connect the various representations students created. For example, Ms. Nichols wanted her students to understand that heat energy plays a role in the phase changes of water. Only one group represented the role of heat in this process, so she purposefully planned to select this group to present last so that they could build upon the representation created by the previous group who discussed the role of heat. Instead of asking group B to present their entire model, Ms. Nichols planned and asked purposeful questions that marked a key idea and moved the discussion forward by building on the work of the previous groups (Cartier et al., 2013). Without careful planning of anticipating, monitoring, selecting, sequencing, and connecting, it is likely that the discussion would not have met the desired learning goals.

Stein and her colleagues (Cartier et al., 2013; Smith & Stein, 2011; Stein et al., 2008) designed the Five Practices as a model to support teachers as they enact classroom discussions. In fact, a lesson that centers on a class discussion where the teacher uses the Five Practices model to plan and orchestrate the discussion enable students to engage in a variety of the SEPs and at the same time gain conceptual understanding of core science ideas (Cartier et al., 2013). By giving teachers time to make decisions about instruction prior to the lesson, they can more effectively manage the discussion and any unexpected ideas that emerge. While it is possible to use single practices divorced from the other practices, it is difficult to do so because of the unique nature of the model. For example, Smith, Cartier, Eskelson, & Ross (2013) detail teachers' limited use of the Five Practices as they planned for and enacted mathematics and science discussions. In these classrooms, teachers often failed to plan for or enact robust discussions that support student learning because they failed to anticipate students' sense making and thinking about a core idea.

2.2.2 Tasks and Activity Structures that Support Five Practices Discussions

Robust classroom discussions are crucial if a main goal of instruction is to have students learn key ideas of the discipline, particularly science. In fact, the practice of classroom discourse is entwined with many of the goals of the *NGSS*, i.e., constructing explanations, engaging in argument from evidence, communicating information, and therefore, should be a main focus as teachers design instruction (Figure 1.1). As teachers design these tasks and discussions, they must choose rigorous content and design tasks that are worthy of discussion. That is, the instructional content teachers select should be challenging and enable multiple perspectives, representations, or points of view. Likewise, in science, teachers need to create lessons in which students must use data, and apply the data as justification to answer complex questions. So, the data, representations, and content must be rigorous enough to support discussion. In other words, the instructional content should provide opportunities for students to make different claims based on their evaluations of the evidence (Berland & McNeill, 2010). It is these conflicting interpretations that allow for a scientific discussion around evidence in which students try to make sense of the phenomenon and persuade others of their understandings. In the next section, I describe the research surrounding academic tasks and tasks that support discussion with particular focus on mathematics and science tasks.

2.2.2.1 Mathematical tasks

Researchers characterize mathematical tasks as activities designed with the sole purpose of directing students' attention on a specific core concept or idea (Stein et al., 1996). Stein and her colleagues (1996) studied teachers' selection and enactment of cognitively demanding tasks, in order to provide students with robust learning experiences as part of the Quantitative

Understanding: Amplifying Students Achievement and Reasoning (QUASAR) project (Stein, Smith, Henningsen, & Silver, 2009).

As a result of the QUASAR project, Stein and her colleagues (Stein et al., 1996; Stein et al., 2009) developed a series of analysis tools to examine the level of cognitive demand of mathematics tasks as designed by teachers; including the Mathematical Tasks Framework, the Task Analysis Guide, and factors associated with the maintenance or decline of cognitive demand. The following section provides a summary of each of these analysis tools.

The Mathematical Tasks Framework. Stein et al. (1996) argue that mathematical tasks unfold in three phases during classroom instruction. First, tasks appear in particular ways in curriculum materials or as designed by teachers. Next, teachers set up the tasks during instruction, and finally, in implementation. During instruction, or implementation, students interact with and complete the task. In doing so, the way in which students' work on the task might differ from the original design or task set up.

In their work, Stein et al. (1996) describe that high cognitive demand tasks were the most difficult tasks to implement well. Often times, the ways in which students work on the task or the ways in which teachers support students work lowers the demand of the task during implementation (Eskelson, 2013; Henningsen & Stein, 1997; Smith et al., 2013). Additionally, Stein and Lane (1996) explain that student learning was greatest in classrooms where tasks consistently supported student high levels of student thinking and reasoning.

The Task Analysis Guide. The Task Analysis Guide was designed by researchers to categorize tasks with regard to their level of cognitive demand (Smith & Stein, 1998). They posited that mathematics tasks compose four categories: memorization, procedures without connections, procedures with connections, and doing mathematics. Smith and Stein (1998) characterize these tasks as follows. Memorization tasks involve students reproducing previously learned facts or definitions and do not require a procedure to solve. Procedures without connections tasks involve the use of a procedure in order for students to solve and require little thinking on the students' part to solve. Procedures with connections tasks require some degree of cognitive effort by the student as they make connections between the procedural aspects of the task and the mathematical ideas. Finally, doing mathematics tasks require complex thinking by the students where they explore a variety of solutions and strategies as they complete the task.

Factors Associated with Maintenance or Decline of Cognitive Demand of Mathematical Tasks. In their analysis of tasks, Stein et al. (1996) identified key factors in lessons that either contributed to the maintenance or decline the level of thinking required of students during a task (Figure 2.6). For example, high cognitive demand tasks are often more difficult and require deep thinking on the part of the student. Because students are typically uncomfortable with tasks of this type, teachers often lower the demands of the task by specifying procedures for the students to follow or completing portions of a task for students (Eskelson, 2013; Henningsen & Stein, 1997; Smith et al., 2013).

Factors Associated with Maintenance	Factors Associated with Decline
1. Scaffolding of students' thinking and reasoning. 2. Students are provided with means of monitoring their own progress. 3. Teacher or capable students model high-level performance. 4. Sustained press for justifications, explanations, and/or meaning through teacher questioning, comments, and/or feedback. 5. Tasks build on students' prior knowledge. 6. Teacher draws frequent conceptual connections. 7. Sufficient time to explore (not too little, not too much).	1. Problematic aspects of the task become routinized (e.g., students press teacher to reduce task complexity by specifying explicit procedures or steps to perform; teacher "takes over" difficult pieces of the task and performs them for the students or tells them how to do it). 2. Teacher shifts emphasis from meaning, concepts, or understanding to correctness or completeness of the answer. 3. Not enough time is provided for students to wrestle with the demanding aspects of the task or too much time is provided and students flounder or drift off task. 4. Classroom management problems prevent sustained engagement. 5. Task is inappropriate for the group of students (e.g,, lack of interest, lack of motivation, lack of prior knowledge needed to perform, task expectations not clear enough to put students in the right cognitive space, etc.). 6. Students not held accountable for high-level products or processes (e.g., although asked to explain their thinking, unclear or incorrect student explanations are accepted; students were given the impression that their work would not "count" (i.e., be used to determine grades).

Figure 2.6: Factors associated with the maintenance or decline of cognitive demand in mathematical tasks (Stein & Smith, 1998)

2.2.2.2 Science tasks

Similar to tasks in mathematics, a variety of tasks, when designed at a high level, can support productive whole class discussions (Cartier et al., 2013). Here I focus on three types of science tasks designed to support discussion and engagement in the SEPs described in the *NGSS:* experimentation, data representation, analysis, and interpretation, and explanation tasks (Appendix B). Whether students are cognitively challenged while completing these three types of tasks relies solely on the teacher's design. The choices the teacher makes as she draws on curriculum materials and resources to design directly influences the cognitive level at which students engage in the task. Similar to mathematics tasks described above, a science task that requires students to provide a rationale for their choices or strategies is a high cognitive demand task (Stein et al., 1996). Where tasks that allow students to memorize and repeat and answer or follow a specified procedure involves low cognitive demand. Cartier et al. (2013) detail examples of low-level and high level tasks of each type. What follows is an explanation of these task types and a comparison between low-level and high-level tasks of each type.

Experimentation tasks require students to develop or carry out a scientific protocol or procedure. These tasks are very common in science classrooms. Typically, students follow a detailed protocol as they proceed through the experiment, but students are seldom required to make connections between the patterns noticed and core ideas of the lesson. In contrast, a high-level experimentation task requires students to develop their own protocols and critique those of their classmates with respect to a well-defined research question.

Data representation/analysis/interpretation tasks require students to represent, analyze, or interpret data, which they collect first hand or provided by the teacher second hand. Low-level tasks of this type fail to provide opportunities for students to create multiple representations of data and require students to represent or interpret data in a single way. High-level data representation tasks support students as they work to identify patterns in the data and provide rationale for those patterns based on the data provided. In doing so, the task allows for students to create a variety of representations and make connections between those representations and others.

Finally, explanation tasks require students to explain and justify the patterns or support their claims with valid evidence. Often times, explanation tasks are low-level because they involve teachers providing direct instruction to students about core ideas and phenomena (Cartier et al., 2013; Lemke, 1990). However, increasing the cognitive demand of explanation tasks allows students to construct their own explanations and make meaning in their own way while meeting the goals of the lesson.

Whether these tasks are low-level or high-level depend on the teacher's instructional design. The materials she draws upon, the selection of tasks, and the sequence in which the teacher implements those tasks all have an impact on student thinking and understanding (Cartier et al., 2013; Remillard, 2005). For example, traditional science classrooms often involve the teacher providing explanations for phenomena initially followed by students participating in a procedural experiment that reinforces the previously learned explanation (McNeill & Pimentel, 2009). In contrast, modifying the task sequence to provide students an opportunity to engage in experimentation and generate their own explanations and understanding of phenomena increases the demand of the task and support student learning and understanding of the phenomena in robust ways (Cartier et al., 2013).

Researchers argue that designing instruction in this way requires teachers to mobilize their available resources and curriculum materials in order to create robust tasks worthy of discussion (Forbes, 2013). By drawing on tools and resources like the Five Practices model and the Learning Cycle, teachers can design instruction that supports students' participation in the SEPs and learning of core scientific ideas. In the next section, I describe research on the Learning Cycle, its relationship to scientific inquiry practices, and how the Learning Cycle can support design of Five Practices discussions.

2.2.3 The Learning Cycle

Reform efforts in science education aim to develop a population of scientifically literate individuals who can participate productively in our increasingly global society (Cazden, 2001). While the reform of science education has been approached from many angles over the past three decades, scholars have increasingly focused their attention on the need for students to develop the critical scientific practices of analysis, synthesis, and critique. As a result, there is increased importance in today's science classrooms for students to practice and develop the reasoning skills necessary to be productive members of a scientific classroom in which social dialogue is critical to learning (Duschl, 2008).

To reach these goals of science education, "science for all," learning environments must be designed so that students engage in classroom communities of discourse and inquiry (Duschl & Osborne, 2002). One of the main components of science discourse is the student-to-student talk through which students analyze data, synthesize arguments, and critique the arguments of others. To develop these communities of discourse, Eduran and Jiménez-Aleixandre (2008) highlight the importance of allowing students to develop and justify explanations in classrooms, thereby gaining a deep understanding of scientific concepts. By participating in learning communities designed specifically for scientific knowledge and skill development, students develop the critical thinking skills needed for reasoning and arguing within the classroom and in social contexts outside the classroom. The social dialogue practiced by the students allows them to externalize their thinking and begin to develop rational arguments while constructing their own scientific knowledge and participating in the SEPs described in the *NGSS* (Achieve, Inc., 2013).

The Learning Cycle framework provides an organizational structure for teachers designed to support the development of lessons that engage students in cycles of inquiry by placing the exploration of phenomena before the development of explanations to explain those phenomena (Bybee, 2007; Cartier et al., 2013; Hanuscin & Lee, 2008; Karplus & Thier, 1967). The Learning Cycle supports student learning of science practices and guides teachers' selection of tasks and the connections between them. Using this framework, teachers focus on key aspects of tasks included in many curriculum materials and design lessons supporting students' scientific sense making through the process of inquiry.

Teachers' use of the Learning Cycle supports the inquiry and application model supported by many researchers and teacher educators (Anderson, 2003; Leinhardt & Steele, 2005; Windschitl, Thompson, & Braaten, 2008). Many versions of the Learning Cycle have been introduced over the years, but they all include the three central phases of instruction: (1) exploration: students explore and experience science phenomena, (2) concept introduction: students build core science ideas through their interactions with curriculum materials, students, and the teacher, and (3) concept application: students build upon these new ideas and apply them to new problems (Brown & Abell, 2007; Karplus & Thier, 1967). The 5E framework, introduced by Bybee (2002), includes engage, explore, explain, elaborate (apply), and evaluate (extend) and aligns with disciplinary practices of science (Figure 2.7). The Learning Cycle begins with student inquiry; students explore phenomena and develop explanatory models to account for the patterns they noticed about those phenomena. Then, students have an opportunity to apply their new understandings to explain or make predictions about new phenomena. In doing so, this framework places explorations of phenomena before explanations and connects directly to scientific practices, which often differs from the learning that occurs in science classrooms (Bybee, 2007; Hanuscin & Lee, 2008).

LEARNING CYCLE PHASE	PURPOSE OF TASK	EXAMPLE
ENGAGE	• Elicit students' prior knowledge and experiences • Focus students' attention on the new concept • Provide motivation for the lessons that follow	• A scenario is described for students and they brainstorm and identify ways to get sugar to dissolve in water more quickly
EXPLORE	• Students engage in hands-on activities in which they: o Actively explore the phenomenon o Collect data	• Students experiment to answer the question, "How does stirring affect that rate of sugar dissolving?" • Students collect data about rate of sugar dissolving • Students describe patterns
EXPLAIN	• Students use their data to create evidence-based explanations of the phenomenon	• Students develop explanations to describe the process
ELABORATE (APPLY)	• Students apply their new understandings of the phenomena	• Students describe another way they think they could get sugar to dissolve faster and apply new understandings • Students conduct new experiment
EVALUATE (EXTEND)	• Summative assessment of the students' understanding of the phenomenon	• Students complete exit slip describing the process of how sugar dissolving occurs.

Figure 2.7: Description of the 5E Learning Cycle Framework (Bybee, 2002)

The design of the Learning Cycle framework supports teachers in the selection and design of tasks that provide opportunities for students to engage in the SEPs described in the *NGSS*. Cartier et al. (2013) characterizes the Learning Cycle with respect to the SEPs in which students engage (Figure 2.8). Consider, for example, the vignette of Mr. Gates' classroom presented in Chapter 1. By designing and sequencing the task in that way, Mr. Gates, whether consciously or unconsciously, engaged students in aspects of a Learning Cycle lesson. Students carried out an investigation of Fastplant growth by designing and carrying out their own investigations, or students engaged in e*xploration*. After analyzing the data, students constructed an explanation to describe typical Fastplant growth, or students engaged in *explanation*. As such Ms. Gates' students engaged in the SEPs by completing a task where they engaged in a whole-class discussion describing the patterns they noticed.

In describing Mr. Gates' actions and moves during the lesson, the vignette details how he embeds a Five Practices discussion into this Learning Cycle (Cartier et al., 2013). Mr. Gates *designed* a high-level experimentation and data representation/analysis task. During the task, he *monitored* students' work and made careful notes regarding students' ideas and patterns they noticed as they work. He selected particular groups that would present their work and *sequenced* each group so that an appropriate storyline of ideas would unfold. Finally, he orchestrated the classroom discussion by *connecting* students' ideas with each other and the disciplinary ideas.

NGSS Science Practice	Learning Cycle stage			
	ENGAGE	EXPLORE	EXPLAIN	APPLY
(SP 1) Asking questions	√			√
(SP 2) Developing and using models			√	√
(SP 3) Planning and carrying out investigations		√		
(SP 4) Analyzing and interpreting data		√	√	
(SP 5) Using mathematics and computational thinking		√		
(SP 6) Constructing explanations			√	√
(SP 7) Engaging in argument from evidence			√	√
(SP 8) Obtaining, evaluating, and communicating information		√	√	√

Figure 2.8: Opportunities for students to engage in the *Next Generation Science Standards* Science and Engineering Practices throughout the Learning Cycle (Cartier et al., 2013, p. 101). Reprinted with permission of the National Council of Teachers of Mathematics

In making decisions about what and how students should learn, teachers, like Mr. Gates, draw on their students' experiences and various curriculum materials and resources to create the enacted curriculum (Figure 2.9) (Cartier et al., 2013; Remillard, 2005). By positioning a Five Practices discussion within a phase of the Learning Cycle, students have opportunities to engage in the SEPs while demonstrating mastery of their new knowledge. A teacher's ability to mobilize these resources effectively is at the heart of PDC (Brown, 2009). Providing teachers, especially PSTs, with the tools that enable them to make good choices about the ways in which they adapt and use their resources materials is important. Drawing on the Five Practices and the Learning Cycle Model, can provide PSTs with the support needed to design tasks that engage students in inquiry and SEPs and supports the PSTs in learning and noticing student thinking through classroom discussion (Cartier et al., 2013).

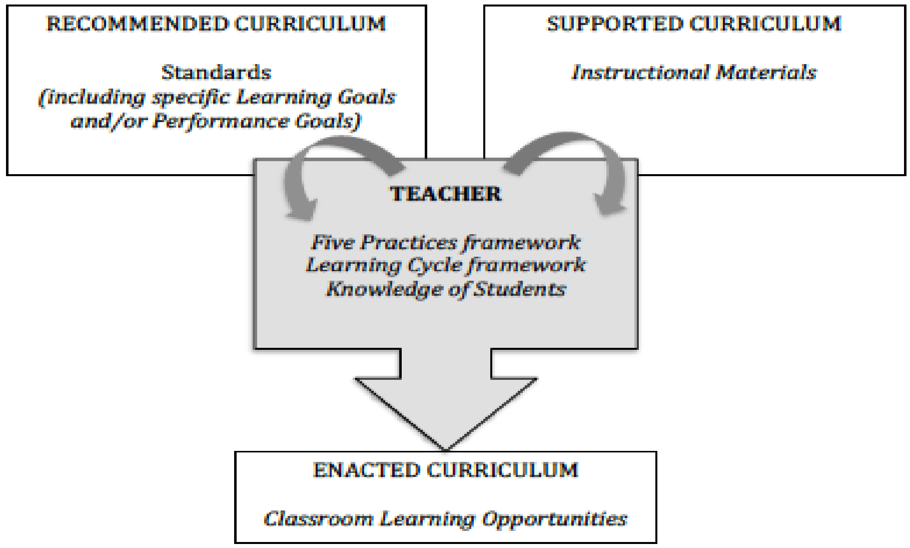


Figure 2.9: The teacher's role in designing the enacted curriculum (Cartier et al., 2013, p. 112). Reprinted with permission of the National Council of Teachers of Mathematics

2.3 PURPOSE OF THE STUDY

A key instructional goal for the secondary science teacher preparation program, in which this study is situated, is to support secondary science PSTs in developing approaches to instructional planning of tasks that support students engagement in the SEPs and are consistent with the model of inquiry-based science teaching described in research (Anderson, 2003; Duschl, 2008; Leinhardt & Steele, 2005; Windschitl, Thompson, & Braaten, 2008). Embedded within this goal is supporting the development of the PSTs' pedagogical design capacity (PDC) by developing their ability to draw upon all available resources, knowledge, materials, etc. to design instruction for Five Practices discussions. PSTs learn how to draw from various curriculum materials and resources to plan lessons that engage all learners. To support this development, teacher educators at this large urban Midwestern University, draw on the Five Practices model and design an intervention aimed at increasing PSTs' PDC related to use of the Five Practices model to selection and design of tasks that engage students in the SEPs described in the *NGSS* (Achieve, Inc., 2013).

An important focus of this preparation program is the selection and design of high-level science tasks. These tasks, as described above, have the greatest impact on student learning (Stein et al., 1996; Stein et al., 2009). Cartier et al. (2013) describe the features of a high-level science task. First, the teacher defines the learning goals, or the understandings students will gain from participating in the lesson. Next, the teacher designs a task that supports students' engagement in the SEPs described in the *NGSS* (Achieve, Inc., 2013). Finally, students have opportunities to create multiple artifacts as a result of the task and engage in a whole-class discussion around those artifacts.

Providing PSTs with experiences in teacher preparation courses that highlight the importance of utilizing their skills to create lessons that follow particular principles of practice supports the development of their PDC (Brown, 2009; Grossman et al., 2009b). By giving the PSTs opportunities to critically analyze curriculum materials and design lessons that engage students in the discussions around the SEPS, they are supported in developing a robust PDC. Without the support of the teacher educators focusing lesson planning of high-level tasks, PSTs focus on management and other practical issues in the classroom (Beyer & Davis, 2009; Forbes & Davis, 2008; Lloyd & Behm, 2005).

Additionally, PSTs require repeated supportive experiences in lesson planning and enactment (Ross et al., 2013). These repeated experiences support the PSTs' reflections on student learning and lesson enactment and build upon that learning in subsequent lessons. Having PSTs plan, teach, and reflect on their initial teaching experiences of these high-level science tasks provides important information for researchers and teacher educators alike. However, support is required in order to further develop the PSTs capacity to design high-quality lessons utilizing tools and frameworks. By embedding these experiences in the context of the teacher preparation program, teacher educators provide the scaffolds necessary to support teacher learning.

Curriculum materials play an important role for all teachers, particularly novice teachers, by providing tools to support their planning and instruction (Forbes & Davis, 2008; Grossman & Thompson, 2008). In particular, PSTs use curriculum materials in critical ways that suggest the development of their pedagogical design capacity (Brown, 2009). Brown (2009) describes PSTs' planning to use instructional tools in each Learning Cycle phase even if the curriculum materials did not provide instructional tools. In doing so, it is evident that the PSTs critically examined the curriculum materials in ways that are equivalent to Brown's (2009) notion of adapting and improvising by creating their own tools or modifying tools provided. These changes in the curriculum materials the PSTs made suggest that the science methods course provides a useful framework for supporting the development of PSTs' PDC.

By providing repeated scaffolded opportunities to engage in micro-planning practices as described above, e.g., select or design specific tools that support student engagement in those authentic SEPs (gathering, organizing, or representing data, identifying patterns), or sequence tasks based on the Learning Cycle framework, the PSTs begin to notice the necessary aspects of planning required for effective teaching. These repeated opportunities enable the PSTs to approximate various aspects of each practice in an effort to develop their PDC (Grossman et al., 2009b). I provide specific details regarding the context of the study, data sources, and data collection and analysis in Chapter Three.

3.0 METHODOLOGY

This descriptive study used qualitative data collection and analysis methods that were intended to better understand the extent to which PSTs' PDC for planning high-level tasks where students engage in discussion developed over their preparation year. Moreover, this study sought to describe and examine PSTs' capacity to use and analyze curriculum materials and various resources in order to design and plan for these tasks. Data for this study included: PST artifact packets (Borko, Stecher, Alonzo, Moncure, & McClam, 2005) from coursework, lesson plans, interviews, and video recordings of teacher preparation coursework. This chapter describes the setting and the methods for this study. I begin this chapter by providing a description of the study context. Next, I describe the possible effects of my role as a researcher, course instructor, and field supervisor on the study itself. Then, I describe participants, the data sources, as well as the collection and coding procedures. I conclude by detailing the data analysis procedures with respect to each research question. What follows is a description of the Secondary Science Teacher Preparation Program.

3.1 CONTEXT OF THE STUDY

3.1.1 The Secondary Science Teacher Preparation Program

This research study focused primarily on the secondary science disciplinary blocks, or methods courses, at a large Midwestern university in the United States during the 2013-2014 school year. This post-baccalaureate program included three semesters of intensive study including a yearlong teaching internship in a secondary school. During the fall and spring 15-week semesters, there were three secondary science methods courses. The fall semester focused specifically on the development of specific instructional strategies and skills related to lesson planning and using curriculum materials and related resources to design high-level tasks where students engage in whole class discussions. During these classes, the PSTs planned and took turns designing tasks and implementing components of science lessons with their peers and then engaged in critical discussions related to those instructional episodes. Throughout the fall semester, PSTs learned and approximated the high leverage practice of planning and orchestrating a Five Practices discussion as well as the following sub-practices and instructional routines: developing high-level tasks, planning a lesson aligned with the *NGSS*, launching and closing a lesson, using instructional representations, planning and enacting a lecture, questioning the author, and developing lessons using the Learning Cycle. Finally, PSTs reflected on various aspects of these practices enacted during their own teaching and classroom observations. The goal of these experiences was to give the PSTs tools and opportunities to engage in approximation of practices that support the development of their PDC. This dissertation study examined PSTs' developing PDC for planning high-level tasks where students engage in discussion. What follows is a detailed summary of how the teacher educators used the Grossman

Framework for Professional Preparation (Grossman et al., 2009a) to engage PSTs in the development of their PDC for planning high-level tasks where students engage in discussion.

3.1.1.1 The Grossman framework for professional preparation

Teacher educators adopted the Grossman et al. (2009a) practice-based focus in the design of this secondary science-teaching program in which PSTs participated in various high-leverage practices, including designing high-level tasks where students engage in task-based science discussions. Stein et al. (2008) suggests that their Five Practices model is a useful tool for mathematics teachers as they orchestrate classroom discussions around inquiry-based tasks. Building on Stein and colleagues (2008) research, the instructors of this program used the Five Practices model as a framework for supporting PSTs as they learned to plan and enact task-based science discussions. Using the model, I, co-planning with other instructors, designed various role-play scenarios in which PSTs engaged in each of the sub-practices through various approximations with increasing levels of authenticity. In the following section, I detail the Five Practices role-play scenario.

The teacher educators divided coursework during the fall semester into sessions in which the PSTs engaged in science as learners and practitioners through iterative cycles of decompositions, representations, and approximations of practice (Grossman et al., 2009a). More specifically, in addition to other practices, the PSTs observed their instructors represent the practice of designing high-level tasks where students engage in discussions by having the PSTs approximate components of this practice by planning lessons around high-level tasks, and rehearsing and formally teaching instructional episodes with peers. Through varying levels of authenticity the teacher educators guided the PSTs to examine specific planning and instructional practices and certain teacher moves that help to support student science learning. Once the

PSTs had the opportunity to unpack these instructional components, they were better able to use those practices in their own teaching (Grossman et al., 2009a).

The central focus of this study was developing PSTs' PDC specifically for designing tasks where students engage in discussion. To support this development, role-play interventions centered on the Five Practices model and provided an opportunity for the PSTs to engage in iterations of simulated whole class discussions while assuming the roles of both the teacher and a student. Figure 3.1 details how the teacher educators used the Grossman et al. (2009a) framework as an instructional model to engage the PSTs in these repeated scaffolded approximations around planning for and enacting whole class discussions.

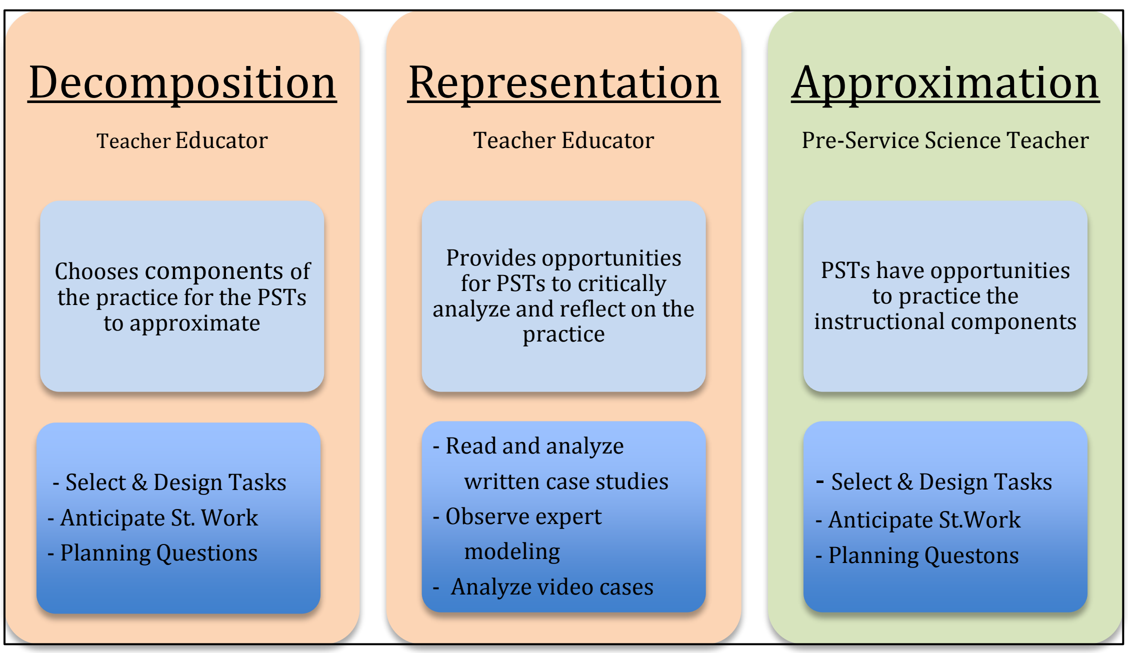


Figure 3.1: Example of the application of the Grossman Framework for planning a Five Practices discussion

Decomposition. Although researchers designed the Five Practices as a tool for teachers to use to make discussion facilitation more manageable (Stein et al., 2008), PSTs may struggle with "seeing" how to utilize this as a planning tool. Breaking apart this framework into its component pieces allowed teacher educators to support the PSTs in identifying and practicing those components alone before complete integration. Teacher educators decomposed the Five Practices within the context the teacher preparation classroom. By decomposing this framework for orchestrating productive discussions into the respective components: (1) anticipating student responses, (2) monitoring student work, (3) selecting student responses for public display, (4) sequencing student responses, and (5) connecting student responses, I hoped the PSTs would begin to attend to, learn, and approximate this complex practice in the safety of their own university classroom before full integration in professional practice.

By decomposing the Five Practices, the teacher educators provided PSTs with an opportunity to focus on certain fundamental skills, routines, and micro-practices that will help them to prepare for and facilitate productive task-based science discussions (Grossman et al., 2009a). Decomposition allowed the teacher educators to call attention to as well as provide immediate feedback to students as they analyzed and reflected on the various components. Through this feedback, the PSTs began to pay attention to particular moves and aspects of this instructional model that help support their discussion planning and facilitation. By focusing their attention on certain aspects of student thinking, student work, and important teacher moves, the aspects of discussion typically viewed as improvisational by many beginning teachers seem less so (Smith & Stein, 2011; Stein et al., 2008). Giving the PSTs a tool for planning and facilitating a discussion helped them feel more comfortable standing to the side of the dialogue and allowing students' opportunities to engage with each other.

In order to support the development of the PSTs' PDC for designing tasks where students engage in science discussions, the teacher educators selected particular micro-practices based on past research, namely: writing specific learning goals, identifying and modifying tasks, anticipating student thinking, planning for monitoring, imagining the discussion storyline, planning questions and marking student ideas, reflecting on teaching. The teacher educators believed that the development of these micro-practices in PSTs' repertoire best support the development of their identity as instructional engineers as well as their PDC for designing task-based science discussions.

Representation. Once the teacher educators selected each micro-practice, they co-planned ways to best represent each. The PSTs observed the expert teachers utilizing the model, read written cases, as well as analyzed student work. Through varying levels of authenticity the teacher educators guided the PSTs to examine specific practices or certain teacher moves that help to support the instructional dialogue that might otherwise go unnoticed. By drawing attention to particular details, the PSTs began to identify and learn ways in which they might begin to build their own teaching repertoire.

Once the PSTs analyzed various micro-practices related to designing task-based science discussions, they have a model, or representation, by which to analyze this complex practice (Stein et al., 2008). For example, by providing PSTs with examples of student work and a case study of how a classroom teacher implements her classroom discussion, the teacher educators foregrounded salient aspects of anticipation, monitoring, selecting, sequencing, or connecting the teacher may have used. Using various representations assisted the PSTs in visualizing ways in which they can begin to use and develop their own identity as an instructional engineer (Grossman et al., 2009a).

Approximation. By simulating and role-playing a Five Practices discussion in their university classroom, the PST engaged in approximations of practice similar to those identified by Grossman et al. (2009a). As they gained experience, they engaged in varying levels and iterations of authentic and complex discussion practices, thereby developing the knowledge and skills necessary to begin to integrate the decomposed pieces of the Five Practices model. Through providing PSTs with public practice and feedback, teacher educators highlighted particular aspects of the model, like anticipating and monitoring, while other, less important, aspects of discussion planning and facilitation were not a focus. By drawing PSTs' attention to these important aspects and allowing them to engage in opportunities to practice, they began to develop their PDC for designing tasks necessary to facilitate productive, engaging science discussions with students.

Early in the preparation program, PSTs have opportunities to approximate less authentic practices, e.g., analyzing a written case, or engaging in the Five Practices role-play within the context of their university classroom. As the year progresses, the PSTs approximate more authentic practices as they gain more experience, e.g., planning lesson and designing tasks regularly at field sites. Figure 3.2 describes the approximation opportunities in which PSTs engaged throughout the university coursework and internship.

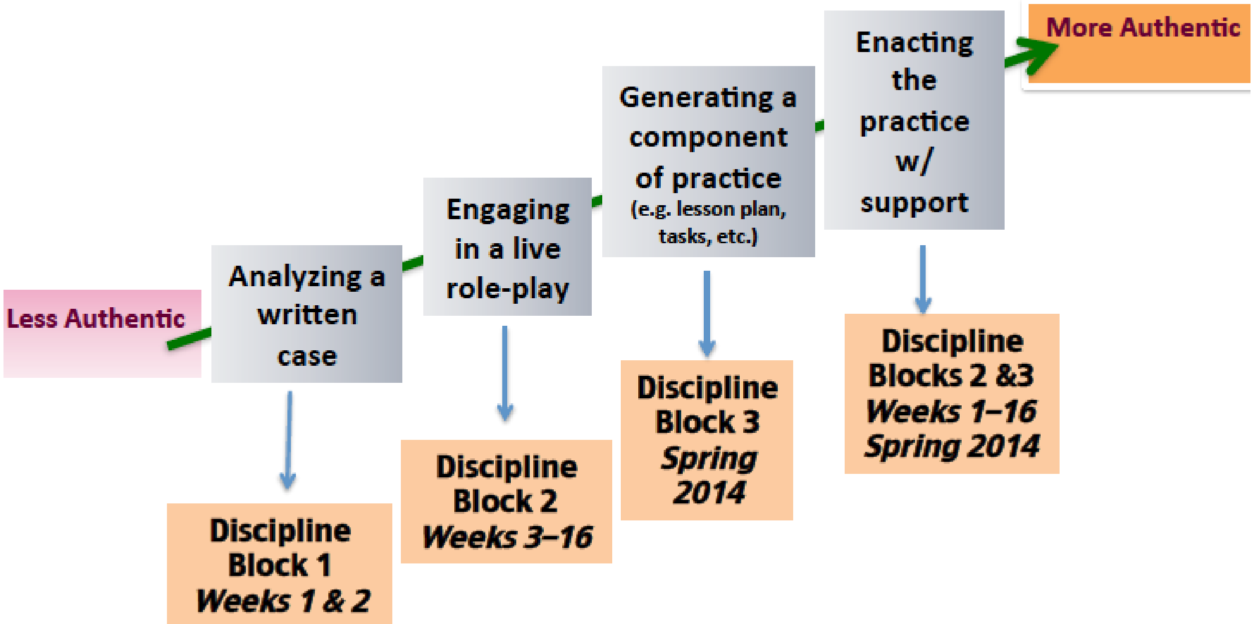


Figure 3.2: Diagram of the levels of approximation in which PSTs engage during the teacher preparation program

3.1.1.2 Pedagogical Cycles of Instruction

Recall that the teacher educators at this university designed role-play scenarios that enable the PSTs to engage in approximations (Grossman, et al., 2009a) of the selected practices previously described. Based on Lewis, Murray, Schutz, and Scott (2010), they used a pedagogical cycle of rehearsal, planning, and feedback that provided the PSTs with opportunities to engage in facilitating a discussion in the classroom (Figure 3.3).

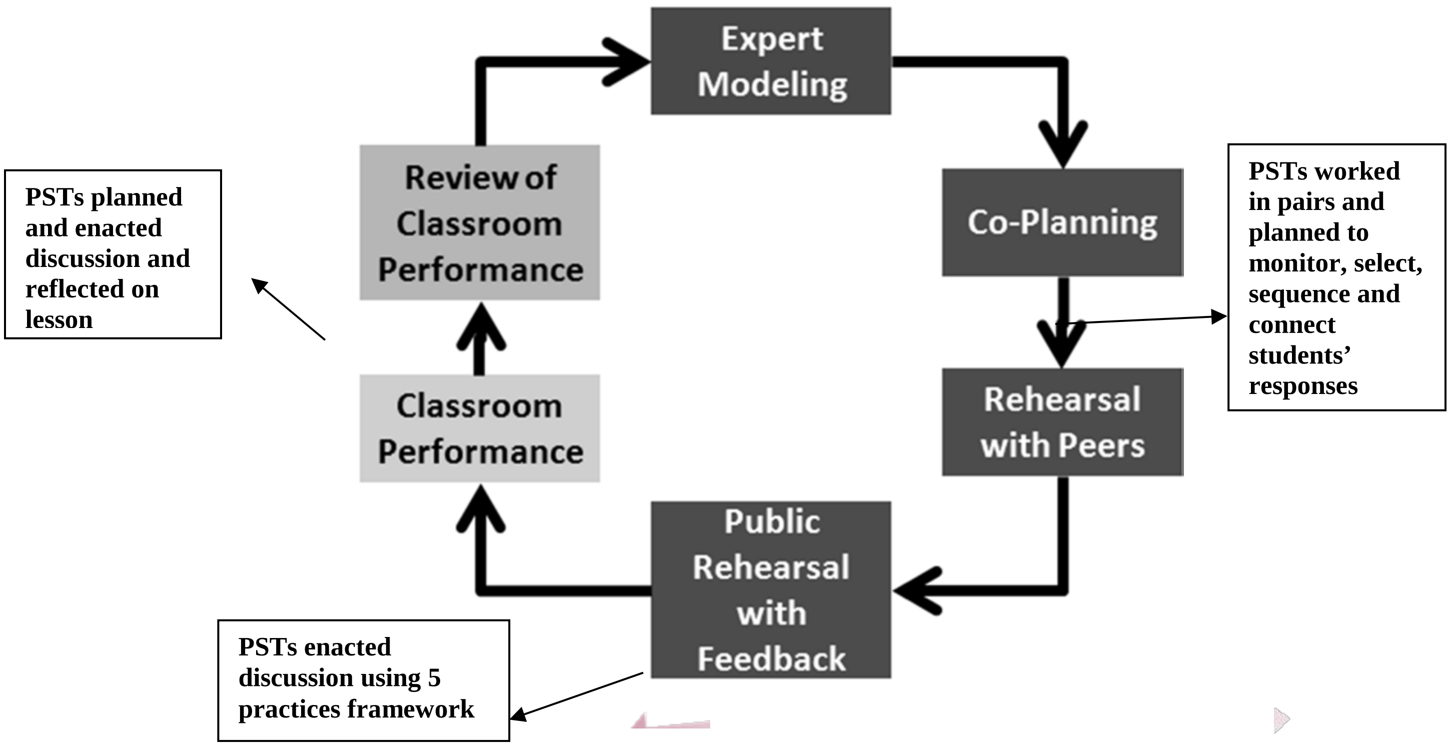


Figure 3.3: Pedagogical cycles for orchestrating task-based science discussions adapted from Lewis, Murray, Schutz, & Scott (2010)

During the methods courses, the PSTs engaged in multiple approximations of each micro-practice as described above (Grossman et al., 2009a). What follows is a summary of the fall and spring semesters including in-class work and out of class assignments pertaining to this study (Table 3.1). The four Instructional Performances, a main data source of this project, are highlighted in the out of class assignment section of the table. Appendix A describes in more detail the learning opportunities and pertinent coursework sessions related to this study.

Table 3.1: Secondary science teacher preparation courses related to task design, lesson planning, and the Five Practices model

Fall Week 1	**In Class Sessions**	A Model of Engaged Science Learning	Engage as Students in *The Fastplants Task*	Supporting Engagement in Science Learning	Review of *NGSS SEPs*		**Out of Class Assignments**		
Fall Week 2		Introduction to Lesson Planning	Examining Initial Lesson Plans	What Belongs in a Lesson Plan?	Why Detailed Planning is Important?			Lesson Plan 1	Lesson Plan 1 Revision
Fall Weeks 3-7		Learning Goals & Objectives (Review) What is a High Cognitive Demand Task?	Micro-teaching practice: *Launch*	Anticipating & Getting Ready to Monitor Role-Play	Monitoring, Selecting, Sequencing, and Connecting Role Play	Anatomy of a Lesson & Lesson Arcs		Anticipating, Monitoring, Selecting, Sequencing, & Connecting Planning for micro-teach role-play	Instructional Performance 1 & 2
Spring Weeks 1-8		Learning Cycle & Five Practices Revisited *Engaging as Students in a Physics Task*	Formative Assessment *What is it and Why it is important?*	High-Demand Tasks Revisited *PSTs own Tasks*	Scaffolding Revisited *Examples of Scaffolding from PSTs*	Maintain Cognitive Demand Revisited *Examples from PSTs*		Instructional Performances 3 & 4	

During week one, PSTs engaged in a protocol design task as science learners, A Model of Engaged Science Learning: The Fastplants Task. In doing so, PSTs recognized the important aspects of a task designed with the *NGSS* in mind. Once the PSTs participated in this lesson, they examined a case study in which a teacher attempted to facilitate a task-based discussion in her classroom regarding Wisconsin Fastplants data her students collected. The teacher educators provided the PSTs with examples of student work, and graphical data representations created to answer the question, "What is Typical Plant Height?" The PSTs examined graphs and considered ways to approach a discussion to answer the question. The PSTs then read and discussed the case study. The case study highlighted many common problems that teachers encounter when facilitating a discussion. The teacher educator foregrounded these issues and supported the PSTs in planning how the teacher might have created opportunities for better student engagement and a more productive discussion. Finally, the PSTs wrote their first lesson plan (LP) drawing on these experiences.

During the remaining weeks, the PSTs had multiple opportunities to assume the role of a student and the teacher by planning and practicing enacting high-level tasks and discussion in the classroom. The PSTs participated in a rehearsal role-play in which they engaged as teachers planning and facilitating a whole class discussion. We developed the elaborate scenarios related to various science ideas (e.g. kinetic molecular theory) (see Appendix A). The materials that supported each role-play scenario include: (a) a description of the instructional activities in which students would participate; (b) samples of student work that have been selected or invented such that typical alternative conceptions are represented; (c) background information for the person playing each student's role; and (d) tools to support teacher's monitoring, selecting, sequencing, and question planning. The PSTs engaged in approximations of all Five

Practices related to discussion facilitation. Specifically, they took turns adopting the role of student and teacher throughout the scenarios and had multiple opportunities to offer and receive feedback on their teaching performances and decision-making throughout each scenario.

The PSTs then worked in pairs assuming the teacher role by engaging in monitoring students' work and asking questions aimed at surfacing student thinking. After considering the student representations/models, they selected and sequenced the models and the order in which they would want ideas to emerge during the discussion. Finally, they connected the ideas together in a practice discussion. This discussion helped to foreground the steps needed to take to plan and prepare for a discussion in order to have a productive discussion with students.

Through the experiences of engaging as a teacher and as students over several iterations in university coursework, the PSTs began to notice important teacher moves necessary for implementing a productive discussion. By making explicit the teacher moves during the role-play, there were several opportunities for the PSTs to develop the skills needed in performing this essential science practice (Achieve, Inc., 2013). Based on Kazemi, Franke, and Lampert's (2009) model for developing pedagogies for supporting novices to enact the ambitious instruction, each rehearsal lasted from 10 to 20 minutes, during which time their classmates or the instructor stopped the rehearsal to ask a question, suggest alternative lines of questioning or reasoning, or make note of appropriate teacher decisions. The coaching and discussion between role-plays helped to support the PSTs in developing the planning and instructional practice necessary to facilitate a productive science discussion.

In the remaining weeks, the PSTs planned, taught, and reflected on lessons they designed to engage students in discussions. These assignments, called Instructional Performances, required that the PSTs create artifact packets (Borko et al., 2005). In these packets, the PSTs provided their lesson plans, tasks, instructional materials, reflections, and student work. These artifact packets were a main data source for this dissertation study as described below. Ultimately, as the PSTs participated in their field experiences at their secondary placement sites during the spring semester, I expected they would begin to incorporate discussions into their lesson planning and implementation. Evidence of the development of PDC by drawing on their curriculum materials, tools, and instructional models was evident in their planning practices.

3.2 THE ROLE OF THE RESEARCHER

During the 2013-2014 school year, I served as one of three course instructors for the three disciplinary block methods courses. As a course instructor, I co-planned and co-taught these classes, as well as provided feedback on certain assignments. In addition, I was the field supervisor for two PSTs, Mark Bryant and Kady Tanner (see Table 3.2). As field supervisor, I observed and provided feedback on the PSTs' planning and instruction at their high school field sites.

During this dissertation study, assuming the roles of instructor, field supervisor, and researcher, required that I define these roles *a priori*. As instructor, I planned and led course sessions, and assessed and provided feedback on written work (including assignments that were part of my data collection). As field supervisor, I provided feedback on lesson planning and instruction, observed lessons, and provided support in all aspects of PST learning. Furthermore, I did not interview the two students I supervised (Mark Bryant and Kady Tanner) in order to avoid any bias in my questioning or their responses. As researcher, I obtained consent from all PSTs to collect part of their university assignments, lesson plans, and video record class sessions.

In addition, I conducted interviews with the subset of PSTs. Conducting interviews with my own students at the conclusion at the fall and spring semesters allowed me to establish a rapport with students that otherwise would not have occurred. This rapport allowed the PSTs to discuss their work and feelings in an open and honest way, which might not have occurred if the interviews were conducted by another researcher (Fontana & Frey, 1994). However, for some PSTs serving as course instructor might have limited their willingness to be as open and honest, a possible limitation of my study. The consistency between what students said during the interviews and what was learned from the analysis of their lesson plans provides evidence of the probable honesty of their comments. For example, three PSTs indicated that the coursework at the beginning of the fall semester was uninteresting and did not pertain to them.

Aside from obtaining consent at the beginning of the fall semester and setting up the camera for recording, I did not assume the role of researcher during course sessions and field supervisions. I felt it was important to provide the best support I could for the PSTs as they develop their skills and teaching repertoires. As for the subset of PSTs interviewed, these interviews minimally impacted our relationship as student and as course instructor. In addition, I explained to the interviewees that their responses were confidential from others and provided them an opportunity to further reflect on their own planning and support the improvement of the teacher preparation program at the university.

3.3 PARTICIPANTS

All of the PSTs were enrolled in a Master of Arts teacher preparation program at an urban Midwestern university and all received undergraduate degrees in science. While all of the PSTs in the secondary science Master of Arts in Teaching program were enrolled in the course (N=15) and consented to participate in the study, I selected a subset of PSTs for the interviews. Table 3.2 provides information about the participants of the study and those selected for interviews.

All the PSTs consented so that I could record video of the desired lessons that focus on lesson planning, task design, and the Five Practices model, and use their Instructional Performances as data sources described in Appendix A. Because I am the principal researcher gathering data and interviewing on this project, I selected nine PSTs to interview based on the combination of scores on the task and discussion rubrics below (Appendix C). PSTs could receive a maximum score of 33 on both rubrics; three PSTs were selected from each group receiving high, medium, and low scores. I identified the highest total scores on IP1 and IP2. From those scores, I categorized the remaining students into the three scoring categories. In selecting PSTs for interviewing in addition to utilizing the rubric scores, I selected a representative a sample as possible from the categories taking into account PSTs' school type (urban/suburban), content areas, grade levels, gender, and age/race/ethnicity.

Table 3.2: Description of study participants

Intern Pseudonym	Content Area	Grade Level	School Type
Mark Bryant	Biology	High School	Suburban Public
Calvin Cary	Physics	High School	Suburban Public
Frank Daniel	Biology	High School	Urban Public
Nicholas David	Biology	High School	Suburban Public
Florence Edward	Biology	High School	Suburban Public
Kelly Hendrick	Biology	High School	Suburban Public
Nancy Hall	Biology	Middle School	Urban Public
Kristen Ingall	Chemistry	High School	Urban Public
Xavier Idol	Biology	High School	Urban Public
Bonnie Kyle	Biology	High School	Urban Charter
Dana Nacey	Biology	Middle School	Urban Private
Kady Tanner	Chemistry	High School	Suburban Public
Nicole Timko	Biology	High School	Urban Public
Mary Wilson	Earth Science	High School	Suburban Public
Scott Xander	Physics	High School	Urban Public

Note: Highlighted Rows Indicate PSTs Selected for Interviews.

3.4 DATA SOURCES

I collected data from coursework, PSTs' instructional performance artifact packets, videotapes of university course sessions, additional lesson plans, and interviews to address the research questions. Recall that the research questions that guide the study were as follows:

I. To what extent do PSTs draw on the *Five Practices Model* to support planning of task-based discussion lessons?

Specifically –

i. To what extent do they anticipate students' work on the task?
ii. To what extent do they plan for ways to monitor students' work during the task?
iii. To what extent do they plan specific questions to elicit, challenge, or extend students' thinking?
iv. To what extent do they plan or imagine a storyline for how they want the discussion to unfold?
v. To what extent do they plan to make connections across students' ideas and connect to disciplinary ideas?
vi. To what extent do they plan for specific marking strategies to highlight important ideas?
vii. To what extent do they purposefully select and sequence the ideas they want to emerge during the discussion?

a. What available *curriculum materials*, including texts, online resources, and standards, do PSTs use during planning of these lessons?
b. What other resources or frameworks do PSTs use to plan task-based discussion lessons?

II. To what extent does PSTs' use of various resources and planning strategies support or hinder their ability to create lessons in which students are engaged in a challenging task where they participate in SEPs and engage in discussion?

III. To what extent does PSTs' pedagogical design capacity (PDC) for task-based science discussion lessons change over the course of their teacher preparation program? Are patterns and changes related to specific learning opportunities or elements within the teacher preparation program?

Included in the coursework were lesson plans and artifact packets produced by the PSTs for the Instructional Performances (IP). PSTs' created two IP artifact packets during both the fall and spring semesters for a total of four. Each artifact packet included: task, detailed lesson plan, instructional materials, student work, and a reflection on their planning and teaching that addressed questions posed by the teacher educators. I also asked the PSTs to identify lesson plans they created for during their internship placements ("In the Wild Lessons Plans"). In addition to the lesson plans and artifact packets, I interviewed the PSTs at the end of the fall semester and again near the end of the spring semester. Table 3.3 provides an overview of the data sources, the frequency of collection, and which research question each data source addresses. Figure 3.4 depicts the timeline of data collection.

Table 3.3: Correlation of research questions and data sources

Data Sources	Frequency and Timing of Collection	Research Question Addressed				
		1			2	3
		a	b	c		
Audiotaped Interview • Audio Recording • Transcripts	2 Interviews - End of fall semester and near end of spring semester	X	X	X	X	X
Initial Lesson Plan	1 – during fall semester Week 1	X	X	X		X
Instructional Performance (IP) Artifact Packets • Task • Lesson Plan • Reflection • Instructional Materials • Lesson Artifacts • Student Work	4 Total – 2 fall semester (Weeks 8-16) and 2 spring semester (Weeks 1-8)	X	X	X	X	X
In the Wild Lesson Plans	3 Total from each PST – solicited during the final three months of the spring semester	X	X	X	X	X
Video Taped University Courses • Video Recording • Field Notes	All pertinent university course sessions					X

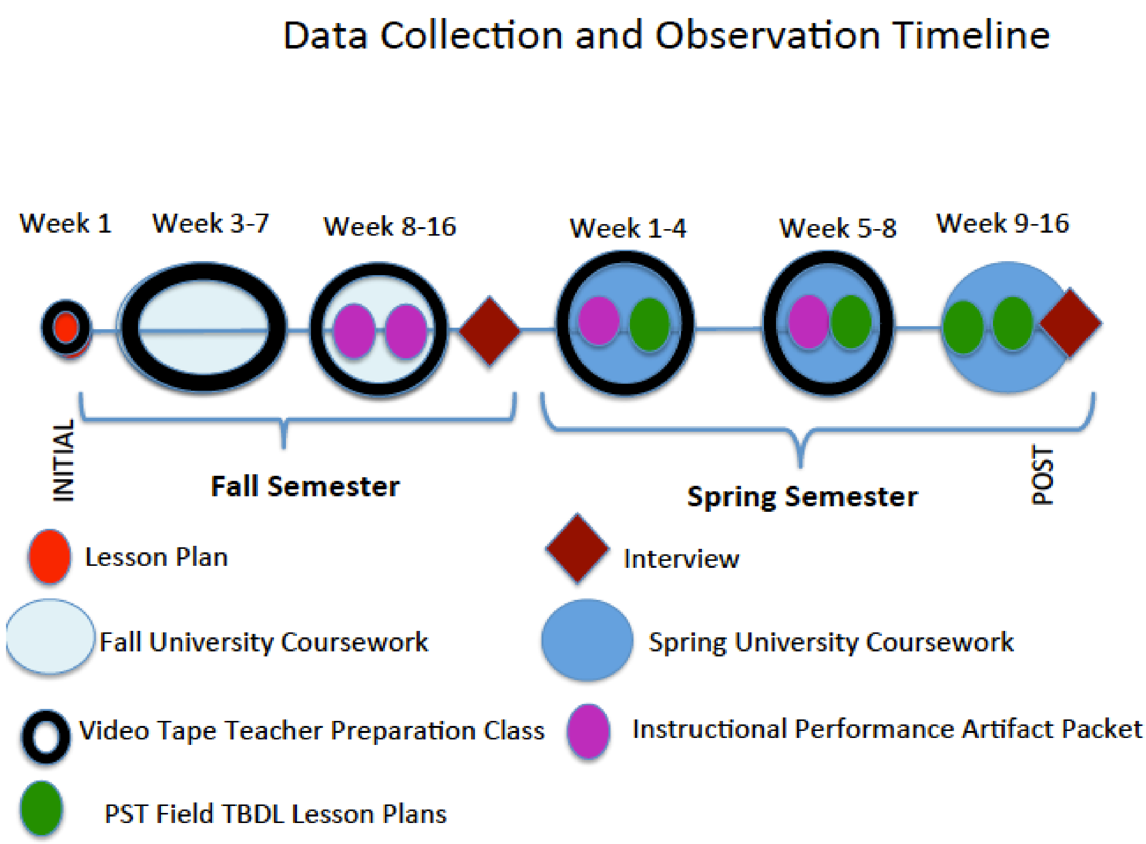


Figure 3.4: Timeline of data collection

3.4.1 Lesson Plan – Baseline

During week one of the fall 2013 semester, each PST created an initial lesson plan (LP) (see Table 3.3 and Fig. 3.4). The instructor assigned this lesson plan after the PSTs had an opportunity to engage in science as learners and begin to unpack supporting student engagement using the SEPs as part of their coursework. This assignment required PSTs to create a lesson plan (see Appendix A for assignment expectations). PSTs included the curriculum materials and other resources they used as part of their planning. The instructors did not give a template or set requirements for this first assignment. The only parameters were the requirement that PSTs plan a lesson for a class discussion meeting some of the SEPs, making this particular lesson plan an appropriate baseline plan to allow for comparison between future lesson plans.

3.4.2 Data of Teacher Preparation Coursework

Because this dissertation study sought to examine PSTs' lesson planning practices in an effort to describe the development of their PDC for designing high-level tasks where students engage in discussion, I observed the teacher preparation courses focusing on lesson planning, designing tasks, and discussion. During these observations, I recorded in-depth field notes (Emerson, Fretz, & Shaw, 1995) and videotaped each university lesson. After analyzing the IP artifact packets and interviewing the PSTs at the end of the fall semester, I used the patterns that emerged from analyzing each in an effort to relate these findings to particular coursework sessions. Once I identified those sessions, I described the lesson and instructional materials identified (Appendix A). Using these videos and field notes helped me to identify the features of the coursework that attributed to the PSTs' planning. These findings support the design refinement and further development of the secondary science teacher preparation program.

3.4.3 Instructional Performance Artifact Packets

As part of the coursework described above, the PSTs completed two instructional performances in each semester, where they planned, taught, and reflected on a whole class discussion lesson focused on engaging students in the SEPs. As part of the assignment, the PSTs generated artifact packets (Borko et al., 2005). Each packet includes: lesson plan, task, artifacts of student work from the lesson (e.g., pictures of graphical representations, student work), and a reflection on teaching and student learning. As part of the reflections, the PSTs answered questions related to the resources and curriculum materials used during planning and how their planning supported student engagement in the SEPs. These artifact packets were the main data source for this dissertation study. From these packets, I examined and described the PSTs' lesson planning practices related to designing high-level tasks where students engage in discussion.

3.4.4 Interviews

At the end of the fall and near the end of the spring semester, I interviewed the selected group of PSTs using the protocols in Appendix E. I selected PSTs based on the combination of scores on the HLTR and LPDR rubrics (Appendix D). I selected nine of the 15 PSTs from representative content areas, school type, grade levels, and demographic groups within each scoring category Low, Medium, and High. Table 3.2 identifies the PSTs selected for interviews. These interviews provided detail pertaining to the PSTs' use of curriculum materials and resources, and use of instructional frameworks, like the Five Practices, lesson planning practices, and challenges to planning and teaching these types of discussions. In addition, these interviews enabled the PSTs to identify specific coursework sessions during each semester that influenced or supported this type of planning. From these interviews, I identified particular university coursework sessions to analyze further through the video as described above.

3.5 CODING AND ANALYSIS

This section describes the coding tools and processes I used to code the data for analysis in this study. I took a number of measures to ensure the reliability and validity of this study. In order to establish reliability in coding this qualitative data study, a second coder coded a subset of the data (Miles & Huberman, 1994). To ensure reliable coding of the interview transcriptions, the second coder coded five out of 18 interviews (25%) using Brown's (2009) "types of curriculum use," i.e., adapt, offload, and improvise, for task selection. In addition, I used the Grounded Theory Model (Boyatzis, 1998) to identify themes and concepts that emerged. The primary coder trained this secondary coder using the coding definitions and examples in Appendix E.3. In double coding these interviews, we were able to achieve an interrater reliability 82%. Where we disagreed, we subsequently discussed the codes and reached a consensus.

In order to ensure reliable coding of the IP artifact packets, the second coder used the lesson plans, tasks, and reflections to code for elements of a high-level task and elements of a lesson plan that support discussion using the Task Analysis form (Appendix B) and High Level Task Rubric (HTLR) (Appendix D.1) and Lesson Plan for Discussion Rubric (LPDR) (Appendix D.2). The second coder coded 15 of the 60 IP artifact packets (25%). The primary coder trained the secondary coder regarding the appropriate coding definition rules for each analysis and the completion of the analysis forms. Using the reliability formula described by Miles and Huberman (1994), I calculated interrater reliability between the primary coder and the secondary coder at 87%. We resolved all disagreements through discussion. This secondary coder was familiar with the study and the Five Practices model, which allowed for such a high reliability score.

3.5.1 Interviews

As noted above, I interviewed each selected participated twice, once after the fall semester using Interview Protocol 1 (Appendix E.1) and once after the spring semester using Interview Protocol 2 (Appendix E.2). I recorded and transcribed each participant interview for a total of 18 interviews (three participants from each scoring category). I coded the transcriptions using the Grounded Theory Model (Boyatzis, 1998) as well as Brown (2009) types of curriculum use (Chi, 1997; Miles & Huberman, 1994). These helped me to identify themes regarding PSTs' perceptions lesson planning, use of planning practices, and influence of coursework (see Appendix E.3 for definition rules and example data excerpts). In order to triangulate with findings on the HLTR and LPDR, I analyzed relevant segments of transcripts relating to the Five Practices, whole class discussions, and relevance of coursework using the online data analysis and management program Dedoose Version 4.12.14 (Denzin, 1978; Patton, 1999). More specifically, I analyzed the PSTs' use of the Five Practices, the ways in which they used their curriculum materials and the support provided by human resources, i.e., mentors and university supervisors. These analyses shed light on the PSTs' understanding of particular features of lesson planning that support student engagement in high-level tasks where students engage in discussion. Furthermore, the interviews provided information regarding the influence of particular topics from coursework sessions and highlight areas that required design modification.

3.5.2 Analytic Tools

I used three main tools to complete the analysis of the baseline lesson plan and IP artifact packets: (1) PST Task Analysis Form (PTF) (Appendix B), (2) the Elements of a High-Level

Task Scoring Rubric (HLTR) (Appendix D.1), and (3) the Elements of a Lesson Plan that Supports Discussion Scoring Rubric (LPDR) (Appendix D.2). What follows is a description of these tools and how I used these tools to analyze the data related to each research question.

3.5.2.1 PST task analysis form and elements of a high-level task scoring rubric

The PST Task Analysis Form (PTF) (Appendix B) served as the initial coding form for each lesson plan (Instructional Performance and "In the Wild"). On the form, the coder described the lesson, task, identified the type of task (experimentation, data analysis/representation/interpretation, explanation), and identified the potential level of cognitive demand of the task (See Appendix B for completed example). To determine the level of cognitive demand, the coder used the Science Task Analysis Table (STAT) derived from Cartier et al. (2013) (Appendix C). After summarizing the lesson and the task in detail using the PTF, the coder used the Elements of a High-Level Task Scoring Rubric (HLTR) (Appendix D.1) to score the task as designed by the PST. The maximum score a PST could receive on this rubric was 10. The HLTR assessed the following parameters of a high-level task that supports a science discussion: lesson goals, potential task demand, support of student engagement *NGSS* Science and Engineering Practices, support of student engagement in productive whole class discussion, and the potential for students to create artifacts as a result of the task.

3.5.2.2 Elements of a lesson plan that supports student engagement in discussion scoring rubric

In an effort to examine the implementation of the Five Practices model and other instructional planning practices presented over the course of the semester, the coder used the LPDR form (Appendix D.2) to analyze the available data. The LPDR scored each lesson plan by taking into account additional research into PSTs' anticipation and lesson goals for high-level tasks (Smith et al., 2013). Using this form, the coder focused her attention on the anticipation, monitoring, and other planning practices supported by the Five Practices model (Smith & Stein, 2011). The coder scored the lesson plan and provided evidence for each score. The coder then input the scores and evidence into a matrix for further analysis. A completed example of the HLTR and LPDR can be found in Appendix D.3.

3.5.3 Data Analysis

I used various measures and analyses of the data corpus collected in this study. This section details the analyses used to address each research question. Table 3.4 describes how I used each particular data source to address each research question and how I analyzed these data.

Table 3.4: Data analysis structure used to address each research question

Research Question	**Data Sources**			**Analysis**
	Video of University Course Sessions	*Interviews*	*Lesson Plan 1 & Instructional Performance Artifact Packets & In the Wild Lessons*	
I	• Video • Field Notes	• Interview Transcripts	• Lesson Plan • Task • Lesson Artifacts • Additional Planning Materials • Reflection • PST Task Analysis Form • High-Level Task Rubric (HLTR) • Lesson Plan Supporting Discussion Rubric (LPDR)	• Interviews coded using Grounded Theory Model to analyze PSTs' use of curriculum materials and resources, use of the 5 Practices, Learning Cycle and other strategies from coursework • Compare the scores on the HLTR and LPDR across LP1 and IPs 1-4 • Generate a within case and cross case matrix that details the scores on each rubric over time • Generate a within case and cross case matrix that details the change in use of curriculum materials and other resources over time
II		• Interview Transcripts	• Lesson Plan • Task • Lesson Artifacts • Additional Planning Materials • Reflection • PST Task Analysis Form • High-Level Task Rubric • Lesson Plan Supporting Discussion Rubric	• Interviews coded using Grounded Theory Model to analyze PSTs' use of how planning supports or hinders PSTs' ability to plan lessons where students are engaged in SEPs • Compare the scores on the HLTR and LPDR across LP1 and IPs 1-4 • Generate a within case and cross case matrix that details the scores on each rubric over time • Generate a within case and cross case matrix that details the change in use of curriculum materials and other resources over time
III	• Video • Field Notes	• Interview Transcripts	• High-Level Task Rubric • Lesson Plan Supporting Discussion Rubric	• Interviews coded using an the Grounded Theory Model to analyze PSTs' use of curriculum materials and resources, use of the 5 Practices, Learning Cycle and other strategies from coursework • Generate a within case and cross case matrix that details the patterns that emerge • Within-subjects repeated measures ANOVA to analyze significance of differences in total rubric scores

3.5.3.1 Research question I

In order to answer Research Question I – (to what extent do PSTs draw on the *Five Practices Model* to support planning of task-based discussion lessons?) – I analyzed the data to answer the sub-questions related to PSTs use of the Five Practices model, available curricular resources, and other resources in their planning of the Instructional Performances. I analyzed the initial lesson plan, Instructional Performances 1-4, and any In the Wild Lesson Plans. I used descriptive statistics and qualitative analyses to provide a measure of how PSTs drew upon the various resources on the dimensions of a high-level task and elements of a lesson plan that support discussion. These results provided a measure of what the PSTs used with respect to particular curriculum materials and other resources, including instructional frameworks, to plan high-level tasks where students engage in whole class discussions when they were explicitly told to design a task-based discussion. I identified similarities and differences between first LP and IPs 1-4 using within case and cross case matrices (Miles & Huberman, 1994).

3.5.3.2 Research question II

In order to answer Research Question II - (to what extent does PSTs' use of various resources and planning strategies support or hinder their ability to create lessons in which students are engaged in a challenging task where they participate in SEPs and engage in discussion?) – I compared the scores of the HLTR and the LPDR with the patterns that emerged during the interviews and coding of the curriculum materials and resources. Based on the materials and resources and the scores, I identified what, if any, planning strategies supported their planning of tasks where students participate in discussion or hindered this planning. In doing so, I drew conclusions related to the ways in which the PSTs planned and utilized the available resources and the level of lesson planned. Finally, I used descriptive statistics, e.g., totals, means, and percentages, for each IP to make comparisons between PSTs to determine the extent to which the level of cognitive demand of the task and detailed lesson planning changes throughout the year.

3.5.3.3 Research question III

In order to answer Research Question III – (to what extent does PSTs' pedagogical design capacity (PDC) for task-based science discussion lessons change over the course of their teacher preparation program? Are patterns and changes related to specific learning opportunities or elements within the teacher preparation program?) – I used total scores from the HLTR and the LPDR (33) for LP and IPs 1-4 in order to make comparisons over the course of the program. I conducted a within-subjects (repeated-measures) analysis of variance (ANOVA) to compare the total HLTR/LPDR scores for each of the 15 PSTs across the five instructional performance times. I investigated the dataset for the inferential analysis assumptions of (a) absence of outliers, (b) normality, and (c) sphericity. Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(9) = 17.90$, $p = .038$. Violations of sphericity can result in an increased Type I error rate. SPSS offers the Greenhouse-Geisser adjustment to the F-statistics in the ANOVA, which corrects for violations of sphericity by adjusting degrees of freedom (Pallant, 2007). All inferences made from the ANOVA analysis were performed using the probabilities obtained using the adjusted Greenhouse-Geisser F-statistic ($\varepsilon = 0.55$).

I performed a check of boxplots for the total HLTR/LPDR scores at each of the five IP times of (a) lesson plan (LP) scores, (b) beginning of fall intervention (IP 1) scores, (c) end of fall intervention (IP 2) scores, (d) beginning of spring intervention (IP 3) scores, and (e) end of spring intervention (IP 4) scores to visually inspect for outliers, and no outliers were indicated.

The lesson plans the PSTs created at the beginning of the fall semester, for IP 1 and IP 2 (end of fall), and IP 3 and IP 4 (spring semester) represented three different time points during their teacher preparation. Comparisons between LP and IP 1 and IP 2 represent the extent to which the university coursework impacted the PSTs' planning immediately following lessons focusing on the dimensions related to the HLTR and LDPR. Additionally, comparisons between LP1 and IP 3 and IP 4 and IPs1-4 represent the uptake and traction of the strategies presented in the coursework by the PSTs in their planning practices.

Finally, I identified patterns with respect to which PSTs' scores on the HLTR and LPDR and the curriculum materials and resources identified during interviews. By comparing these data with the video data of the coursework sessions, I created a detailed narrative of PSTs' that developed high levels of planning practices with respect to challenging tasks that support discussion versus PSTs' that developed medium and lower levels of these planning practices. Responses to the interview questions asked during both interviews as well as data from coding the PSTs' lesson plans served as data for each narrative.

3.5.3.4 In the wild lesson plans

At three time points during the spring semester, I solicited lesson plans from the PSTs. These solicitations occurred in February, March, and April. I asked PSTs to email me lesson plans of lessons taught at their internship sites that were not for a course assignment, an "In the Wild" lesson plan. Only three PSTs responded. Because the response rate was so low, I did not include these scores in my analyses. I did; however, include a line of questioning in the final interview protocol that addresses challenges the PSTs faced when planning and teaching these types of lessons with the goal of learning possible reasons why the response rate was so low.

3.6 SUMMARY

This chapter described the study context, participants, and the methodological approaches used in this study to address my research questions. This study used a descriptive and quantitative mixed-methods approach to investigate development of PDC for designing challenging tasks that support student engagement in whole class discussions. This study allowed me to describe the evolution of PSTs' instructional practices over the course of their participation in the teacher preparation program. I drew upon course assignments, interview transcripts, and classroom observations collected throughout the teacher preparation year. In coding the data, I developed, refined, and revise the coding schemes to account for emergent codes. After coding the data, I quantified some of the codes, as appropriate, in order to make meaningful comparisons between the data and to describe the PSTs' lesson planning practices for task-based discussions. In addition, I summarized the change over time of the PST planning scores for supporting science discussions. Chapter Four presents the results of these analyses.

4.0 RESULTS

This chapter reports the results of the data analyses described in Chapter Three used to answer the research questions of this study. It is organized into three main sections. In section 4.1, I provide detailed narratives of the PSTs' use of the Five Practices Model. Narratives focus on interview participants' scores on Instructional Performance 4, which demonstrated PSTs' learning over the course of the year. Section 4.2 describes how the PSTs use of various resources support or hinder their ability to create lessons where students engage in discussion. Section 4.3 describes the development of the PSTs' PDC over time and identifies which teacher preparation course sessions had the most impact on PSTs' learning, as identified by the PSTs. Results show improvement of the PSTs' lesson-planning practices for discussions over time as well as the design of high-demand tasks.

4.1 PRE-SERVICE TEACHERS' USE OF CURRICULAR RESOURCES AND INSTRUCTIONAL FRAMEWORKS IN PLANNING DISCUSSIONS

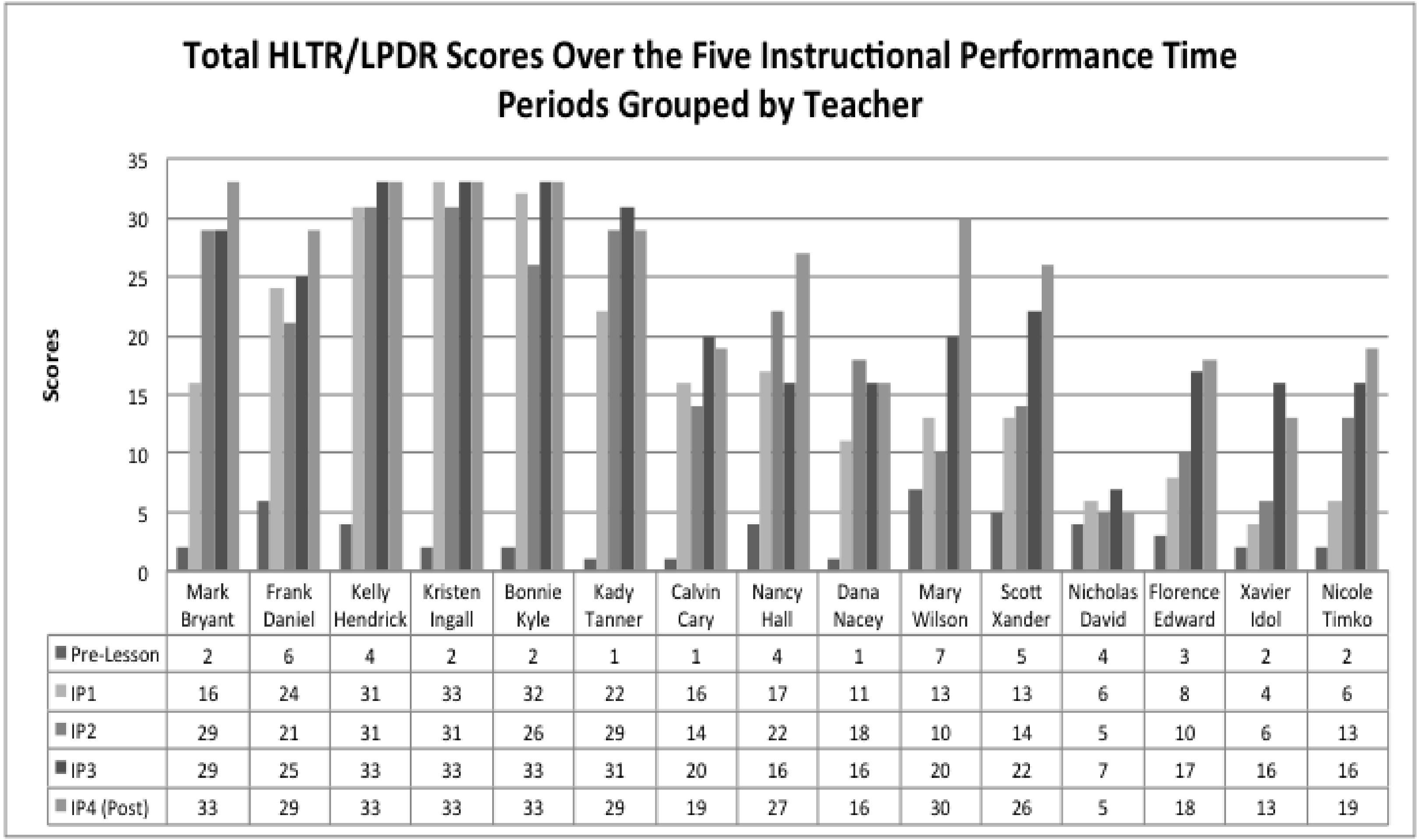
4.1.1 Use of the Five Practices Model

Research Question I: To what extent do PSTs draw on the Five Practices Model to support planning of task-based discussion lessons?

In the first phase of the analysis for this study, I examined the ways in which PSTs drew on the Five Practices model to support their planning of task-based discussion lessons. In doing so, I used the HLTR and the LPDR (Appendix D) to score the PSTs' lesson plans as described in Chapter Three. Table 4.1 displays the PSTs' total scores on the baseline lesson plan, Instructional Performances 1, 2, and 3, as well as Instructional Performance 4, which occurred after the completion of the six-month intervention. After the fall semester, I selected the PSTs for interviews based on their scores on IP 1 and IP 2. Six PSTs scored high with scores of 45-64. Five PSTs scored in the medium range with total scores of 23-39 and four PSTs scored low with scores from 10-18.

Overall, the PSTs' scores improved over time indicating that as the year progressed students drew on the Five Practices model to a greater degree in their planning. The majority of the PSTs remained in the same scoring category throughout the year. For example, the six PSTs scoring high (Kristen Ingall, Kelly Hendrick, Bonnie Kyle, Kady Tanner, Mark Bryant, and Frank Daniel) scored high consistently. However, eight of the nine PSTs scoring medium and low improved their scores over time. Nicholas David is the only PST whose low scores did not seem to improve with time. It is difficult to know from this data why Nicholas David's scores did not improve. Additional data are needed in order to examine his performance.

As, described in Chapter Three, my analysis involved examining the characteristics of a PST demonstrating high, medium, and low PDC for planning task-based science discussion lessons. Here, I describe the ways in which PSTs used the Five Practices Model in the planning of their lessons.



	Mark Bryant	Frank Daniel	Kelly Hendrick	Kristen Ingall	Bonnie Kyle	Kady Tanner	Calvin Cary	Nancy Hall	Dana Nacey	Mary Wilson	Scott Xander	Nicholas David	Florence Edward	Xavier Idol	Nicole Timko
Pre-Lesson	2	6	4	2	2	1	1	4	1	7	5	4	3	2	2
IP1	16	24	31	33	32	22	16	17	11	13	13	6	8	4	6
IP2	29	21	31	31	26	29	14	22	18	10	14	5	10	6	13
IP3	29	25	33	33	33	31	20	16	16	20	22	7	17	16	16
IP4 (Post)	33	29	33	33	33	29	19	27	16	30	26	5	18	13	19

Note: Grouped by scores: Mark Bryant – Kady Tanner (High), Calvin Cary – Scott Xander (Medium), Nicholas David – Nicole Timko (Low)

Figure 4.1: Bars represent the total HLTR/LPDR scores for each instructional performance time, according to individual teacher (N = 15)

Table 4.1: Total scores (out of possible 33) of the PSTs' pre-lesson and instructional performances over the course of the year

		Instructional Performances					
Intern Name	Pre-Lesson	IP1	IP2	Sub Total (1 & 2)	IP3	IP4 (Post)	Total (1-4)
Kristen Ingall	2	33	31	64	33	33	130
Kelly Hendrick	4	31	31	62	33	33	128
Bonnie Kyle	2	32	26	58	33	33	124
Kady Tanner	1	22	29	51	31	29	111
Mark Bryant	2	16	29	45	29	33	107
Frank Daniel	6	24	21	45	25	29	99
Nancy Hall	4	17	22	39	16	27	82
Calvin Cary	1	16	14	30	20	19	69
Dana Nacey	1	11	18	29	16	16	61
Scott Xander	5	13	14	27	22	26	75
Mary Wilson	7	13	10	23	20	30	73
Florence Edward	3	8	10	18	17	18	53
Nicole Timko	2	6	13	19	16	19	54
Nicholas David	4	6	5	11	7	5	23
Xavier Idol	2	4	6	10	16	13	39
Mean	3.07	16.8	18.6	35.4	22.3	24.2	117.3
Maximum Score	7	33	31	64	33	33	130
Minimum Score	1	4	5	9	7	5	23

Note: Total scores listed for IP 1 and IP 2, which I used as a parameter for selecting PSTs for interviews. Each grouping of PSTs' scoring in the High, Medium, and Low, respectively categories are separated by dotted lines. First column numbers correspond to Figure 4.1.

4.1.1.1 Use of the Five Practices model by PSTs demonstrating high pedagogical design capacity

One of the goals of this study was to define and operationalize PDC for planning task-based science discussions. In the first part of my analysis, I identified the PSTs scoring high, medium, and low after the first semester in order to select interview participants for the year. In doing so, I identified six PSTs that scored high on Instructional Performances 1 and 2: Kristen Ingall, Kelly Hendrick, Bonnie Kyle, Kady Tanner, Mark Bryant, and Frank Daniel with scores ranging from 45-64 (Table 4.1). Of these six, four (Kristen Ingall, Kelly Hendrick, Bonnie Kyle, and Mark Bryant) also scored highest with a score of 33 on the final IP 4 and all six were among the highest scoring PSTs throughout the year.

As one might expect, over the course of the year, certain characteristics emerged in these PSTs' planning. Specifically, high scoring PSTs created detailed Learning and Performance Goals. Their tasks as designed were high demand where students create artifacts around which the discussion is based. In their lesson plans, they anticipated students' correct *and* incorrect thinking. In addition, they created a monitoring tool and planned questions to elicit students' thinking as well as to make connections between students' ideas and disciplinary ideas. These PSTs also clearly planned for selecting and sequencing students' ideas and/or work. They also planned for marking and charting students' ideas during the discussion. By identifying features of high performing PSTs on Instructional Performance 4, which occurred post-intervention, it was possible to identify the extent to which these PSTs' used the Five Practices Model in planning. What follows is a detailed analysis of the interviewed PSTs and their use of the Five Practices model in their planning.

(a) Kristen Ingall

For Instructional Performance 4, Kristen, a chemistry intern in an urban public school, designed "The Mole Task," a task adapted from the school's curriculum where students determine the number of moles in an unknown substance. During her interview, when asked, "What curriculum resources did you use when designing this task?" Kristen explained that she recognized the need to adapt the task provided in the curriculum in order to make it more appropriate for a Five Practices discussion.

> My, um… the curriculum has this mole lab, right? That's in there that they… give us. Um with no directions. And it wasn't formatted really well… um, and it was just like, "Do the mole lab." Okay. so I had that mole lab, and from… that – I mean, I had all these lists of, how many whatevers – how many molecules in a sugar cube, how many this or this? So I changed some of them to be more practical, um, 'cause I wasn't gonna go find, like, a liver or something.

Her students answered the question, "How many moles of aluminum are in a can of soda?" She instructed the students to record their protocol to answer the question and their conclusions. This task was an experimentation task where students developed their own protocol and made decisions about what data to collect and how to collect that data. Kristen planned specific learning goals and performance goals for the lesson (Table 4.2).

Table 4.2: Kristen Ingall's learning goals and performance goals for instructional performance 4

Learning Goals	To convert between two different units of measurement, a conversion factor is needed. When working with moles, this conversion factor is 1 mole = 6.022 X 10^{23} .
	The molar mass of a compound is calculated by totaling the number of grams of each element contained in one mole of the compound.
Performance Goals	Given a sample of an element or compound, students will be able to collect the necessary data and calculate the number of moles contained in that sample with 70% accuracy.
	Given the number of moles of an element or compound, students will be able to calculate the number or atoms contained in that sample with 85% accuracy.
	Using their knowledge of gathering data, students will be able to determine the ordered steps in a procedure to calculate the number of moles, atoms, or molecules in a designated sample with 80% accuracy.

Kristen anticipated students' correct and incorrect thinking in her planning for this task in detail. First, she anticipated the ways in which students might correctly answer questions she planned to ask during the task and how she would support students who were struggling.

> What do you need to find in order to calculate the number of moles of a substance? I expect students to tell me that they need to have either the mass of the substance or the number of atoms in order to calculate the number of moles. I will push them to think about what is practical in this situation (i.e., can they count the number of atoms?). They should realize that they need to first find the mass of their sample before they can do any calculations about how many moles or atoms they have. If they are having trouble coming up with an answer to my question, I will encourage them to consult their mole conversion roadmap.

In addition, Kristen provided an example of an ideal poster she expected students to create (Figure 4.2). Kristen clearly identified the protocol, data, analysis, and conclusions she expected. From here, she designed a detailed monitoring tool based on organizing trends for their artifacts with specific questions for each group to push the students' thinking forward (Appendix F.1).

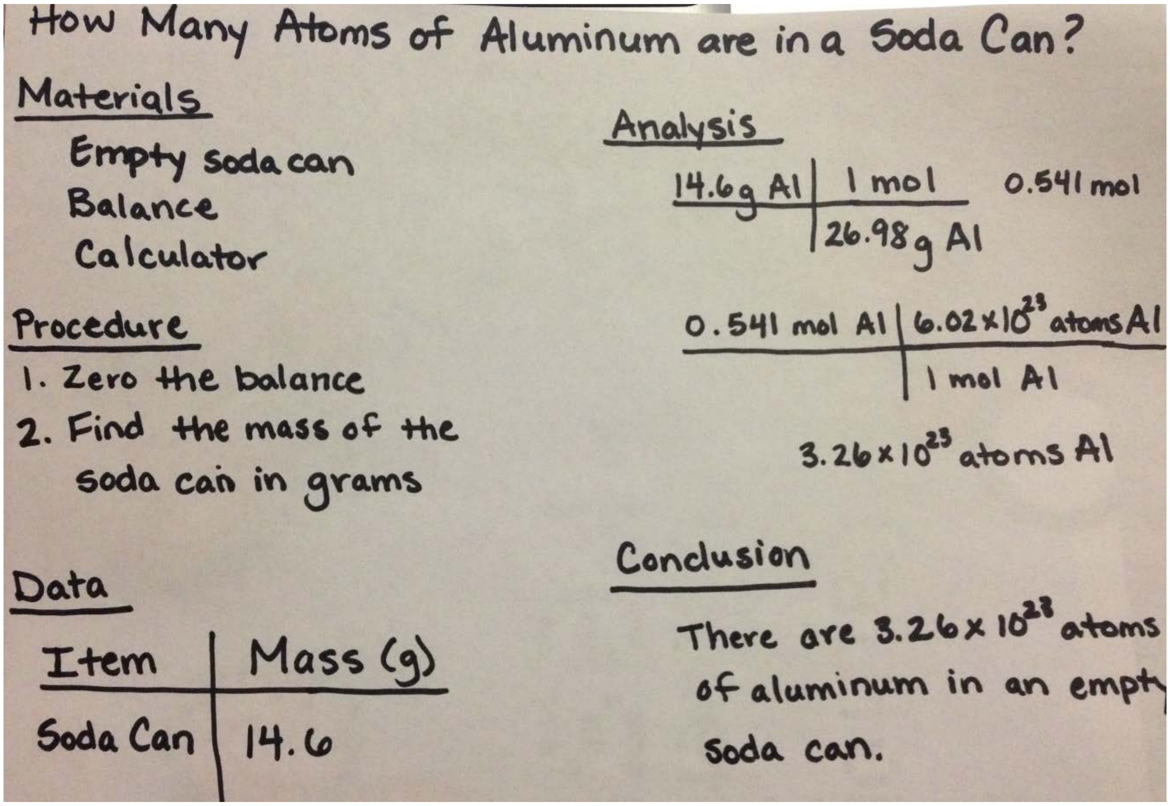


Figure 4.2: Kristen Ingall's anticipation of students' correct artifact for the Mole Task

While Kristen did not explicitly select or sequence in her lesson planning for this lesson, when asked during the interview, "If you would look through your lesson plan, how did you plan for sequencing, selecting, and connecting?" Kristen explained her rationale for not providing as much detail for selecting and sequencing.

> Um, yeah so I arranged these, um, kind of in order of strength. I didn't have a lot of groups. I had, um… had a lot of students absent, which is why I only ended up with, what? ten students? And so I – I used all of my groups. So selecting, I guess, not so much; but sequencing for sure. Um, and I started with groups that had done something right, like to start off with, they had done a couple things right and kind of progressively got to students who did more things right.

In terms of planning for the discussion itself, Kristen planned for a variety of questions throughout her lesson plan for "The Mole Task" and the subsequent discussion. She planned questions to elicit students' thinking and push students' thinking forward in the monitoring tool in Appendix F.1. In planning for the discussion, she provided an outline detailing what she would say and the particular order in which she would progress in the discussion, she wrote, “Using the monitoring tool, keep track of the groups in the order that they will participate in the discussion.” While her storyline for the discussion in this lesson plan was not as detailed as previous Instructional Performances, she indicated questions she planned to ask students during the discussion.

> Also, there will be several questions that I will want to ask groups to start them thinking about and/or discussing the phenomenon they are seeing.
>
> - What does the atomic mass on the periodic table represent? I expect students to tell me that the atomic mass indicates the mass of one atom of the element (in amu) and/or one mole of the element (in grams). It is important for students to understand the difference between these two quantities as students are often confused by the difference between atoms and moles.
> - What do you need to find in order to calculate the number of moles of a substance? I expect students to tell me that they need to have either the mass of the substance or the number of atoms in order to calculate the number of moles. I will push them to think about what is practical in this situation (i.e. can they count the number of atoms?). They should realize that they need to first find the mass of their sample before they can do any calculations about how many moles or atoms they have. If they are having trouble coming up with an answer to my question, I will encourage them to consult their mole conversion roadmap.
> - How did you decide what conversion factor you needed to use when converting into atoms? I expect students to tell me that they knew that one mole equals 6.022×10^{23} atoms (this is the conversion factor) from class over the past couple of days. They should then tell me that they multiplied the number of moles of their substance by 6.022×10^{23} to calculate the number of atoms. They should also show all of their work and use the “train-track” method. Another good check for understanding here is to make sure they multiplied by 6.022×10^{23} instead of dividing. Students tend to initially be very confused when working with these types of calculations.

One sees from this excerpt that Kristen had a definite plan for the discussion and what ideas she hoped to emerge, and clearly indicated with which group she wanted to begin following the order in her monitoring tool. In addition, she clearly indicated her plans to chart and mark student thinking by stating that she would “chart important ideas on the blackboard with sections for each of the sections that should be expected on each group's poster." Using her anticipation poster (Figure 4.2) as a guide, she generated her marking tool capturing students' ideas during the discussion.

The detail with which Kristen planned for Instructional Performance 4 and throughout the year, as evident in her high scores (see Figure 4.1 and Table 4.1) demonstrated her high pedagogical design capacity for planning task-based science discussions. When asked, "You have a lot of detail in terms of planning for the Five Practices. I'm wondering what prompted you to write your lesson plans in this way and to plan this way for the discussion." Kristen responded.

> The day we did it in class, because my group had super planned, do you know what I mean? We wrote like, I didn't. This was not my idea. But one of my group mates was like, "We should write out a whole script." I was like, "Wow, that sounds like a lot of work, okay." But having written all that script it kind of showed like the flow. I really wanted that flow to be in this discussion. I knew that it was a Wednesday and they are always tough at my school because of advisory days.
>
> So, from the beginning, this, like, I – I guess I got lucky with that very first one. Like, I had really intense planning, 'cause I knew my mentor wasn't gonna be there, it was gonna be really stressful, and I, like, planned the whole thing – and it worked. So then every time I have to do one of these lessons I just kind of… plan the same way, because it worked. It was one of those "if it ain't broke, don't fix it", you know? It – it relieves a lot of stress. Um, 'cause I think otherwise this student-led discussion this could be a little stressful. But when – when I need the students to do a lot of talking or the students to do a lot of thinking or the students to do a lot of something, I tend to write more. Um, 'cause then I'm like, "Okay well if they say this, I'm gonna say this. And they might say this, they might do this, they might –" so the more that I kind of let control go, I write more about it.

Kristen explained a key characteristic of a PST's planning for a Five Practices discussion. Preparation and detailed planning most likely led to a successful class discussion lesson. At the very least, Kristen felt prepared and believed the lesson was more successful because of her planning. As a result, she continued to plan with similar detail throughout the year. This idea of the importance of success continued to emerge throughout the interviews for PSTs regardless of scores.

(b) Kelly Hendrick

Kelly Hendrick was another PST who planned in great detail consistently throughout the year and demonstrated high PDC. Kelly interned teaching biology in a suburban high school using block scheduling. She was the only PST in the cohort teaching on a semester schedule where she had the opportunity to teach the same class twice (fall and spring). In doing so, Kelly had the opportunity to teach her first Instructional Performance again for Instructional Performance 4. Kelly scored a 31 out of 33 on IP 1 and a 33 out of 33 on IP 4, improving her score and planning slightly between the two lessons, while consistently demonstrating high PDC throughout the year.

In Kelly's task, "The Mitosis Task," students created a graphical representation of data in order to answer the question, "Where do cells spend most of their time?" In order to answer this question, students studied and analyzed images of microscope slides to generate their representations and conclusions. Similar to Kristen, Kelly also planned specific learning goals and performance goals (Table 4.3). This particular task Kelly created herself. When asked, "Where did you get the idea for this task?" Kelly responded that it was something she designed herself after consulting with her mentor and supervisor.

> The idea for the task really kind of just came out of nowhere. I just had this kind of crazy idea. I went to my mentor, I went to my supervisor, and I went to several other people saying, is this totally nuts. How do I do this so that it makes sense for the students and isn't too overwhelming.

Kelly also anticipated students' correct and incorrect thinking including the ways in which she planned to support students' thinking under each circumstance.

- I anticipate that several groups will make a bar graph with each phase given being a different bar.
    - This approach does work and shows the data, but it perhaps might not be the best to answer the question.
    - Ask the students why they think this design best shows the answer to the question?
    - What information does a bar graph provide that helps to answer the question?
- I also anticipate groups will try making a scatterplot with the data.
    - This method is really hard to get across the idea of where cells are spending their time.
    - If students begin with dots (not connected), will ask students about the dots because when we connect the dots into a line a graph it shows that there is some sort of relationship happening between the points.
        - First ask what does connecting the dots into a line mean and then ask if they plan on connecting the dots.
        - What does connecting the dots help other students in the classroom see?
    - If they already have connected lines ask them why they connected the data – is one point related to another?
    - It is also possible that a group may create a line of best fit for the data, question them about how that line helps to answer the question.
        - What type of information does a line of best fit provide for the audience?
- I hope that a group creates a pie chart and manipulates the data to create a percent of time that cells are in each phase.
    - This may not occur (although I put calculators on the stations to get them thinking about manipulating data).
    - If it doesn't occur, I will guide a group to this decision (or will stack the deck with slides that I made previously).
        - Besides just using the numbers that you were given, is there a way to alter the numbers to create a representation that truly show the percent of time a cell spends in each phase?
        - Use the word percent only with this group to get them thinking about math.
    - If a group already makes a pie chart question them about how they came up with the idea to make this chart.
        - Ask them how they are calculating the sections of the pie to make sure they would be able to explain it to the class if called upon.

As one can see, Kelly was very thorough in her anticipating. She discussed the type of representations students might make as well as how she planned to support students if misconceptions and/or questions arose.

Table 4.3: Kelly Hendrick's learning goals and performance goals for instructional performance 4

Learning Goals	When representing data, there are multiple ways to graph the collected data, including scatterplot, bar graph, line graph and pie chart to answer the proposed question.
	A percentage refers to parts per hundred and can be used to express the part of a whole
	The cell cycle includes interphase where DNA is replicated (S phase), mitosis and cytokinesis. Mitosis consists of the stages, prophase, metaphase, anaphase and telophase. a. Important characteristics of prophase are nuclear membrane breakdown, appearance of chromosomes and centrioles migrate. b. Important characteristic of metaphase is that chromosomes align on the equatorial plane. c. Important characteristic of anaphase is that chromatids move to opposite ends of the cell. d. Important characteristic of telophase is that the chromosomes stop moving and the nuclear membrane reforms.
	In cells that divide often, like root tip cells and skin cells, the cells spend the majority of time in the phases of mitosis.
	In cells that divide less frequently, like older cells and brain cells in adults, cells spend the majority of their time in interphase.
Performance Goals	Given a data set, students will be able to create a graphical representation of that data.
	When presented with the class options of representations, the students will be able to correctly decide the best model to represent the question, “Where do cells spend most of their time?”
	Given a paper version of a slide containing cells in various phases, students will be able to correctly identify which stage the cell is in 90% of the time.
	With a group consensus on the best representation type, students will be able to create a graphic representation of the data they collected.
	After group presentations, students will be able to identify the two main patterns of where cells spend most of their time.
	Given instruction by a peer, students will be able to correctly calculate five different percentages to use in their final representation.

Because IP 4 was the second time Kelly taught this lesson, she had the opportunity to revise her planning and instructional materials. She described this in her lesson plan regarding her monitoring tool (Figure 4.3).

- I am trying a new type of monitoring tool.
- Each large box represents the lab stations that students will be at – the large boxes are divided into two sections representing each one of the two activities.
    - I will look for what type of graph they made and if they did any type of math processes to alter their numbers.
        - If possible, jot down some important graph features for some graphs to mention to the class.
            - Graph features would include things like a title, key, labeled axis, color-coding, etc.
            - If students don't include any of these things, prompt them to think about if they were reading this in their book, does it contain all of the information they would need to be able to understand what it was showing.

Kelly was unsatisfied with her initial monitoring tool (IP 1) and created a different tool that was more functional and useful for her, but still addressed the features and learning goals of the lesson. She explained during her second interview, "It was generally the same except I changed my monitor – monitoring tool, which was, like, this one was far beyond much better than the other one."

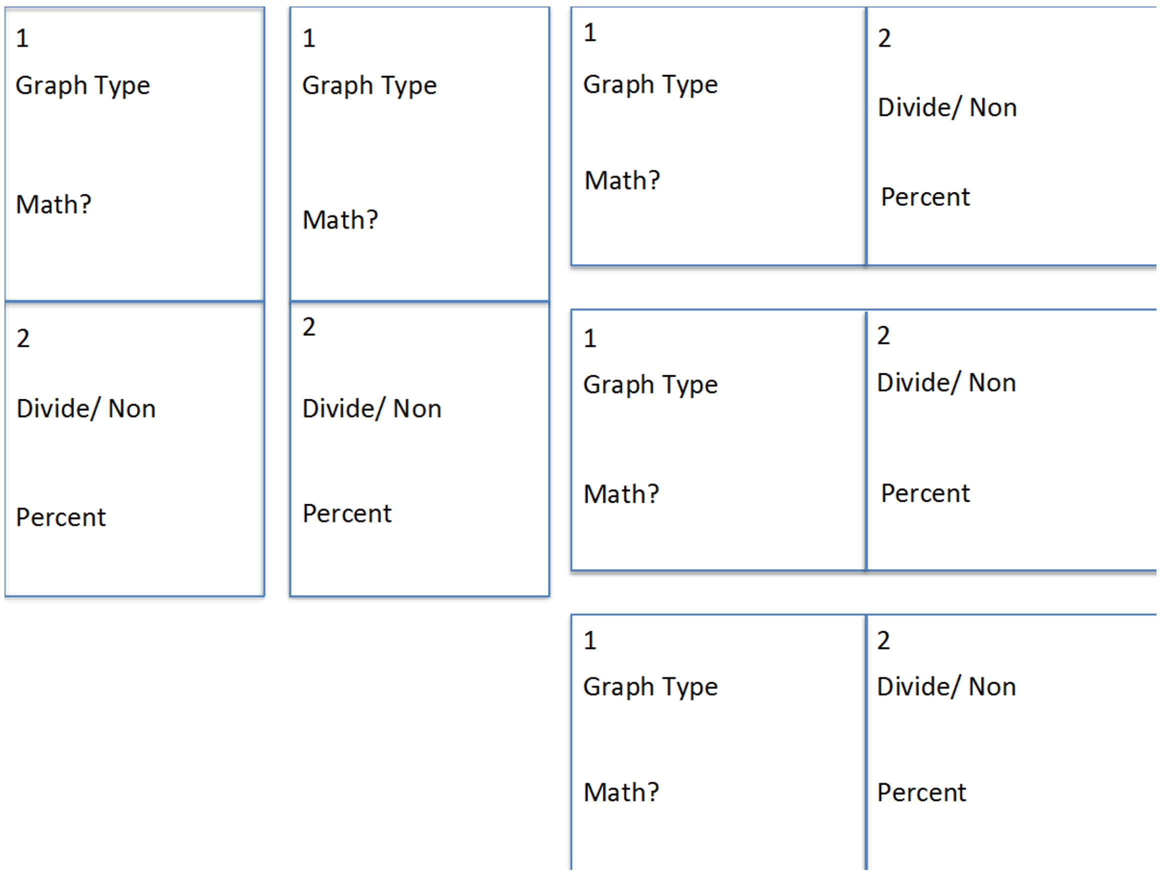


Figure 4.3: Kelly Hendrick's monitoring tool for Instructional Performance 4

Another feature of Kelly's planning that demonstrated high PDC was her planning for selecting and sequencing. She detailed her plans explicitly in her writing describing the order of the anticipated representations.

- Sequencing – when possible group students with like representations together. I will use the slide about important representation elements to mark important things that students say.
  - Even when there are like representations, use monitoring tool to note if certain groups used titles or axes or keys etc. and can point those out as important aspects.
  - Do NOT go in order with the pie chart being last.
    - Perhaps, bar graph → pie chart → line graph → any other types of representations!
    - Unlike the last time, I don't want it to be obvious that the pie chart is the best because it's last, so I will go in a different

> order to really elicit students' ideas about the best representation.

It is clear that Kelly's anticipating aided her in selecting and sequencing the representations that emerged during the discussion. When asked, "Why did you plan selecting and sequencing in this way?" Kelly had a clear understanding of what planning in this detail did for her as a teacher:

> Because it is an important part of getting the conversation to go where you want to go, without realizing it is where you've been wanting to go. That's how I kind of use sequencing. So in order for the kids to think that they are in control, I have to have some idea of where I am going to go with it.

This feature of detailed anticipating and detailed sequencing as well as the demonstrated understanding of the usefulness of such detailed preparation was a characteristic that emerged in all the PSTs demonstrating high PDC (see Table 4.11).

In addition, when planning for the discussion, Kelly planned questions to elicit students' thinking, support students in making connections between each other's ideas, as well as questions to support students in making a connection between their ideas and the disciplinary ideas. For example,

- Questions to ask each group:
  - Please explain how you decided to use this method and any key features of your graph that you would like to point out.
- Transition between groups with same type of graph.
  - Did you have any additional reasons why you used this type of graph? Is there anything that is different about your graph (this would be a point to note special graph things like title, etc.)?
- Transition between groups with different graphs.
  - How does your graph compare to the one that was just presented.
    - Could you explain why you chose to make this type of graph?
  - Which type of representation that you saw do you think best represents the answer to the question we are asking?
    - If they seem to be having trouble – attempt to go the opposite direction and eliminate answers that they don't think represent it well and see what we are left with.

Finally, Kelly clearly indicated when and how she would mark and chart students' ideas. She included a PowerPoint slide indicating how she would record the information with notes regarding how she would complete the chart (Figure 4.4).

- Go back to the class after each main type has presented to see what the class thinks about the representations.
  - This will be the point to record important graph information – let students know that I am going to take notes on the board and that I will give them time at the end to jot down the important information.
  - Cells in Bones and Connective Tissue of adults.
  - Muscle Cells and Nervous System Cells (after birth).
  - Cells lining the digestive system.
  - Root Tip Cells and Living Layer of Skin Cells.

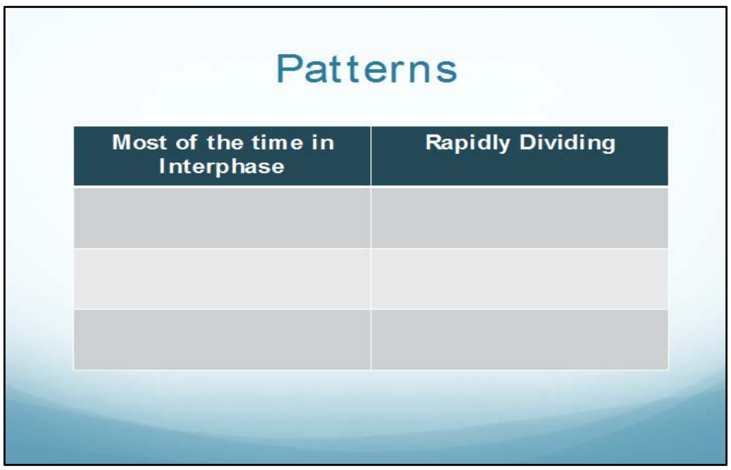


Figure 4.4: Kelly Hendrick's chart created to record students' ideas during discussion

(c) Bonnie Kyle

Bonnie Kyle was a biology intern teaching biology and chemistry in an urban charter school. She consistently demonstrated high PDC for planning task-based discussion lessons throughout the school year. Because she scored some of the highest scores on Instructional Performances 1 and 2, I chose to interview her. Like Kristen and Kelly, she also scored a 33 out of 33 on Instructional Performance 4. Bonnie's planning was consistent with that of other PSTs demonstrating high PDC. I detail her planning for IP 4 below.

This particular task was a chemistry task Bonnie taught in one of her classes. Bonnie acknowledged that this lesson differs from her other biology Instructional Performances and one that she created. She explained, "Um that was one that I created on my own. It was actually from my chemistry class. So it was a different class from all my other Five Practices." For this, "Characteristics of Reactions" task, students identified patterns of particular chemical reactions based on experimental data they acquired the previous day. In her plan, the learning goals and performance goals were specific for this particular task (Table 4.4).

Table 4.4: Bonnie Kyle's learning goals and performance goals for instructional performance 4

Learning Goals	Types of reactions share common characteristics, qualities, and patterns.
	Many chemical reactions can be classified as one of five different types of reactions - single displacement, double displacement, synthesis, decomposition, and combustion.
Performance Goals	Given types of reactions with example equations, SWBAT develop a list of characteristics (at least 2 per reaction type) that correctly distinguish between types of reactions.
	Given descriptive data with chemical equations, a list of the types of chemical reactions, and self-identified patterns within reaction sets, SWBAT match the equations with the correct type of reaction with 80% accuracy.

In terms of anticipating, Bonnie clearly specified her anticipations in her lesson planning. Some of Bonnie's anticipations were not as detailed as Kristen's or Kelly's. In fact, some are very general, only indicating what students might find easy or with what they might struggle. Bonnie's anticipations were; however, more detailed than the other PSTs who scored medium or low. Bonnie's anticipation was as follows:

- I anticipate that the identification of patterns will initially be difficult for students; however, once they have identified 1-2 patterns, I think it will be easier. If after about 1 minute of work time it looks like groups are struggling, I will pull the class back together and model and example pattern. E.g. I notice water is always a product in reaction set 5.
- Students may also struggle with polyatomic ion examples. I will remind students that just like we did when we first looked at ions, it is helpful to treat the polyatomic ion as a single unit that stays together.
- I expect students will find it easiest to identify patterns in synthesis and decomposition reactions.
- I also anticipate that students with single and double replacement will struggle identifying patterns. I will prompt them to use arrow to show how elements are moving around. And to think about what types of elements are usually involved (i.e. metals).
- The combustion reaction many be difficult to describe patterns, but I will encourage students to look back at their observations from yesterday's lab to see that in this type of reaction, something was burned.

Furthermore, Bonnie's planning for monitoring was as detailed as Kelly's and Kristen's. She designed a monitoring tool (Appendix F.2) and specific questions to ask students to elicit their thinking during their group work. In addition, she indicated that she planned "question cards," or hint cards, to support students as they worked in groups; a notable instructional design strategy that helps the PST scaffold students' work.

> During monitoring, I can ask the following questions to probe for patterns and student thinking. I have created question cards for the questions that I think I will use most frequently.
> - How are the bonds changing?
> - Where are bonds broken? Where are they formed?
> - How is the number of compounds or elements changing from one side of the equation to the other (increasing, decreasing, the same)?
> - What did you notice about the types of elements that are involved in this reaction set?
> - Look at your observations from yesterday to see if they can help you name the reaction.
> - Try drawing arrows to show how the reactants move around.
> - What other patterns do you notice?

Bonnie also clearly demarcated in her planning where she selected, sequenced, and connected, which indicated an awareness of the importance of including these in her planning.

Although her selecting and sequencing was not as detailed as Kelly's or Kristen's, she displayed selecting and sequencing at a higher level than other students scoring lower. She clearly had a plan for the order in which intended to discuss students' work.

> <u>*Selecting/Sequencing/Connecting*</u>
> We will discuss the reaction types in sequential order based on the way the sets were numbered. I deliberately labeled them in this order. I anticipate that synthesis and decomposition will be the easiest for students to understand because the two names are words that they have heard or used in context before. Additionally, these were some of the easier patterns to identify.
>
> I will start by asking one group who had reaction set one to share their patterns. After the first few patterns I will pause to ask if the rest of the class agrees with the patterns, or if they need clarification. I hope that as the discussion progresses, students will maintain this questioning without my direct prompt. After the first group finishes sharing their patterns, I will ask if there are other patterns another group wants to add.

Although, Bonnie's planning for her discussion was not as detailed as Kristen's or Kelly's, her planning did include a general outline that began in the excerpt above and continued with questions she wanted to ask her students during the discussion.

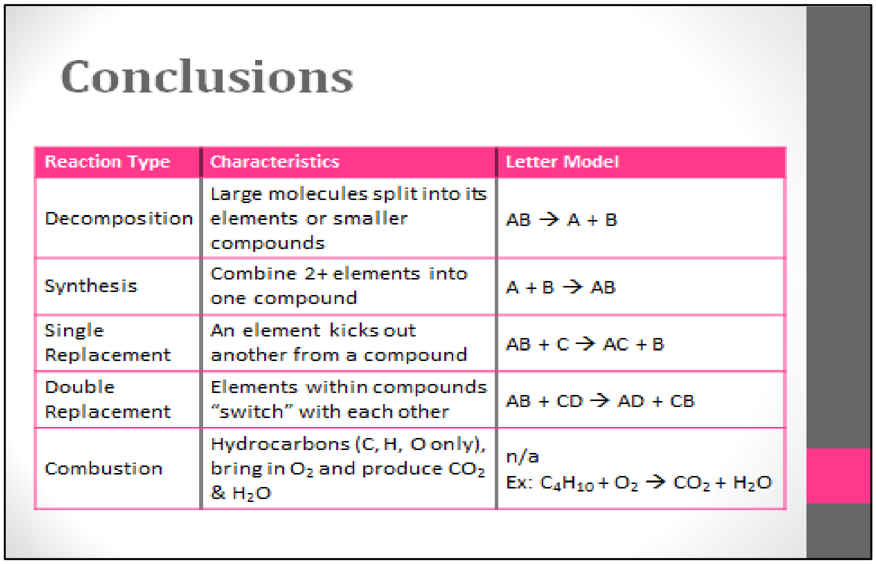
> Questions I can ask students to elicit their thinking include:
> - What does that word mean in other contexts?
> - How does your evidence support that choice?
> - What is a way we could represent this reaction pattern using general letters instead of specific elements?

This limited planning for connecting detail speaks to several questions asked during interviewing discussed later, namely, a PST's developing PDC as well as time constraints. For instance, when asked, "How has your planning changed over the course of the year?" Bonnie's response indicated an awareness of value of writing lesson plans and creating plans that are useful and unique to her own needs, but not necessarily with great detail.

> More like, I know I need to talk about these three bullet points. The exact phrasing, or whatever that I use, is less important than that they get these ideas. I've also started to focus a lot more on looking for, like, the ideas or the

underlying misconceptions, or underlying thought processes behind student thinking, instead of looking for specific responses.

Finally, similar to Kristen and Kelly, Bonnie had a clear plan for marking and charting students' ideas and important disciplinary ideas during the discussion. In her planning, she included a table with these important ideas (Figure 4.5).



Conclusions

Reaction Type	Characteristics	Letter Model
Decomposition	Large molecules split into its elements or smaller compounds	AB → A + B
Synthesis	Combine 2+ elements into one compound	A + B → AB
Single Replacement	An element kicks out another from a compound	AB + C → AC + B
Double Replacement	Elements within compounds "switch" with each other	AB + CD → AD + CB
Combustion	Hydrocarbons (C, H, O only), bring in O_2 and produce CO_2 & H_2O	n/a Ex: $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$

Figure 4.5: Bonnie Kyle's chart created to record students' ideas during the discussion

Kristen Ingall, Kelly Hendrick, and Bonnie Kyle demonstrated detailed and thorough planning for task-based science discussion as part of their coursework. The detail with which they anticipated, monitored, selected, sequenced, connected, and designed tasks was exemplary. Moreover, they consistently planned in this way across all four Instructional Performances, unique among the cohort. What follows is a summary of PSTs' planning when scoring medium and low on Instructional Performance 4.

4.1.1.2 Use of the Five Practices model by PSTs with medium pedagogical design capacity

PSTs demonstrating what I defined as a medium PDC, total scores between 23 and 39 after IP 1 and IP 2, were capable of planning challenging tasks where students engage in a whole class discussion. However, their planning was not as detailed as PSTs scoring high, which made analyzing their planning difficult. Although many of the PSTs interviewed indicated that they thought about certain aspects of planning a Five Practices discussion, they did not include their thoughts in the written documents. Nancy Hall, Calvin Cary, Dana Nacey, Scott Xander, and Mary Wilson scored between 16 and 30 on Instructional Performance 4. This group had the most variability between Instructional Performance 1 and 4 scores (Table 4.1). However, there were unique features in their planning by the end of the year. Specifically, their tasks as designed were generally challenging with IP 4 tasks scoring a 10 on the HLTR. Their anticipating was less detailed than their higher scoring cohort members and typically only addressed correct thinking. They created a monitoring tool, but it was often only functional for the PST and not designed with specific anticipations in mind. Generally, medium-scoring PSTs planned minimally for selecting and sequencing. Finally, there were no plans for marking and/or charting students' ideas during the discussion. I selected Nancy Hall, Calvin Cary, and Scott Xander for interviews based on the criteria described in Chapter Three. What follows is a summary of their planning related to these common features.

(a) Nancy Hall

Nancy was a biology intern teaching in an urban middle school. Her lesson planning was more detailed than other PSTs in the medium PDC group. For IP 4, she designed the "Genetics Task" herself. She asked students to develop an explanation that describes how traits are inherited.

This task scored a 10 out of 10 on the HLTR, which included specific learning and performance goals (Table 4.5).

Table 4.5: Nancy Hall's learning and performance goals for instructional performance 4

Learning Goals	The phenotype of an organism (what its outward traits are) is linked to its genotype (the contents of its genome).
	Mendelian patterns of inheritance can be explained by the manner in which dominant and recessive versions of traits (alleles) are inherited from parents via chromosomes.
Performance Goals	Students will work cooperatively in small groups to create a presentation that attempts to explain the connection between phenotype and genotype that incorporates Mendel's ratios, Punnett squares, and chromosomal inheritance from both parents.

Nancy’s anticipations were very general. They focused on where she felt students might struggle. She did not include possible explanations students might create, or incorrect and correct thinking.

> I think that students may be somewhat intimidated by this task, which is why I gave them the start of a model of what I am asking for on the back of the sheet. I am not sure if students will have questions at this point. I think that they may find this task difficult so I anticipate a bit of push back. I am hoping that my monitoring and questioning will boost students' confidence and push them in productive directions while working. I also want to push them to use the materials that they have gathered over the course of the week, because these will help them complete the task.

Nancy’s planning for monitoring was characteristic of PSTs demonstrating medium PDC. She included a detailed monitoring tool (Appendix F.3). However, a tool was the extent of monitoring in her planning. She did not include questions to elicit students’ thinking as they worked on the task. Including a detailed monitoring tool focused on features demonstrated high PDC for planning task-based discussions, but her lack of planned questions and/or ways to support students’ thinking was minimal. Although Nancy created a tool more detailed than other PSTs scoring similar or lower, she expressed difficulty utilizing the monitoring tool and having enough time to think about creating a functional tool for herself.

> And then in my monitoring tool, I sort of say which group got which reading with Xs. It's so confusing though when I'm holding it. I'm trying to both listen to what students are saying, which may or may not make sense to me. Like I think that – like that's like a huge, huge part of monitoring is I find it really distracting to be simultaneously trying to listen to what students say and trying to figure out where I'm going to cross things off on my monitoring tool. I haven't really like felt like I had a lot of time to put in the thought to really think like what is going to be a monitoring tool that's really going to work.

Nancy's comments were indicative of PSTs in this medium category. They often described difficulty in finding a monitoring tool that they could use efficiently and effectively. Nancy was very explicit in her selecting and sequencing, which was also unlike other PSTs scoring similarly (Appendix G). Furthermore, she detailed the order in which she planned to have the groups present and described the rationalization for her choices. Even though she planned in a little more detail in her selecting and sequencing, I chose to interview Nancy because she was the single PST teaching in an urban middle school setting.

Finally, Nancy did not indicate clear plans for marking or charting of students' ideas. Because her planning was very detailed compared with other PSTs scoring in this category, it is clear that she has the potential to develop high PDC for planning task-based discussion questions, but faced challenges. During her interview, she described that her planning was not as detailed as in previous lessons because of time constraints.

> I like hate to say this, but I feel like in some ways my planning has like backslid a little bit. I mean I – in that just like I mean things are crazy a bit or whatever with everyone graduating a little bit. If you're going to learn this through an inquiry method, you are probably going to need more time than what I allotted.

(b) Calvin Cary

Calvin was a physics intern in a suburban high school. Calvin's planning was also indicative others scoring in this medium range. For the "Kepler's Law Task," students answered the question, "What is the relationship between the orbital radius (semi-major axis) and the period of an orbiting body?" Using various data and computer programs, Calvin designed this task where students generated representations explaining this relationship. Calvin's learning goals and performance goals were specific and detailed (Table 4.6).

Table 4.6: Calvin Cary's learning and performance goals for instructional performance 4

Learning Goals	Mathematical models can often be developed by looking at trends in data and fitting a general equation to the values.
	The square of the period of an orbiting body is proportional to the cube of the semi-major axis of the orbit divided by the mass of the system.
Performance Goals	SWBAT analyze data to determine trends and develop mathematical models to describe them.
	SWBAT determine if a mathematical model holds up against other empirical evidence.
	SWBAT use Kepler's third law to solve for missing orbital parameters in a system.

Calvin's anticipations were very general. He named some representations students might create and how students might approach the task, but he did not provide clear detail regarding what students' correct thinking would be. Calvin's anticipations differ from a PST demonstrating high PDC because he did not include specific challenges or misconceptions his students might have.

> Once this thinking time is completed, I expect many groups to attempt to plot the data points in a scatter plot. They can do this on the computers using the LoggerPro software that we have available. Some students may ask for Excel, which we may have but if we don't, I'll ask them what they want to use it for and then point them to Logger Pro.
> Another potential strategy students may use is to just look for general trends to begin with. The only one they should see is that with an increase in orbital radius

> the period goes up as well. All other general trends move both up and down which does not make much sense when thinking about how this would work. In the end, students should find that the Period squared is proportional to the radius cubed. Students may come to this by finding that the period is proportional to the radius to the 1.5 power [*sic*].

Additionally, Calvin's planning for monitoring was minimal. He included a statement that indicated his plans to monitor, indicating his awareness of the practice, but failed to include a monitoring tool or questions he planned to ask to elicit student thinking, "During the lesson, I will be monitoring students and noting the methods they take to create their claims." During his interview, when asked about a monitoring tool and planning for monitoring, Calvin described using a seating chart because it was the best functionally for him. However, he did not include this seating chart or any other monitoring tool in his artifact packet nor did he articulate why the tool was not included when questioned. He only said, "Um, the monitoring tools, and things to add, stuff like that. And I really liked having kind of like a spread out – seating chart."

Calvin's planning for the discussion and connecting was minimal in this lesson plan. Beyond listing topics he hoped to discuss, he failed to include specific questions he might ask students to support them in making connections between each other's ideas or connections to the disciplinary ideas, or how he planned to mark and/or chart the emerging ideas of the discussion.

> Once students get to the spot where they have developed the relationship, and put their representations on the boards, we will have a small discussion about what they have done. I expect some groups will put up their graphs of the data as well as the equations they came up with. It is possible that some groups may have used a sixth order polynomial to fit their data which while it would fit the solar system, it will receive critical feedback from the class. I'll want the students to talk about their methods and how they went about solving for their relationship. As a class, we should arrive at the proper relationship, which will allow us to move on within the lesson. I will tell the class that this is where I got to at Penn State but I couldn't get beyond this. [10-20 mins] (this is where the class break happens).
>
> Topics I expect to see in the discussion are how students went about creating a graph, how they selected which parameter(s) to look at, how they established

> trends, error analysis (maybe), and correcting potential differences between the groups.

During the interview, I asked Calvin about his planning for the discussion. He explained that he "thought about right or wrong" and various scenarios that might happen, but he was not explicit about those thought processes in his planning, which was common for many PSTs.

> So, yeah. I thought about a whole bunch of stuff in there. That was different 'cause I, I think normally I do like maybe one – like did they get it right – or did they get it wrong, or where can you go from there. But, this one I thought about right or wrong, and like a bunch of different scenarios that could happen – depending on how they thought – right or wrong.
>
> Oh, there was, um – in this one I have, I have this like five-way road map going on. Um, so depending on – so once they get to – they have a trend they're notice [Clear throat] and they fit some – so, originally like they should have fit some data trend, data line –

(c) Scott Xander

The final PST interviewed demonstrating medium PDC was a physics intern teaching in an urban high school. His "Two Dimensional Collisions Task" asked students to answer the question, "How conservation of momentum applies to two dimensional collisions?" Using a computer simulation, students generated an answer to this question. Scott explained that this is a task that he co-designed with his mentor and was not a part of the school's curriculum.

> So the task that I had them do for that was a – was a two-dimensional collision simulation. Um, it was a PhET simulation and, um, my mentor was more involved with that one – at least – at least with setting up the ov-, helping me set up the overall structure and, um, seeing some of the things that we wanted to emerge from that.

The learning goals and performance goals for this lesson are in Table 4.7. While the first learning goal did not seem to include the necessary detail for this task, the final two were more specific and detailed.

Table 4.7: Scott Xander's learning goals and performance goals for instructional performance 4

Learning Goals	Momentum is a vector.
	Momentum is conserved even when colliding object move at an angle to one another.
	To analyze momentum for angular directions we use vector techniques discussed in prior units.
Performance Goals	Students will be able to use ideas of conservation of momentum to solve problems involving collisions, explosion, etc.

Scott did not anticipate in his lesson planning and further described some issues that occurred during the lesson because of his lack of anticipation. He explained in the excerpt below that he did not anticipate the unnecessary challenges that students might face with the computer simulation, and therefore did not make appropriate accommodations in his planning. While this recognition upon reflection of when to minimize challenges like these is a key feature of a PST demonstrating high PDC, Scott's failure to do so initially in his planning produced a lesson that did not go as smoothly as he planned.

> Well, just – so number one, the worksheet that I had them going through –um, I don't know. They were – they were bored by it [laughs] and it was – and, um, a lot – a lot of the things ended up - there were some technology problems. They weren't – they weren't huge. Yeah, so scaffolding is the big thing there. And they were so distracted by the unnecessary challenges. So I know now at least if I were to use that simulation again, to give them.

Although Scott did not explicitly monitoring or select and sequence in his lesson, it was clear that he and his mentor put thought into how students' ideas should emerge. When asked about selecting and sequencing in this lesson, Scott replies:

> Um, yeah, where is – I might not – I might not – I submitted my – no, I had to have submitted my other lesson plan. Um. Hm. Yeah, there's – well, yeah, either way. Um, yeah, there was a lot of sequencing. Me and my mentor teacher laid them out on the floor and talked about which ones we wanted to go through first.

From Scott's response, it was evident that he thought about or even planned using parts of the Five Practices, but did not include it in his artifact packet.

Finally, for the discussion, Scott planned a detailed outline of the questions he planned to elicit students' thinking and to support them in making connections. The excerpt below is from Scott's discussion outline. He clearly planned to support students in making comparisons between each other's solutions as well as the law of conservation of momentum.

- I want us to look critically at classmates' solutions. You should always be thinking….does this physical situation make sense? [in terms of both numbers and pictures]
- I want you to see if you can think of ways to not only solve this problem, but also if you can abstract from what we see in this problem to find general solution paths for all two dimensional problems.
- What direction do you think the cars should move in after the collision?
    - Northeast.
    - It is good to get an intuitive understanding of what the *after* situation will probably look like.
    - Why do you guys think that the car will move to the northeast?
        - Should arrive at the one car has northward momentum. The other has eastward momentum. When they combine, their momentum combines.
    - Show other situations: southward and eastward moving cars. Predict outcomes.
- We know they have some momentum in the northeast direction?
    - How northeast is it?

When asked about planning for connecting, Scott explained that because he had extra time to plan in detail, he could clearly think about the types of questions he could ask as well as how he wanted those ideas to emerge.

> I just knew the types of things that I wanted to see come out and I just – it – it was – it was especially easy because I had – it – the task was on Friday and then the discussion was on Monday. So I had a full – not only just a night, but a – even a weekend to prepare for it.

Scott's comment demonstrated his learning over the course of the semester. Part of the success of Five Practices discussions in science involves planning the lesson over a multiple days. Doing so gives the PST time to think about the discussion with the student artifacts.

Evident in the medium scoring PSTs was a large amount of variability in planning. However, within this variability, their lesson plans all lacked sufficient detail for a reader to recognize their use of the Five Practices model. This theme also continued in the PSTs' planning who demonstrated low PDC. What follows are summaries of the three PSTs selected for interviews that scored low on Instructional Performance 4.

4.1.1.3 Use of the Five Practices model by PSTs demonstrating low pedagogical design capacity

PSTs scoring low on Instructional Performance 4 had scores ranging from 5-19. As one might expect, PSTs with these scores not only lacked detail in their plans, but also designed tasks that were not high demand tasks. What follows are summaries of Florence Edward, Xavier Idol, and Nicole Timko whom I selected as interviewees.

(a) Florence Edward

Florence was a biology intern in a suburban high school scoring 18 out of 33. In her task for Instructional Performance 4, "The Pedigree Task," students generated the rules for pedigrees after examining various pedigree diagrams. Florence modified this task from curriculum used by her mentor. When asked about her design of this task, she responded, "So I modified one of the lessons because it wanted the students to identify the patterns based on the roles that they gave them." For this task, Florence had several learning goals and performance goals (Table 4.8).

The number of goals indicated that this particular lesson last for several days, which is indicated in her plan.

Table 4.8: Florence Edward's learning goals and performance goals for instructional performance 4

Learning Goals	• Pedigrees are diagrams that show parents and offspring in several generations that can be used to show in which individuals certain traits are present. • The inheritance pattern of traits can be determined by examining a pedigree. • Autosomal Dominant traits can equally affect males and females, do not skip generations, trait is present whenever the corresponding gene is present, male-to-male transmission is possible. • Autosomal Recessive traits can equally affect males and females, often skip generations, only homozygous individuals have the trait, traits may appear in offspring that are not seen in parents, if the parent is affected offspring that are not affected are carriers. • X-Linked Dominant traits affect all daughters of an affected male, no male-to-male transmission; a female may or may not pass on the gene to son or daughter. • X-Linked Recessive traits affect males more commonly than females, all daughters of a male who is affected are heterozygous carriers, sons of female carriers can receive the trait 50% of the time, no male-to-male transmission, and daughters of female carriers have a 50% chance of being carriers. • Human traits and disorders can be traced using pedigrees to determine the inheritance and genotypes of individuals. • Mitochondria have their own DNA. • Mitochondrial disorders are always passed from mothers to all offspring because only the female gamete provides the zygote with organelles such as the mitochondria.
Performance Goals	• Students will be able to label and read a pedigree, distinguishing between male and female, affected and unaffected, offspring and mating, and generations with complete accuracy given their reading from the previous night, brief introduction in class, and pedigree key. • SWBAT work in small groups (2 or 3) to develop rules for the inheritance of traits within a certain inheritance pattern by examining two pedigrees showing that inheritance pattern with complete accuracy given two examples with inheritance pattern identified, and eliciting questions from teacher. • SWBAT to find examples of their inheritance pattern given their text or internet research after achieving accuracy on their rules in order to better understand the relevance of tracing inheritance patterns in humans. • SWBAT share their rules for inheritance of their pattern and discuss the overlap and differences between their inheritance pattern and others. • SWBAT interpret a new pedigree and correctly identify its inheritance pattern by using the rules set out by themselves and other groups.

Florence's anticipating was specifically related to her acknowledgement of student frustration with the task. She did not anticipate student thinking, how students might approach the tasks, or the pedigree rules students could generate.

> Students will be up to the task of analyzing pedigrees; however developing their own rules will be difficult and potentially frustrating. It is important that students are aware of certain features of (autosomal/sex-linked, recessive/dominant) from their punnett square work and recall this for this activity. Encourage students to give a "name" to the disorder if they are struggling thinking abstractly.

Florence acknowledged in her interview that university instructors gave her feedback related to including more detailed anticipating in her planning. However, it appeared that Florence was content with this amount of detail in her anticipating, which eludes to her pedagogical design capacity for planning task-based discussions.

> I was frequently told to include more anticipating what I thought students might do, how I thought the students might approach the task, and how being pushed to include how I wanted the discussion to go.

In addition, Florence successfully created a monitoring tool in her planning (Appendix F.4). She included examples of a completed monitoring tool in her artifact packet. Her monitoring tool was a functional type and based on the learning goals for the lesson. In addition to the tool, Florence planned three questions to ask students as they worked, "What do you notice about the males and females in your pedigree? Who do you notice is passing on the trait? Are traits being inherited from parents who are affected or not?"

Finally, Florence selected and sequenced at a basic level in the outline of her discussion by listing the order of genetic disorders she wanted to emerge. In the following excerpt from her lesson plan, one sees that Florence's planned questions were minimal, and those that were planned were low-level questions (rote memorization). She also failed to plan specific questions that elicited students' thinking, supported students' connections between each other's ideas, and supported students' connections to disciplinary ideas. Her minimal planning for a storyline of the discussion, questions, and marking/charting was characteristic of a PST demonstrating low PDC for planning task-based discussions.

- Autosomal Dominant Pedigree (Huntington's Disease).
  - Student thinking: trait is inherited by most offspring, does not skip generations, and affects males and females equally.
  - Students consider any trait to be learnt as a disorder and do not often make the connection that any trait can be dominant or recessive. Because of this, it may take prodding or repeated reference to their rules to encourage them to see that the trait is dominant. Be sure to give examples of dominant genetic disorders (Huntington's, Achondroplasia, etc.) to give relevance.
- X-Linked Recessive Pedigree (Hemophilia).
  - Trait skips generations, affects males differently.
  - Students may have trouble noticing that it is being passed from mother to son, encourage students to look at families individually.
- Challenging pedigree (non-Mendelian).
- Mitochondrial Disorder (Leber's hereditary optic neuropathy).
  - Students will use their rules to evaluate, which apply and do not apply to this pedigree.
  - Students should notice that the inheritance is ONLY from mother to ALL offspring.
  - Ask students (if stuck) one or so of the following:
    - Where else can genes exist in a cell?
    - What other organelles have DNA besides the nucleus?

    Recall that mitochondria and chloroplasts have DNA of their own, why only from mothers? Because egg provides the majority of what a zygote needs, the sperm ONLY gives its haploid set of DNA.

    Encourage students to work through each of the inheritance patterns to rule out those possibilities, then agree that it does not follow our rules... so what could it be?

(b) Xavier Idol

Xavier Idol was a biology intern in an urban public school. He repeatedly scored low on his instructional performances over the course of the year (Table 4.1). His task for Instructional Performance 4, "Natural Selection Task," asked students to follow a protocol and answer questions. This task, as Xavier explained was, "more or less off the top of my head," and not a demanding task for students (Appendix H). This task appeared to be a traditional activity, or "cookbook lab," that often accompanies school curriculum. Table 4.9 details his learning goals and performance goals for this lesson. In examining his learning goals, one notices that they were not the overarching canonical ideas expected of a learning goal. These goals were specific to the task/lesson itself and made no specific connection to the underlying disciplinary ideas behind natural selection.

Table 4.9: Xavier Idol's learning goals and performance goals for instructional performance 4

Learning Goals	As generations pass, the number of white "mice" decline while the number of brown "mice" grow in this population.
	Different environmental factors can come into play and can have a great effect on the population of mice. • These factors are sometimes completely random.
	Neither the snakes nor the hawks have a particular advantage in this simulation.
Performance Goals	Students will be able to identify trends in the data they collect from the mouse experiment.
	Students will be able to identify different environmental factors and describe the consequences of them by means of if X happens, the brown/white population increases/decreases.
	Students will be able to explain what it means if neither the snakes nor the hawks eat more mice by describing the equal number of mice taken in each generation.

Interestingly, Xavier did not include any anticipation in his lesson planning. However, similar to all the PSTs' planning for Instructional Performance 4, Xavier Idol also created a monitoring tool (Appendix F.5). Xavier adopted this practice during the spring semester, which coincided with improved lesson planning practices. His monitoring tool appeared to be a tool that was functional for him. Instead of focusing on features or disciplinary ideas in a typical monitoring tool, Xavier's tool was designed based on student behavior and classroom management.

Finally, the excerpt below shows Xavier's planning focused on what he will do and what students will do, more linear lesson planning. He planned general questions that seem lower level. He did not plan questions that helped students make connections between each other's idea or helped to support student talk.

> Once the students successfully come to the idea that color has something to do with whether hawks find the mice, I am going to try to push them to tell me why that matters. I want them to explain how it just makes sense that mice that are brown blend into the forest better than mice that are bright white. I might ask things like:
>
> - Why do the brown mice survive against the hawks better than the white mice?
> - Why does the color matter? What difference does it make?
> - So if it helps them to survive, what does that mean? How does it do that?
> - Do the mice choose what color they are going to be?
> - Then how does this happen?
> - So if it's inherited, what does that mean about the mouse's parents?
> - What do you think happens then if this brown mouse is able to survive better than its white friends?
> - We've mentioned the term a few times throughout the year, but what term applies to this concept?
> - Can anyone restate the overall concept for me?
>
> One of the big things that I want the students to see is that natural selection does NOT have to be complicated. The idea should already make sense in their heads. If something is better at surviving, it is going to have a better chance of reaching sexual maturity, and therefore reproducing and passing on its genes to the next generation. I imagine that it is going to take a lot of redirecting and bouncing of ideas to get them to even mention the color of the mouse having to do with it being able to survive.

During Xavier's interviews, I wanted to capture his rationale for his planning practices. When asked, "What other influences are there in your planning?" Xavier explained.

> Yeah, okay. A lot of this stuff was things that at the time when we were doing it, I was very not into it. I thought that a lot of it was just like kind of busy work, that it wasn't really beneficial. I still feel that way about some of the things, but a lot of it after doing things for a while; I started to think back. I was like actually that kind of does makes sense now that it ties in with this. It has just taken a lot to actually get to that point. Because, I don't know, I always feel that like because I'm a little bit older, a lot of the times I always think like this is not

> beneficial to me. I'm like, I'm 26, and I don't need to know this right now. This doesn't matter.

His response was uncharacteristic of other PSTs interviewed. But, his candor forces teacher educators to examine the ways in which they present content and pedagogy and how it is grounded in practice for future teachers.

(c) Nicole Timko

Nicole Timko was another biology intern teaching at an urban public school. She admittedly struggled throughout the year in her planning. For Instructional Performance 4, Nicole used "The Mitosis Task" created by Kelly Hendrick.

> I used some resources from one of my colleagues. Um, it was a lesson that she had done previously on mitosis, and I thought that it would be helpful for my students.

Because Nicole used Kelly's task, her learning goals and performance goals were similar (Table 4.10). With access to a detailed lesson plan and instructional materials, it was interesting to examine the ways in which Nicole used and adapted these materials. In many ways, her adaptations and planning demonstrated low PDC. For example, Kelly's detailed anticipation described previously was not evident in Nicole's planning. Instead, she detailed misconceptions students might have and problems students might encounter during the task.

Misconceptions:
- Chromosomes do not occur in all types of cells.
- Chromosomes are divided up at each cell division, such that when a single body cell forms two body cells, the resulting cell contains fewer chromosomes than the original cell.

Anticipated problems: Picture F and Picture D
- o Picture F is an example of a cell with two nuclei. This cell is in interphase. It is possible that the cell failed to complete cytokinesis and has now joined back together or two cells have formed together.
  - o Cells are smaller than chromosomes.
  - o Not all types of cells contain DNA molecules.

- Picture D is an example of prophase. The circle in this picture is the nuclei not the whole cell. In the nucleus, we can see that the DNA has been supercoiled into chromosomes. The chromosomes are now visible.

Table 4.10: Nicole Timko's learning goals and performance goals for instructional performance 4

Learning Goals	Interphase occurs before cell division. During interphase, the cell grows and prepares for cell division by replicating its DNA. Cells spend most of their time in this phase. • Following interphase, the cell proceeds through the process of cell division: Prophase, Metaphase, Anaphase, Telophase, and Cytokinesis. • The first phase of mitosis is prophase. In prophase, the genetic material inside of the nucleus condenses and the duplicated chromosomes become visible. Outside the nucleus, the spindle starts to form. • The second phase of mitosis is metaphase. During metaphase, the centromeres of the duplicated chromosomes line up across the center of the cell. Spindle fibers connect the centromere of each chromosome to the two poles of the spindle. • The third phase of mitosis is anaphase. During anaphase, the chromosomes separate and move along spindle fibers to opposite ends of the cell. • The last phase of mitosis is telophase. During telophase, chromosomes gather at opposite ends of the poles and a nuclear envelope begins to reform around each cluster. The spindle begins to break apart. A cleavage furrow begins to form.
Performance Goals	After viewing a slide of cells, students will be able to determine the phase of mitosis for each cell with 90% accuracy.
	After gathering data, students will be able to represent first hand data in an accurate graph.
	After representing the data, students will be able to draw conclusions about patterns demonstrated in the data to answer the question, “Where do cells spend most of their time?”

Nicole’s plans for monitoring also differed. She planned some questions to elicit students’ thinking during the task and to guide student thinking to what matters.

Which picture on your key looks like the cell you are looking at?
What is happening with the chromosomes in this cell? In what phase does this happen?

Where are the chromosomes in this picture?
What kind of graph might be used to represent this data and why?

However, Nicole did not have a monitoring tool for this task even though Kelly created a monitoring tool in her planning. When asked, "Did you create a monitoring tool for this lesson?" Nicole explained.

> I felt like I didn't need a monitoring tool because students were going to be making a graphical representation, and I felt like I could see what I needed to see from that representation. Um, but reflecting on it now, it's something that maybe I would have done to capture more student thinking rather than, um, their collection of data. So, because the discussion itself kind of fell to pieces in the end, because I think I really didn't know who had certain ideas, and there really was no sequence there in the end, because I didn't know who I wanted to have talk first, and where I wanted that to go. And so without being able to utilize what I actually heard from students during the task, I wasn't able to really tie things together conceptually.

While her reflection was enlightening, this decision to not create a monitoring tool initially was indicative of her low PDC for task-based discussion lessons. Moreover, Nicole did not select or sequence students' work in her planning and her planning for connecting during the discussion was very general and not detailed. The extent of Nicole's planning related to selecting, sequencing, and connecting is below.

Teacher guides discussion with the following questions:

- When students say claim without evidence, teacher asks students to "show us where your graph explains your claim? Where do we see the evidence that cells spend most of their time in ______ phase?"
- Toss to other students and ask if they agree or disagree with the student's pattern.
- Show us on the slide which cells you marked as dividing cells (or interphase cells).

*Teacher has the picture of the slide that the group used up on the SMART board under the ELMO so that we can refer to it if necessary. *

Anticipated Answers:

Dividing Pattern
Non-Dividing Pattern: Most all

Which kind of cells do you think your group had? How do you know?
Why do you think we see two patterns emerge? Discuss with your partner. (3 min)
Students share out their responses and teacher charts on the SMART board. (3 min)
Teacher guides students with questions during pair and share:
What kind of cells do you think divide often? Why? How do you know that?
What kind of cells do you think don't divide? Why? How do you know that?

Nicole planned questions that asked students to support their answers and provide a rationale for their thinking, but did not include a clear outline or storyline for the ideas she wanted to emerge and when during the discussion. Moreover, she did not have many questions planned to support students in connecting each other's ideas. This practice was a key feature of planning often lacking in PSTs demonstrating low PDC.

As we compare and contrast the PSTs' planning, it is easy to see when a PST demonstrates high PDC for planning task-based science discussions versus when a PST does not. In the remaining sections of this chapter, I detail PSTs' planning practices and other features that may provide insight into how a PST develops high PDC as well as how teacher educators can support the development of high PDC in PSTs.

In summary, analyses of the post-intervention lesson plans provide evidence of improvement in students' ability to plan a discussion. PSTs scoring high met many of the *a priori* identified goals and expectations for planning a Five Practices discussion. Low and Medium scoring PSTs' scores improved over time with their planning including more use of the Five Practices model in planning over time. Table 4.11 summarizes the use of the Five Practices model by PSTs post-intervention. The data suggests that many PSTs can use the Five Practices when asked to do so in the context of their university coursework. While the level of use of the

Five Practices varied between categories, the improvement over time indicates the PSTs' learning over repeated iterations of the assignment.

Table 4.11: Summary of characteristics of PSTs' planning practices with respect to the Five Practices post-intervention

Use of the Five Practices Model in Planning ***(Post-Intervention)***	**Low**	**Medium**	**High**
Lists Performance Goal(s) and Specific Learning Goal(s)	✓	✓	✓
Experimentation, Data Analysis/Interpretation, or Explanation task at high level			✓
Task as designed of support of student engagement in SEPs	✓	✓	✓
Task as designed supports student engagement in productive whole class discussion			✓
Students can create multiple artifacts as a result of the task			✓
Anticipates students' correct thinking		✓	✓
Anticipates students' incorrect or incomplete thinking			✓
Plans for monitoring student work on the task including monitoring tool	✓	✓	✓
Plans questions to elicit, challenge, or extend students' thinking	✓	✓	✓
Plans for a storyline for how the discussion unfolds			✓
Plans to make connections between students' ideas and to disciplinary ideas	✓	✓	✓
Plans to select and sequence the ideas that will emerge during the discussion			✓
Plans marking strategies to highlight important ideas			✓

Note: Low, Medium, High indicates scoring category related to total scores of HLTR and LPDR.

4.1.2 Use of Curriculum Materials and Resources

Research Question – Ia: What available curriculum materials, including texts, online resources, and standards, do PSTs use during planning of these lessons?

To address this research question, I examined transcripts of the PSTs' interviews identifying the various curriculum resources they used. A clear pattern did not emerge when examining the curriculum resources used. The resources PSTs mentioned using when planning their task-based discussion lesson varied (Table 4.12). As expected, school curricula were a major resource for the PSTs. Interestingly, five out of the six PSTs interning in an urban public school discussed using their school's curriculum when planning. Xavier Idol did not specifically mention using the school's curriculum, but he did use materials his mentor created, which most likely was based on the school's curriculum.

PSTs demonstrating high and medium PDC mentioned using their own experiences as students or their own knowledge as resources when planning these types of lessons. The internet and other web-based materials also played a large role in PSTs' planning, as expected. Interestingly, only three PSTs mentioned using their university instructors as a resource when planning these lessons and all three PSTs scored in the medium or low categories. While only one PST mentioned using state or national standards as a resource in her planning.

Interestingly, low scoring PSTs used school curricula, mentor created materials and peer lesson plans as resources more often that high scoring PSTs. High scoring PSTs reported using their own personal knowledge and experiences and school curriculum, but more often reported designing tasks without resources. This difference in resource use, particularly between low and high scoring PSTs suggests high scoring PSTs may feel more agency with the curriculum compared with lower scoring members of the cohort.

The majority of the PSTs interviewed either adapted or improvised (created) (Brown, 2009) the curriculum resources they used when planning their Instructional Performance lessons (Table 4.13). The majority of the time the PSTs improvised and either created their own lessons or used a curriculum resource as a basis or idea for a completely revised lesson. The ability to recognize the affordances and drawbacks of available curriculum materials and analyzing those materials with a critical lens is important for all teachers and indicative of PDC. Furthermore, those PSTs scoring high demonstrated an ability to adapt or create high cognitive demand tasks. Lower scoring PSTs seemed aware that their curriculum materials did not support students' engagement in the SEPs and needed modifications, but their modifications often were as cognitively demanding. This finding suggests that the task selected and/or designed and the demand of that task indicates the PSTs' PDC for designing tasks and lessons where students can engage in productive classroom discussions.

Table 4.12: Resources PSTs used during the planning of their task-based discussion lessons

	Resources								
Intern	Family/ Friends	Mentor Created Materials	Peer Lesson Plans	Personal Knowledge/ Experiences	Personal Texts	School Curriculum	Standards	University Instructors	Web-Based
Kristen Ingall	1			1		1			2
Kelly Hendrick		1		1					
Bonnie Kyle	1	1		1		1			1
Nancy Hall				1		2		1	1
Calvin Cary	1	1		1		1			
Scott Xander				3	1	2			1
Florence Edward		1	1			1		1	
Xavier Idol	2	2	1						1
Nicole Timko			3			2	2	2	1
Total	5	6	5	6	1	**10**	2	4	**7**

Note: The PSTs are listed scoring high, medium, and low, respectively. Each scoring category is separated by a dotted line.

Table 4.13: Pre-service teachers' types of curriculum use when planning for task-based discussion lessons

Intern	Adapt	Improvise	Offload
Kristen Ingall	2	2	
Kelly Hendrick	1	3	
Bonnie Kyle	1	3	
Nancy Hall	3	3	
Calvin Cary		3	1
Scott Xander		4	
Florence Edward	1	2	1
Xavier Idol	2	2	
Nicole Timko	2	2	
Total	12	24	2

4.1.3 Use of Other Resources and Instructional Frameworks

Research Question – Ib: What other resources or frameworks do PSTs use to plan task-based discussion lessons?

To address this research question, I examined the transcripts of the PSTs' interviews in order to identify any patterns. One of the other main instructional frameworks about which I questioned the PSTs during the interviews was their use of the Learning Cycle during their planning and instruction of these Instructional Performances. Not one PST acknowledged using the Learning Cycle as part of their planning. Bonnie described the sentiment of many of the PSTs when she explained her use of the Learning Cycle.

> The second one was definitely I think an engage. Because once we got past this lesson we didn't talk about who discovered DNA so much, but we talked about the structure and that's what launches into the structure of DNA in transcription and translation.

When prompted *ad hoc*, the PSTs typically "assigned" their lesson to "engage" phase of the Learning Cycle. In using the term engage, the PSTs regularly designed task-based discussion lessons where students discussed their prior knowledge and experiences. These types of lessons seemed to be where the PST felt most comfortable attempting these types of challenging lessons.

Other resources the PSTs when planning these lessons were human resources, mentors and university supervisors. These individuals played a key role in the development of these beginning teachers. With the complexity of planning classroom discussions using the Five Practices Model, the support university supervisors and mentors provided was an asset or a hindrance to the PST's success.

During the interviews, I asked the PSTs to describe the ways in which their mentors sand university supervisors supported their planning. Table 4.14 describes the varying types of mentor support identified by the interviewees. Quickly examining the table, one can see that the majority of the time mentors supported the PSTs in task design or did not provide any support/feedback for the instructional performance planning. Kristen, Kelly, and Bonnie (High PDC PSTs) described more overall support from their mentors at some level from planning to task design. In general, mentor support varied. For example, Scott described co-designing a task with his mentor teacher.

> So a lot of them are just tasks that my mentor teacher has used before. We sit down a day or few before we use them. She says these were the parts of the tasks that I did like last year. Then we just talk about, we alter them together.

On the other hand, Nancy explained that her mentor was more hands off and allowed her to plan lessons freely. She said, "So, he is intentionally very hands off with planning. I think he will only come in if he senses like the ship sinking." Both Scott and Nancy scored in the medium range and the support of their mentor teachers might speak to his/her perceived ability of their PST.

As with mentor support, university supervisor support varied (Table 4.15). The majority of the support from supervisors occurred during the planning phase of the lesson. Many PSTs described challenges in providing lesson plans to their supervisors in advance, ultimately hindering any planning support. Calvin humbly admitted this constraint during one of his interviews.

> So, it is not really feedback going into a lesson. That's also kind of my fault because I should be sending him stuff a week ahead of time, or to get feedback and then modify. But I don't really get stuff out, maybe 2 days ahead of time if I'm lucky and like, "Help me out we still good for this date." His feedback afterwards actually is extremely helpful and same with my mentor teacher. I mean we are actually get it ran out. Normally he is like in verbal feedback. But it is a lot of like feedback, and then I respond to that feedback for the next, or within my next classes of practices, so then I show them what I have done.

Furthermore, all of the PSTs demonstrating high PDC described seeking support from their supervisors in designing one or more tasks for a lesson, while no other PSTs sought out their supervisors as a resource. While a definite reason for this finding is unclear, it is something that further research hopes to uncover. Furthermore, two of the three interviewed PSTs demonstrating high PDC, Kelly and Bonnie, had a graduate student supervisor familiar with the university program. In addition, I supervised two other PSTs scoring in the high category, Mark and Kady (Table 4.1). Although supervisor support alone might not speak to the success of PSTs' development of their PDC, the combination of mentor and supervisor support was a definite influence positively or negatively.

Table 4.14: Mentor support described by PSTs in planning instructional performances

	Mentor Support					
Intern	None	Planning	School/ Team Support	Selecting & Sequencing	Supplies	Task Design
Kristen Ingall	4	1	2	1		1
Kelly Hendrick	2		1		1	2
Bonnie Kyle		1				2
Nancy Hall	2					
Calvin Cary		2				2
Scott Xander		1		2		4
Florence Edward	1	1	1		1	1
Xavier Idol	1					1
Nicole Timko	3					
Totals	13	6	4	3	2	13

Note: Numbers indicate times PSTs indicated receiving support from mentor in that category.

Table 4.15: Supervisor support described by PSTs in planning instructional performances

	Supervisor Support				
Intern	None	Planning	Instruction	Logistics	Task Design
Kristen Ingall	2	1	2		1
Kelly Hendrick		4		1	3
Bonnie Kyle		4		1	2
Nancy Hall	1		2		
Calvin Cary	1		2	1	
Scott Xander		3	3		
Florence Edward	2	1		1	
Xavier Idol	1				
Nicole Timko	2	2			
Totals	9	15	9	4	6

Note: Numbers indicate times PSTs indicated receiving support from supervisor in that category.

4.2 PSTS' PLANNING STRATEGIES AND THE AFFECT THEIR ABILITY TO DESIGN CHALLENGING DISCUSSION LESSONS FOR STUDENTS

Research Question – 2: To what extent does PSTs' use of various resources and planning strategies support or hinder their ability to create lessons in which students are engaged in a challenging task where they participate in SEPs and engage in discussion?

In order to answer research question two, I examined the PSTs' lesson plans and interview transcripts. Appendix I includes selected lesson plans for Instructional Performance 4 from three PSTs: Kristen Ingall, Scott Xander, and Nicole Timko, high, medium, and low scoring teachers, respectively (Table 4.1). In these lesson plans, one sees how PSTs' planning clearly influenced their ability, or in some cases inability to create challenging task-based discussion lessons. The thought and detail Kristen included in her planning, as described above, is a strategy that supported her confidence and ability to create these challenging lessons. Kristen explained that for her first Instructional Performance, her mentor teacher was not in class so she prepared thoroughly for that lesson and continued to plan in that way based on that lesson's success.

> Because I thought that the first way, like the first time I did it like, what I really thought was really good about my lessons was my planning. That allowed me not to fall apart. So I was like, 'Great, okay let's do that again.'

In addition, her mentor co-planned with her to ensure she was prepared for this lesson. Her mentor had previous experience with the Five Practices model. Her questioning and support of Kristen forced her to think through the task and the lesson in detail, which supported her planning, lesson design, and development of high PDC.

> But as far as, so I explained it to her [the Five Practices]. We talked together about selecting and sequencing. That helped immensely because it was the first time I'd done all Five Practices. She didn't help a lot, but she knew more about

> the students than I did. It was more like, “Are sure you want them to talk about that, because I think they might have better kind of prior knowledge,” and things like that.” Maybe something that I hadn’t noticed before, in being more of a passive observer.

The PSTs demonstrating high PDC planned in detail and created a variety of instructional materials and scaffolds to support their students’ learning. PSTs demonstrating medium or low PDC had more variability in their lesson planning and instructional materials. Planning strategies by medium or low scoring PSTs, therefore, had a tendency to hinder the planning and task design. Just the act, the process of, thinking through the lesson and recording those ideas proved to be a supportive tool for PSTs.

Although Scott’s planning was not as detailed as Kristen’s, his final Instructional Performance 4 included the most detail than his other lesson plans. He acknowledged that this strategy, the act of thinking through the lesson and thorough planning, supported the success of his class discussion.

> I think, like we mentioned in class, making the monitoring tool, it wasn't super helpful for actual – actually during the discussion –but it was really helpful for planning purposes. So, yeah, um, the big takeaway to me with the discussions is just describing what the discussion is supposed to look like.
>
> And I think that was part of the reason for the success. Um, I'm trying to think if there were any other aspects of last – um, well, just – just – yeah, designing the task. So I think – I think my tasks last semester were a little too easy.

Scott gained a level of reflection and awareness over the course of the year that is exemplified in the above excerpt.

As one can see in Appendix I.3, Nicole’s planning for Instructional Performance 4 lacked the detail and thoroughness seen in PSTs’ receiving higher scores. Her planning was an exemplar of the PSTs demonstrating low PDC. A major hindrance to PSTs’ successful planning appeared to be time management and/or organization on behalf of the PST. Nicole honestly explained in one of her interviews that she often did not get support from her supervisor before her observation.

> My supervisor didn’t give me any feedback because that was my fault, because I didn’t put up my lesson 48hours in advance, let alone 24 hours in advance. So, I didn’t get any feedback from her in advance on this one.

In addition, Nicole seemed to have difficulty understanding the expectations of planning for rigorous and challenging tasks, which may be a characteristic of many PSTs demonstrating low PDC. Another characteristic of the interviewed PSTs’ demonstrating low PDC was their feeling that they did not need to think about or include certain items or materials in their planning. Nicole explained. This thinking appeared to be a major hindrance to PST success.

> I felt like I didn’t need a monitoring tool because students were going to be making a graphical representation, and I felt like I could see what I needed to see from that representation.
>
> I don't think so, I think I put, I will choose them randomly. So, I didn’t feel like I needed to sequence them in any kind of specific order.

4.3 CHANGES IN PSTS’ PEDAGOGICAL DESIGN CAPACITY FOR TASK-BASED DISCUSSION LESSONS OVER TIME

Research Question – III: To what extent does PSTs’ pedagogical design capacity (PDC) for task-based science discussion lessons change over the course of their teacher preparation program? Are patterns and changes related to specific learning opportunities or elements within the teacher preparation program?

4.3.1 Quantitative Findings

The researcher performed within-groups repeated measures ANOVA to investigate differences in mean scores over the five time points of (a) pre-lesson plan (LP) scores, (b) beginning of fall intervention (IP 1) scores, (c) end of fall intervention (IP 2) scores, (d) beginning of spring intervention (IP 3) scores, and (e) end of spring intervention (IP 4) scores. Results indicated a significant within-groups main effect across all five times points Wilk's Lambda = .098, F (4, 11) = 25.36. p <.0005. The effect size was large (η^2 = .753). According to Cohen (1988), effect size guidelines are .01 = small effect, .06 = moderate effect, and .14 = large effect.

Post-hoc comparisons via Fisher's Least Significant Difference LSD corrected marginal means indicated that the mean total HLTR/LPDR score at the LP measurement time (M = 3.07, SD = 1.87) was significantly lower than the mean total HLTR/LPDR scores at the IP 1 measurement time (M = 16.80, SD = 9.68; p = .001), IP 2 measurement time (M = 18.60, SD = 9.11; p <.0005), IP 3 measurement time (M = 22.27, SD = 8.03, p <.0005) and IP 4 measurement time (M = 24.20, SD = 8.68, p <.0005). Table 4.17 presents a summary of the ANOVA overall model fit. Table 4.18 presents a summary of findings for the post-hoc analyses of the ANOVA results. Figure 4.6 presents a graphical representation of the mean total HLTR/LPDR scores over the five time periods.

Table 4.16: Frequencies and percentages summarizing the number of teachers in each scoring category

		LP1		IP1		IP2		IP3		IP4	
Variable	Scoring Range	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
HLTR											
	High (7 – 10)	---	---	9	60.0	13	86.7	13	86.7	13	86.7
	Medium (4 – 6)	4	26.7	4	26.7	2	13.3	2	13.3	2	13.3
	Low (0 – 3)	11	73.3	2	13.3	---	---	---	---	---	---
LPDR											
	High (16 – 23)	---	---	3	20.0	5	33.3	6	40.0	9	60.0
	Medium (8 – 15)	---	---	3	20.0	3	20.0	5	33.3	3	20.0
	Low (0 – 7)	15	100.0	9	60.0	7	46.7	4	26.7	3	20.0
Total											
	High (24 – 33)	---	---	4	26.7	5	33.3	6	40.0	9	60.0
	Medium (12 – 23)	---	---	6	40.0	6	40.0	8	53.3	5	33.3
	Low (0 – 11)	15	100.0	5	33.3	4	26.7	1	6.7	1	6.7

Note. Freq = Frequencies of teachers; % = Percentages of teachers; HLTR = High-level task rubric; LPDR = Lesson plan discussion rubric; LP1 = pre-lesson plan; IP1 = instructional performance 1; IP2 = instructional performance 2; IP3 = instructional performance 3; IP4 = instructional performance 4 (post).

Table 4.17: Results of ANOVA findings for overall model of total HLTR/LPDR at the five time periods

Time Period	*M*	*SD*	*F*	*p*	η^2
Total HLTR/LPDR			42.60	<.0005	0.75
Pre-lesson (LP1)	3.07	1.87			
Instructional performance 1 (IP1)	16.80	9.68			
Instructional performance 2 (IP2)	18.60	9.11			
Instructional performance 3 (IP3)	22.27	8.03			
Instructional performance 4 (IP4) (Post)	24.20	8.68			

Note. *M* = Mean; *SD* = Standard Deviation.

Table 4.18: Results of the post hoc comparisons of ANOVA model findings for the multiple time periods

Instructional Time Periods (I)	Instructional Time Period (J)	Mean Difference (I – J)	*SE*	*p*
LP1	IP1	-13.73	2.55	.001
LP1	IP2	-15.53	2.51	<.0005
LP1	IP3	-19.20	2.19	<.0005
LP1	IP4	-21.13	2.21	<.0005
IP1	IP2	-1.80	1.32	1.000
IP1	IP3	-5.47	1.21	.005
IP1	IP4	-7.40	1.53	.003
IP2	IP3	-3.67	1.15	.065
IP2	IP4	-5.60	1.40	.013
IP3	IP4	-1.93	1.07	.926

Note. *SE* = Standard Error; LP1 = pre-lesson plan; IP1 = instructional performance 1; IP2 = instructional performance 2; IP3 = instructional performance 3; IP4 = instructional performance 4 (post).

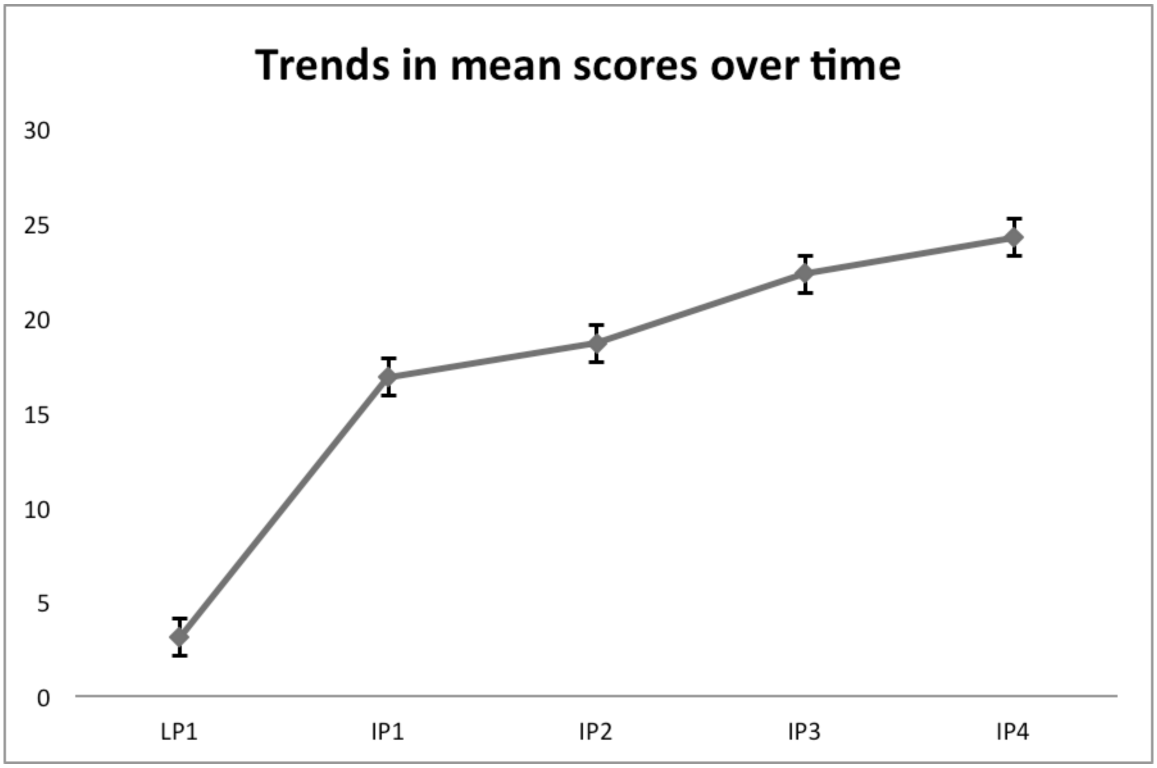


Figure 4.6: The mean total HLTR/LPDR scores at each time period. The confidence intervals are represented at each time period

The significant difference between pre-lesson plan scores and Instructional Performance scores suggests these patterns and changes were directly linked to the teacher preparation program. While there is not a significant difference between the IP scores, there is a general increase in scores over time across the cohort. This increase in scores between the IP 1 and IP 2 (fall) and IP 3 and IP 4 (spring) can be attributed to the repeated and scaffolded design of teacher preparation. Further analysis by scoring category shows that low and medium scoring PSTs scores increased over time (Figure 4.7). This subset of the cohort appears to benefit from the longitudinal practice over time provided during teacher preparation. The mean increase in Instructional Performance scores during the course of the teacher preparation year further supports the effect of the teacher preparation coursework. During the interviews, I asked the

PSTs to identify course sessions that supported their planning of task based discussion lessons. What follows is a summary of these findings.

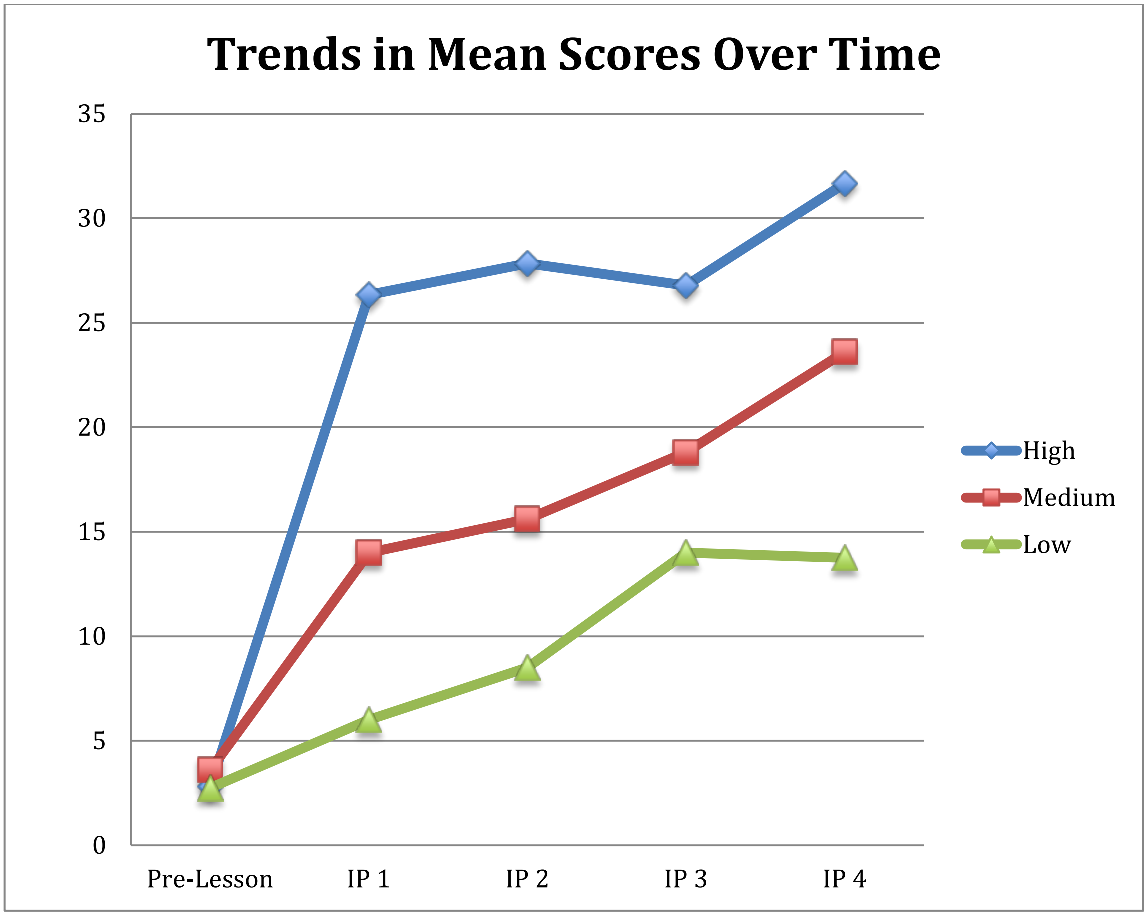


Figure 4.7: The mean total HLTR/LPDR scores at each time period by scoring category

4.3.2 Qualitative Findings

At the end of the fall semester, I interviewed the selected PSTs. During part of the interview, I asked what university course sessions were important and/or supportive in their learning to design and plan challenging tasks where students engage in discussion. I provide detail summaries of the pertinent university course sessions in Appendix A. Tables 4.19 and 4.20

indicates the number of PSTs in each scoring category whom identified these important sessions in Teaching & Learning 1, 2, and 3 (methods courses), respectively.

When asked to circle and discuss important class sessions, the class sessions identified in Tables 4.19 and 4.20 PSTs were most often identified. Interestingly, during the fall semester, all three high scoring PSTs listed all classes in Teaching and Learning 1 and 2 unanimously. Kristen explained her rationale for the importance of the first course session, a model of engaged learning, to her.

> So definitely, when we started talking about the model of engaged science learning, California is on the Direct Interaction Instruction, so the DII model. So pretty much everything I'd ever grown up with was just lectures. High school, we do lectures, college, we do lectures.

Table 4.19: Total number of PSTs interviewed identifying important university course sessions during the fall semester

	Teaching and Learning 1		**Teaching and Learning 2**		
# PSTs	<u>Class 1 and 2</u> A model of Engaged Learning (Fastplants)	<u>Class 5</u> Introducti on to Lesson Planning	<u>Class 1</u> • LGs & Objectives (review) • Task selection • Anatomy of a lesson • Micro-teaching practice: ***Launch***	<u>Class 3</u> Anticipating and Monitoring Role Play	<u>Class 4</u> Monitoring, Selecting, Sequencing, Connecting Role Play
High	3	3	3	3	3
Medium	1	3	2	3	3
Low	0	2	1	3	3

Table 4.20: Total number of PSTs interviewed identifying important university course sessions during the spring semester

# PSTs	Teaching and Learning 3				
	Class 2 Learning Cycle and Five Practices	Class 3 & 6 Formative Assessment	Class 4 High-Demand Tasks	Class 7 Scaffolding	Class 8 Maintaining Cognitive Demand
High	3	3	1	2	3
Medium	3	3	1	1	2
Low	3	2	1	1	3

Kelly described the structure of the same class, where the PSTs engaged as students, as crucial in her learning.

> So the first thing that I have is kind of all the portions of the first plan, so that they engage in science learning. Because I think that making us do it ourselves was very helpful in realizing, this is supposed to be the outcome. I mean that spanned over several lessons.

Finally, Bonnie agreed with her cohort members regarding the importance of the opportunity to engage as students.

> So this tangent really gets the heart what students should be doing, and why they should be doing it. As opposed to just, well they should be doing this fact. But no, they should be arguing, or they should be supporting their claim with evidence, because that is important for convincing people of your position and that kind of stuff.

Differences between the PSTs' answers arose between the low and medium scoring PSTs and their appreciation for Class one and two of Teaching and Learning 1 and Class one of Teaching and Learning 2 (Tables 4.19 and 4.20). But, all PSTs identified the Five Practices role-play sessions as important in supporting their planning of discussions. Xavier eloquently described his feelings related to the role-play Five Practices classes. His comments were representative of the PSTs also scoring low (Florence and Nicole).

> It started to make a lot more sense to me like; I'm not going to go to these same people all the time. If I want to make it easy on myself that's what I would do, but that's not really helping the rest of them. So, I started selecting and sequencing a lot more based upon that. Then that made more sense to me with the whole 5 practices thing is, that it is just something that even if you are not going to use it, as being like a select in that sequence that you originally thought. It is the idea that you thought about it, and that if you needed to do it, it was available to you. If you like a have a monitoring sheet or something like that with you, like I said that is something that didn't come to me till much later. But if you had that like with you, you could be just be like, 'All right, well I know that your Tessa has this. So Nate what were you thinking whenever you talked about it?'

During the second semester, the first seven weeks of Teaching and Learning 3 centered on revisiting many of the topics and concepts from the fall semester as described in Chapter Three. Returning to and presenting these topics in a different way, after the PSTs began teaching every day, truly resonated with PSTs regardless of their demonstrated level of PDC. Classes two, three, and six centered on the Learning Cycle, the Five Practices, and Formative Assessment where the PSTs engaged once again as students before unpacking the various teacher moves. When asked why these sessions were important, the responses were similar amongst the PSTs. Nicole described her feelings about the value of the formative assessment lessons.

> Okay, so the first two lessons we already talked about. I felt like those were really helpful because, I mean, I knew what formative assessment was, and I knew how to make a monitoring tool, but I didn't know how to use it in a way that would make it work for me. So I felt like it had to be this thing that I had to have, but I didn't really see a whole lot of value in it.

Calvin summarized the thinking similar to that of the university instructors during the design of this preparation program.

> Um, so in the fall whenever we talked about the Five Practices, we talked about a lot of the theory behind it. Like if you're going to have Five Practices, you need a

> high cognitive demand task. And we're like, "Okay Like that's a neat word. We've got to build these. Like let's talk about that." Um, then like, oh, these engaging discussions. Like, okay, engaging discussions. What's, what's an engaging discussion look like?
>
> Like we didn't know – we knew all of these things we needed to have and we knew how to like design them, but what they actually like looked like being implemented from like a very experienced teacher, like I haven't seen yet. Um, so, whenever –Prof. Williams came in and whenever he started talking about the bowling alley, um, 'cause, 'cause I think, I think Dr. Curtis might have said that he was coming in to talk about the Five Practices.
>
> And whenever he started talking he didn't talk about the practices. These alarm bells off –were going off in my head and I was like, "What are we learning today?" And then about a minute later whenever he started talking about like, "Oh, I've got this problem," I was like, "Oh, my goodness. He's doing a practice [laughter]." And from there I was like, "Okay. Just like play along, but just absorb everything you can." And from that moment like I was – like every transition Brian made, and every like different movement, and like what he was thinking or where he was in the classroom, I just tried to pay attention to 'cause I really wanted to see what this actually looked like – um, for someone to be doing that.

Chapter Four addressed the three research questions using the analyses presented in Chapter Three. It did so by comparing and contrasting the PSTs' lesson planning at the three levels of demonstrated PDC. Interview excerpts provided insight into the support PSTs received from mentors and university supervisors, the resources they used in their planning, and class sessions they felt were most important in their development as a teacher. Chapter Five explores possible explanations for the variation in PSTs' PDC and their ability or inability to design high-demand tasks and plan lessons that support productive whole class discussions, and highlights the contribution this study provides to the field, and provides suggestions for future research based on this study.

5.0 DISCUSSION AND CONCLUSIONS

A key instructional goal for the secondary science teacher preparation program, in which this study is situated, is to support secondary science PSTs in developing approaches to instructional planning of tasks that support students engagement in the SEPS and are consistent with the model of inquiry-based science teaching described in research (Anderson, 2003; Duschl, 2008; Leinhardt & Steele, 2005; Windschitl, Thompson, & Braaten, 2008). Embedded within this goal is supporting the development of the PSTs' pedagogical design capacity (PDC) by developing their ability to draw upon all available resources, knowledge, materials, etc. to design instruction for Five Practices discussions. PSTs learn how to draw from various curriculum materials and resources to plan lessons that engage all learners. To support this development, teacher educators at this large urban Midwestern University, draw on the Five Practices model and design an intervention aimed at increasing PSTs' PDC related to use of the Five Practices model to selection and design of tasks that engage students in the SEPs described in the *NGSS* (Achieve, Inc., 2013).

In this study, an intervention in the secondary science methods courses during the 2013-2014 school year was studied. This intervention focused on selection and design of tasks and use of the Five Practices model to support student engagement in the SEPs. The PSTs engaged in the roles of student and teacher as they participated in various learning opportunities and approximations of practice. This study investigated PSTs' planning practices by assessing their selection and/or design of high-demand tasks and their use of the Five Practices model when planning for a whole class discussion. The study also examined uptake of task and lesson design strategies from university coursework by analyzing changes in PSTs' planning practices over the course of the teacher preparation program.

The findings presented in Chapter Four suggest that overall PSTs' lesson planning for task-based discussion lessons improves over time and that the design of the teacher preparation program influenced this improvement. By selecting ambitious planning practices, the teacher educators presented these contextual discourses through iterative cycles of decomposition, representation, and approximations of practice. These contextual discourses supported the PSTs in developing not only discussion specific pedagogical design capacity, but also necessary critical pedagogical discourses about their role as teachers in their classrooms (Thompson et al., 2013).

While all PSTs except for one, Nicholas David, showed improvement in their planning practices, there was obvious variation in the levels of improvement. Furthermore, almost half of the PSTs (six out of 15) demonstrated high-level pedagogical design capacity for designing lessons of this type. In fact, these PSTs consistently demonstrated planning practices consistent with high pedagogical design capacity. It might be expected that with PSTs demonstrating improvement that some PSTs with low PDC would eventually develop planning practices of a teacher with higher PDC. However, this was not the case as the PSTs with lower PDC did improve in their planning and design of tasks, they did not improve significantly. In Section 5.1, I explore possible explanations for the findings of this study. Section 5.2 defines what the planning practices of a PST with high PDC for task-based discussions. Section 5.3 describes possible implications of this research in the design of teacher education programs. Section 5.4

discusses the limitations of this study and provides suggestions for future research. Finally, Section 5.5 concludes with the contributions of this study to the body of literature related to this topic.

5.1 EXAMINING THE FINDINGS

To answer the first research question, I investigated to what extent the PSTs used the Five Practices model in their planning for the Instructional Performances course assignments and any "In the Wild" lesson plans. PSTs scoring high consistently wrote detailed lesson plans while PSTs scoring lower created plans that were much lesson detail (see Appendix I for examples). As such, it is easy as a researcher to assess PST planning for those that provide these detailed plans. However, for PSTs that do not provide detailed plans, it is difficult to truly capture their thinking during planning. This finding supports previous research that suggests teachers' written lesson plans do not completely represent teacher thinking when planning (Hughes, 2006; Shoenfeld, 1998). Because much of what teachers think is not represented in their written plans, it is difficult to capture exactly how the PSTs in this study think during planning for Five Practices discussions. Interview evidence points to supporting this fact. At various points during interviews, the 6 PSTs' scoring low or medium often remarked that they thought about certain aspects of planning, but failed to thoroughly include those thoughts in their written lesson plans. To this point, during an interview, Xavier explained:

> I will say that I often forget to include my anticipation for sooner response like I'm thinking it. I want to come up with the questions without thinking like, what they might be answering it. But I will admit in my writing, what I am thinking is never always on the paper, but sometimes I think that it's there.

Further examination of the findings suggests that field placement setting does not impact PSTs' lesson planning practices. Three of the six high scoring PSTs, Kristen Ingall, Bonnie Kyle, and Frank Daniel interned in an urban high school. While four of the 9 lower scoring PSTs interned in an urban school. In addition, Frank Daniel and Nicole Timko interned teaching biology at the same urban high school using the same curriculum. Yet, Frank consistently scored high and Nicole consistently scored low (see Table 4.1), indicating school setting did not affect PSTs' planning practices.

To answer research question 1A, I examined the curriculum resources the PSTs used during their planning practices. Recall that, the majority of PSTs adapted and/or improvised tasks when planning for Five Practices discussions, suggesting their awareness that many curriculum materials are not sufficient for these types of lessons. However, the capacity to create demanding tasks varied between high and low scoring teachers. Table 4.12 shows that low scoring PSTs, Florence Edward, Xavier Idol, and Nicole Timko indicated during interviews that they typically used mentor-created materials, peer lesson plans, and their school's curriculum when designing tasks. While high scoring PSTs indicated less reliance on their school's curriculum. This finding suggests that high scoring PSTs have more agency with regard to curriculum. Moreover, high and medium scoring PSTs' use of personal knowledge and experiences is indicative of better-developed content knowledge for teaching (CKT) and specialized content knowledge (SCK) (Ball, Thames, & Phelps, 2008). Ball and colleagues indicate that CKT and SCK are important knowledge types for teaching.

In order to address research question IB, I examined the types of mentor and field supervisor support as indicated by the PSTs during their interviews. Tables 4.14 and 4.15

summarize these findings. High scoring PSTs sought mentor and supervisor support for task design and planning. In contrast, low scoring PSTs did not identify mentor or supervisor support, typically stating they did not receive support from either. Low scoring PSTs often indicated they did not provide their lesson plans in enough time for feedback or failed to seek out feedback from these human resources.

PSTs that sought support and feedback in their planning and design of such lessons typically scored higher than those that did not. Coupled with the ways in which these PSTs used the available resources, these findings suggest that high scoring PSTs have a more self-efficacious mindset to design tasks and lessons and seek out critical feedback for those plans. Whereas, low scoring PSTs, failed to seek out support. The confidence high scoring PSTs had in their planning and teaching is further evident in their search for additional feedback from university instructors. Anecdotal information provided by one of the university instructors indicates that all six high scoring PSTs asked her to provide feedback on their lesson planning and observe that lesson at their field sites. The remaining nine lower scoring PSTs did not ask for additional observations. These findings indicate the more successful students have more agency and sought help from others more frequently. Consequently, we, as teacher educators, need to better understand how we can help PSTs develop this mindset to seek out critical feedback.

Further evidence of the importance of critical feedback is indicated in the supervisor feedback. Four of the six high scoring PSTs had a university affiliated field supervisor (as explained in Chapter 3, I supervised two of these students). These students also received feedback from supervisors related to task design and lesson planning.

Moreover, low scoring PSTs report not receiving the same level of support from their field supervisors. Receiving this critical feedback from an experienced individual seems to be key in these PSTs development. Therefore, it is important for teacher preparation programs to provide better training for field supervisors and mentors in providing critical feedback.

To answer research question two, I examined the PSTs' planning strategies. As indicated in Chapter Four, PSTs demonstrating high PDC typically used their own personal knowledge and resources to create high demand tasks (Table 4.12). Their planning using the Five Practices model was very detailed (see Table 4.11). These PSTs were also purposeful in seeking mentor and supervisor support (Tables 4.14 and 4.15). The combination of these planning practices is supportive of the PSTs' planning and design of these task-based discussion lessons. While low scoring PSTs often used school curriculum and mentor created materials, indicated less agency with the curriculum. They also indicated using peer created lessons, but the planning differed. Finally, the support of their mentors and field supervisors was not focused on task design or planning, but often instruction and logistical items. These types of planning practices seemed to hinder these PSTs' planning for these types of lessons. Future research should examine how to develop PSTs' agency with the curriculum and their willingness to seek out critical feedback.

Finally, to answer research question three, the changes in PSTs' planning practices over time, I analyzed the PDC scores for statistical significance. Findings indicate that there is a significant difference between the baseline lesson plans and the instructional performances. This result suggests that PSTs are able to plan in particular ways when asked to do so in their teacher education courses. While there is not a significant difference between the Instructional Performances scores, there is an overall increase in scores (Figure 4.6). Because the cohort was small, statistical testing did not capture individual differences between the PSTs. There is a subset of PSTs (low and medium scoring) that appear to benefit from the longitudinal approximations of practice provided in the teacher education program (Figure 4.7). In addition, the difference in scores between IP 1 and 2 and IP 3 and 4 (see Figures 4.6 and 4.7) can be attributed to the repeated approximations of practice in the teacher education program. Pilot research indicated that repeated approximations and longitudinal practice over time is important in PST education (Ross, Kessler, & Cartier, 2014).

5.2 DEFINING PEDAGOGICAL DESIGN CAPACITY FOR TASK-BASED DISCUSSIONS

The main purpose of this study was to examine PSTs' uptake of the Five Practices model and their developing PDC for task-based discussion lessons. There are common characteristics between all PSTs demonstrating high PDC as described in Chapter Four. These PSTs were able to uptake the various strategies, tools, and planning routines introduced in their university coursework and produce demanding tasks and robust lesson plans, which showed a deep understanding of the strategies presented. These PSTs showed an ability to critically analyze not only the available curriculum materials and resources effectively, but also incorporate knowledge of their students, content knowledge, and pedagogical content knowledge when planning Five Practices discussions (Figure 5.1).

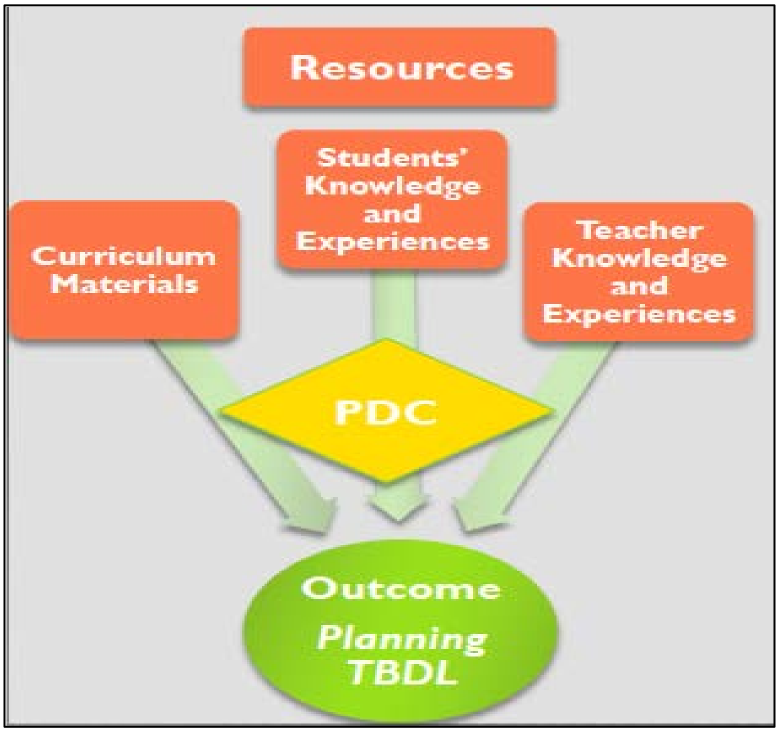


Figure 5.1: Visualization of a PSTs' pedagogical design capacity for designing task-based discussions

PSTs with a strong PDC for designing task-based discussion lessons also, not surprisingly, demonstrate a strong content knowledge for teaching (Ball et al., 2008). More specifically, as detailed in Chapter Four, these PSTs developed a strong capacity to:

- Critically analyze available curriculum materials
- Draw on a variety of resources in order to design tasks
- Design a challenging high-demand task where students participate in one or more SEPs
- Thoroughly think through a lesson planning protocol (Smith et al., 2008)
- Plan questions to elicit, extend, and evaluate students' thinking
- Integrate ambitious planning practices for Five Practice discussions introduced in coursework

Through the incorporation of these practices at a high level these PSTs demonstrating high PDC for task-based discussions have assumed the role of instructional engineer and can effectively design these challenging lessons.

Moreover, one might expect that these PSTs with high PDC would continue to plan to teach Five Practices discussions beyond the scope of their coursework. In fact, only two PSTs scoring high (Kelly and Mark) did so, but not only once. Kelly scored 18 out of 33 on the HLTR and LPDR rubrics and Mark scored 4 out of 33. Only one other PST planned a Five Practices discussion outside of her coursework (Mary) scoring a five out of 33. While the PSTs demonstrated the ability to plan detailed task-based discussion lesson for course assignments, they failed to continue this practice outside of their coursework ("In the Wild" Lesson Plans). It seems that as the PSTs assume more responsibility in their internship sites and continue with their course load, they lack the time personally or within the constraints of the curriculum to have Five Practices discussions in their classrooms. Calvin described the time constraints he felt:

> Which when I was talking to my mentor teacher about it, he was like, "You need to stop doing that [laughter] 'cause like those discussions are kind of long. You're not getting through enough material." And, and at first I was like, "Okay. Like he's right. Like I need to get through more material." But, as I started to think about it more, I'm kind of disagreeing with that 'cause, you know, it would be, it would be like a simple question, but the students would go back and forth like challenging each other's ideas for 30 minutes.

In addition to curriculum constraints, personal time constraints were an issue with many PSTs. Nicole explained:

> So first off, not having enough time to plan them, because it does take a lot of effort to be able to anticipate and build some questions that are really going to guide students to where you want them to be, but also within the curriculum. You don't necessarily have time for students to construct their knowledge, which is ridiculous, but that's really what it is.

Although the PSTs did not tend to plan Five Practices discussions outside their coursework, PSTs showed the capacity to plan these types of lessons effectively. While six PSTs demonstrated these high level planning practices and high PDC, the remaining PSTs developed varying levels of PDC. An important outcome of this study is to understand this variation in PDC development in PSTs and how to support this development in teacher education. What follows are possible implications for the design of teacher preparation programs.

5.3 IMPLICATIONS FOR PRACTICE: DESIGNING EFFECTIVE TEACHER PREPARATION PROGRAMS

The results of this study indicate that PSTs that receive intensive instruction on ambitious planning practices for task-based discussion can effectively develop the PDC to analyze curriculum materials productively in order to design these lessons. Recall that the teacher educators involved in this study used the Grossman Framework for Teaching Practice (Grossman et al., 2009a) as an instructional design model for teacher preparation. Supporting the findings of Grossman and her colleagues (2009a), iterative cycles of decomposition, representation, and approximation are effective as a design model for teacher preparation.

As explained in Chapter 3, this study illustrates the need to support PSTs in developing their PDC for developing high-quality task-based discussion lessons. Teacher educators must provide more opportunities for the PSTs to plan, teach, and reflect on lessons of various types and at varying levels of authenticity. As the PSTs' ability to critically analyze and design this type of instruction develops, their lessons will become more aligned with the science disciplinary practices put forth by the *NGSS* (Achieve, Inc., 2013). Furthermore, embedding these experiences in the context of the approximation of various tools and routines, teacher educators provide the scaffolds necessary to support teacher learning.

Recall that curriculum materials play an important role for all teachers, particularly PSTs, as resources to support their planning and instruction (Forbes & Davis, 2008; Grossman & Thompson, 2008). In particular, PSTs that use curriculum materials and resources in critical ways suggest the development PDC (Brown, 2009). In this study, the PSTs planned tasks that support whole class discussions even if the curriculum materials did not provide instructional tools to do so. Through their adaptations and improvisations of their provided curriculum materials (Table 4.13), there is evidence to suggest that PSTs are aware of the limitations of curriculum in supporting students' engagement in discussions and the SEPs. In doing so, it is evident that the PSTs developed an ability to critically examine the curriculum materials and resources in ways similar to Brown's (2009) notion of adapting and improvising as they created their own tools or modified tools provided. Revisions like these suggest that university coursework that was part of this study provided the necessary support for PDC development.

Additionally, this study offers insight into how teacher educators might design learning contexts to support PSTs' planning for more authentic science practices. By providing repeated scaffolded opportunities to engage in micro-planning practices as described above, e.g., select or design specific tools that support student engagement in those authentic science practices (gathering, organizing, or representing data, identifying patterns), orchestrate Five Practices discussions, the PSTs begin to notice particular aspects of ambitious planning practices. These repeated opportunities to revisit tools and routines learned in the fall semester gives the PSTs multiple opportunities to approximate various aspects of each practice in an effort to develop their PDC (Grossman et al., 2009b). Mapping the findings of this study onto the Grossman

Framework (Grossman et al., 2009a) (see Figure 5.2), one sees that the repeated scaffolded approximations of this intervention supported the PSTs' development (see Tables 4.19 and 4.20). Early in the school year, the PSTs experienced less authentic approximations of practice, but as the PSTs gained more experience the approximations became more authentic. By the spring semester, the PSTs brought their own lessons and tasks into their courses to analyze and provide detail on their scaffolding and maintenance of cognitive demand. This revisiting of topics from the fall semester with more authenticity resonated with the PSTs. Having the opportunity to revisit these topics with their own materials supported them in developing their planning practices.

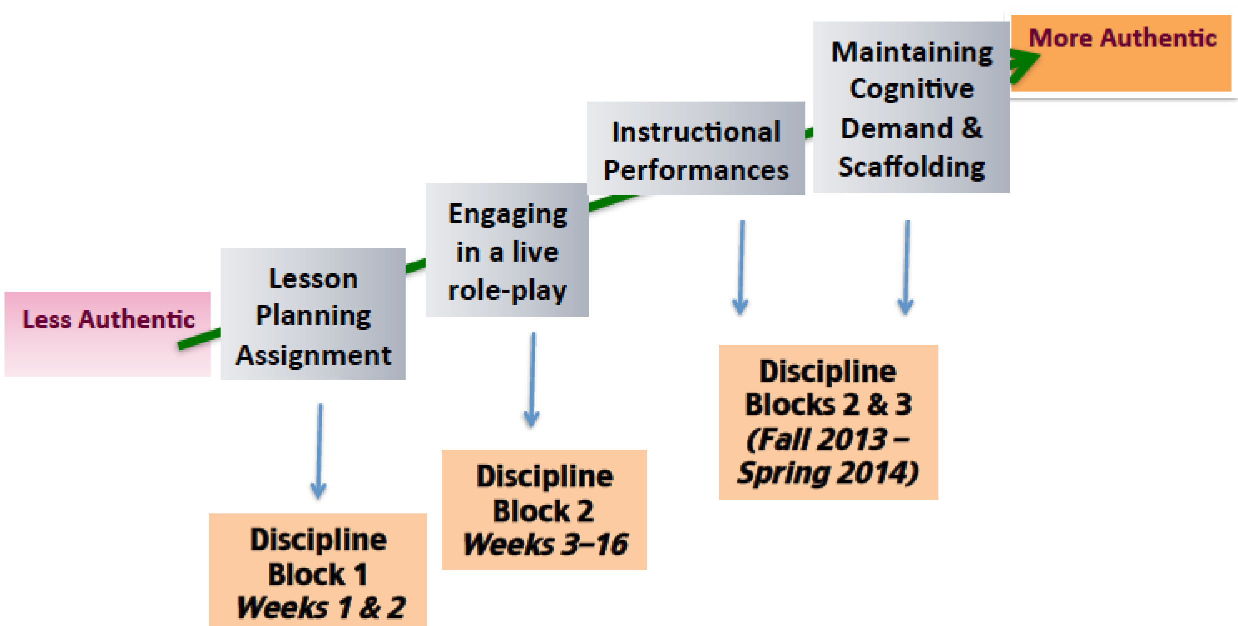


Figure 5.2: Examples of authentic approximations of practice in the teacher preparation program

5.4 LIMITATIONS AND IMPLICATIONS FOR FUTURE RESEARCH

This study has some limitations, most of which shed light on future research possibilities. To start, the sample size was small (N=15) leading to only two physics, two chemistry, one earth science, and the remaining biology PSTs. As a result, I was unable to make causal claims related to a PSTs' content area. Anecdotal evidence from past research suggests that content area does have an influence on a PST's success in planning task-based discussion lessons (Ross et al., 2011). Future research should aim to obtain a larger sample size allowing for more comparisons.

Second, PSTs were faced with many time constraints throughout the teacher preparation year, particularly during the spring semester. Weather played a major factor in the PSTs' ability to complete their Instructional Performances in a timely manner, which often resulted in PSTs not devoting the necessary time to plan these types of lessons. During the spring semester, frequent snow days and delays due to snow and frigid temperatures at the school sites forced the PSTs to fit in their assignments wherever they could. This factor might have also led to the limited number of "In the Wild lesson Plans." While controlling weather may not be a possibility in future research, a more realistic aim should be to provide the PSTs with more time to plan and teach their lessons. Unfortunately, the time constraints of the completion of this study did not allow for flexibility.

Another limitation was interviewing. I was only able to schedule interviews at two time points during the year. The resulting interviews regarding important coursework often was not very specific or detailed. The PSTs often forgot exactly what happened during each course session and had difficulty articulating precisely the coursework design that was most supportive. Future research should aim to conduct interviews more frequently and/or conduct frequent surveys in order to better understand the tools and routines that were most important in supporting the planning of task-based discussion lessons.

Another limitation is related to the nature of lesson planning which led to variations in the PSTs' artifact packets. By the very nature of the task, PSTs had the freedom to interpret many of the expectations in their own way, resulting in varying products. Consequently, the brevity of some PSTs' explanations led to many inferences on the part of the coders and discrepancies in coding. Many PSTs were not explicit on the choices made in their lesson plans. For this reason, each coder interpreted some data differently. Many might argue that the task itself should be more constrained and explicit for PSTs making interpretations of purpose and analysis easier. However, I argue that constraining the task itself would change the nature of the task and would not examine PSTs' ability to critically analyze curriculum materials and resources to plan task-based discussion lessons.

Finally, this study examined PSTs' lesson planning practices. As a result, I cannot make any causal claims related to instruction or lesson implementation. Because a PSTs' PDC for planning these discussion lessons has not previously been studied, it was a goal of this study to understand these planning practices and make connections back to university coursework. In doing so, the teacher educators can work to better support the development of this PDC at a high level. However, limiting the study to planning practices does not provide a complete picture of the PSTs' PDC. In order to understand a PSTs' PDC for task-based discussions, future research should aim to examine the totality of teaching practice: planning, instruction, and reflection.

5.5 CONCLUSIONS AND CONTRIBUTIONS TO CURRENT KNOWLEDGE BASE

Understanding how PSTs critique and adapt curriculum materials is critical to designing teacher education experiences and appropriate scaffolds that promote the development of their identity as instructional engineers. Curriculum materials are an essential component of classroom practice, shaping teachers' decisions about what and how to teach. However, many science curriculum materials are of poor quality, failing to address student thinking and whole-class discussion (Beyer & Davis, 2009; Cartier et al., 2013). Therefore, it is crucial that PSTs learn how to adapt science curriculum materials in order to meet the needs of ambitious teaching practices (Thompson et al., 2013). Learning how PSTs use these materials and how they can be supported in the developing their PDC for planning task-based discussions is an important part of reform oriented teacher preparation. Research to better understand the participatory relationship between PSTs, the university context, and the development of their identity as instructional engineers as well as supporting this development is essential.

This dissertation adds to the body of literature concerned with pre-service teacher education (Beyer & Davis, 2009; Davis & Smithey, 2009; Forbes & Davis, 2008; Zembal-Saul, 2009), planning discussions using the Five Practices model (Smith & Stein, 2011; Cartier et al., 2013; Eskelson, 2013) and the development of PSTs' pedagogical design capacity (Brown, 2009). In particular, I described the extent to which PSTs take up certain ambitious planning practices related to task-based discussions using curriculum materials as they plan a lesson for an actual classroom. It also has important implications for the design of science teacher education and preparation. Thus, this research helps the field conceptualize how beginning teachers analyze curriculum materials, lesson plans, and how they can be supported in providing worthwhile learning experiences for their students.

APPENDIX A

DESCRIPTION OF UNIVERSITY COURSE SESSIONS PERTINENT TO THIS STUDY DURING THE 2013-2014 SCHOOL YEAR

What follows is a detailed description of the courses and the important course sessions, class materials, in-class tasks, and assignments for each course session pertinent to this study during the 2013-2014 school year.

TEACHING AND LEARNING I
FALL 2013

Teaching & Learning in Secondary Science I is a 1 credit course offered in 6 two or three hour sessions during Jumpstart, weeks 1 and 2 of the fall semester. The course is designed to help PSTs develop a vision for what "engaged learning" might entail in a secondary classroom, as well as the many considerations a teacher must address when preparing to support such engagement. The course will also provide PSTs with opportunities to reflect on the history of science education in the United States as well as the nature of scientific knowledge and practice.

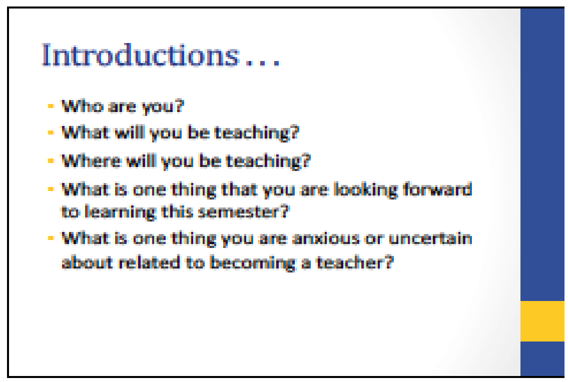
What follows are summaries of the important course sessions, instructional materials, and assignments.

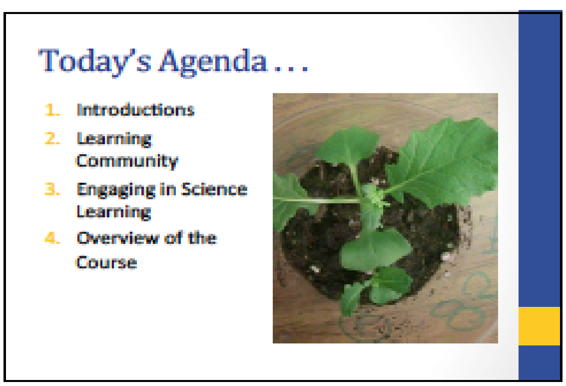
Class 1

A Model of Engaged Science Learning (Part 1)

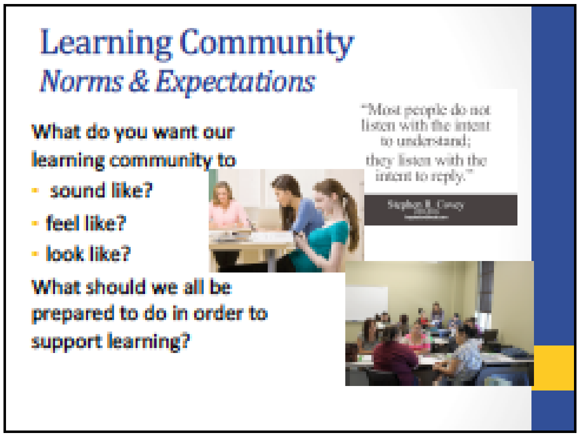
During Class 1, after introductions, the PSTs participate in the main task of the day, *A Model of Engaged Science Learning: The Fastplants Task*[4]. The instructors provide each group of PSTs two plants and laboratory materials, then give the instructions, "Develop a protocol to determine, 'How much do Fastplants grow during their life cycle?'" PSTs use the remaining time to develop protocols using materials of their choosing. What follows are the slides used by the instructors for Class 1.

Class 1 Slides

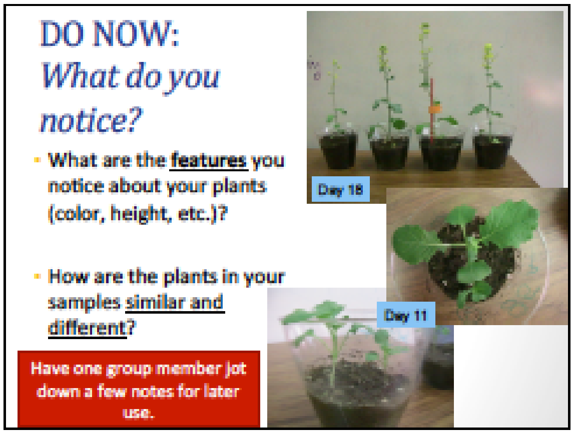


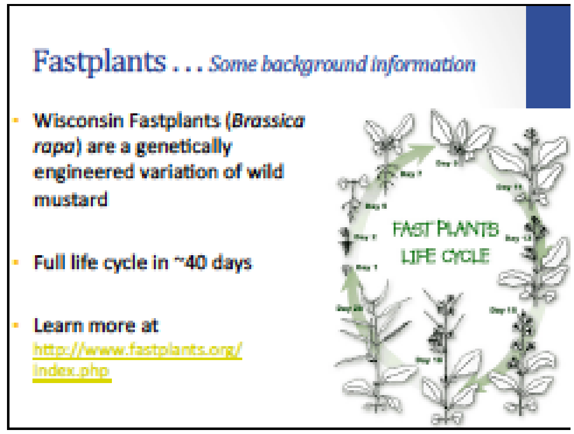


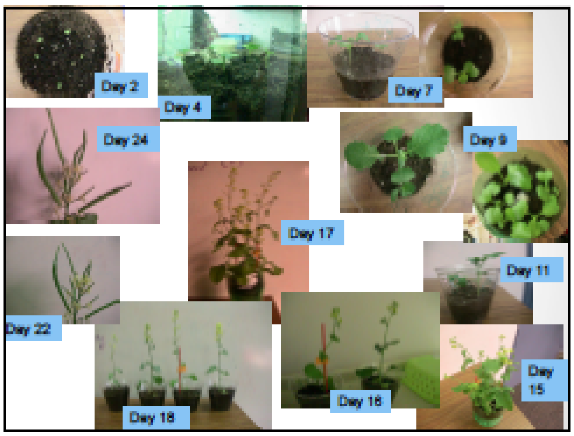
More information about Wisconsin Fastplants available at: [4]
http://www.fastplants.org/index.php

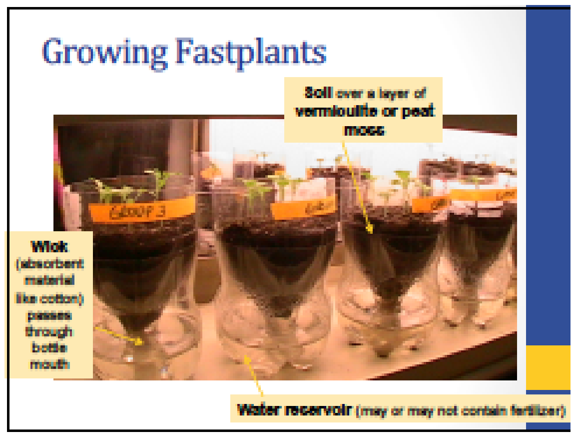

Learning Community
Norms & Expectations
What do you want our learning community to
sound like?
feel like?
look like?
What should we all be prepared to do in order to support learning?
"Most people do not listen with the intent to understand; they listen with the intent to reply."
Stephen R. Covey

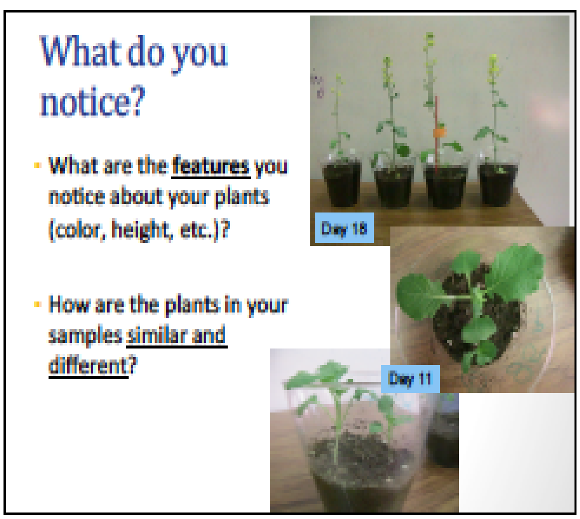

The Measuring Fastplants Task
ENGAGING IN SCIENCE LEARNING

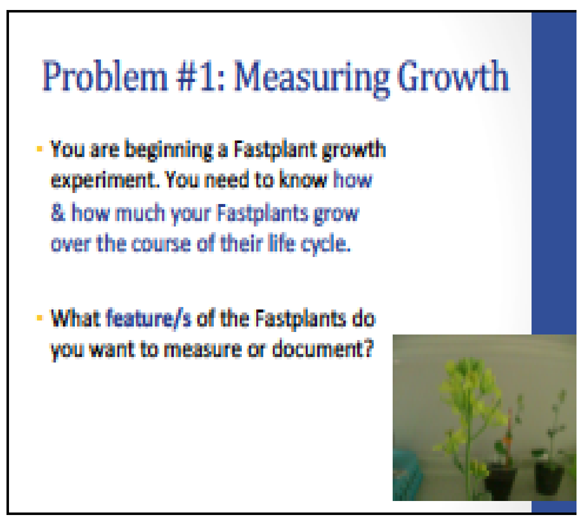

DO NOW:
What do you notice?
What are the features you notice about your plants (color, height, etc.)?
How are the plants in your samples similar and different?
Have one group member jot down a few notes for later use.
Day 18
Day 11


Fastplants . . . Some background information
Wisconsin Fastplants (Brassica rapa) are a genetically engineered variation of wild mustard
Full life cycle in ~40 days
Learn more at http://www.fastplants.org/index.php
FAST PLANTS LIFE CYCLE


Day 2
Day 4
Day 7
Day 9
Day 24
Day 17
Day 11
Day 22
Day 15
Day 18
Day 18


Growing Fastplants
Soil over a layer of vermiculite or peat moss
Wick (absorbent material like cotton) passes through bottle mouth
Water reservoir (may or may not contain fertilizer)


What do you notice?
What are the features you notice about your plants (color, height, etc.)?
How are the plants in your samples similar and different?
Day 18
Day 11


Problem #1: Measuring Growth
You are beginning a Fastplant growth experiment. You need to know how & how much your Fastplants grow over the course of their life cycle.
What feature/s of the Fastplants do you want to measure or document?

Measurable Features of Fastplants

- Height of plant overall
- Spread of plant (width at widest point)
- Area of leaves
- Volume (space that the plant takes up)
- Number of leaves
- Number of flowers
- Number of seed pods
- Number of seeds produced

How can we **gather data about these features** to help us answer the following questions?

- How do Fastplants grow?
- How much has a typical Fastplant grown at different points in its lifecycle (e.g. Day 5, Day 11, etc.)?

Developing a Measurement Protocol

- Which <u>feature</u> will you measure?
- <u>How</u> will you measure it?
- Be *specific.*
  - Tool
  - Process
  - Number of measurements
  - Frequency of measurements

Use your white board to describe your procedure in detail. Draw pictures to support your description as needed.

Tomorrow: Sharing Measurement Protocols

- Could you use this protocol exactly as it was intended?
  - Is anything unclear?
  - Are there aspects of the protocol that might be challenging to perform reliably?
- Will this protocol get you the data you want? (Will it help you answer the questions, *How do Fastplants grow? Or How much has a typical Fastplant grown at various points in its lifecycle*?)

Teaching & Learning in Secondary Science 1 - Overview

Course Information on Blackboard

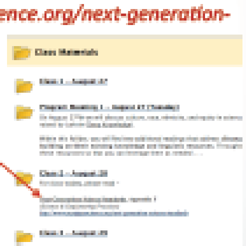
- Syllabus and Policies posted – keep a copy for reference!
  - Academic Integrity
  - Classroom Recording
  - G-grades
  - Sexual Harassment
  - Disabilities Services
  - Attendance & Participation (tied to overall course grade)
- Required Readings
- Class Materials
  - Slides and Handouts
  - Readings
- Assignments – details will be posted when assignments are distributed

For Tomorrow . . .

<u>Next Generation Science Standards</u>, Appendix F

(Science & Engineering Practices)

http://www.nextgenscience.org/next-generation-science-standards



Class 2

A Model of Engaged Science Learning (Part 2)

Following up the protocol development task from Class 1, Class 2 begins with the PSTs completing their protocols. Next, the PSTs present their work just as a secondary student would in a Biology classroom. PSTs as audience members assume the roles of other students in the class and critique each other's work.

The second half of class involves a study of the *Next Generation Science Standards* (Achieve, Inc., 2013). PSTs read Appendix F of the NGSS in preparation for class today. Following a short introduction, PSTs spent time analyzing and discussing the two versions of the Jeremy Vacation Task (Cartier et al., 2013). What follows are the Jeremy Task example distributed in class as well as the PowerPoint Slides used to organize class and prompt discussion that day.

Jeremy Vacation Task Handout[5]

Jeremy Vacation Task

From Cartier, Smith, Stein, and Ross (2013). Five Practices for Orchestrating Productive Task-Base Discussions in Science

	Amber Lake		Bakersville		Chesterton	
	Mean Low Temperature °F	Mean High Temperature °F	Mean Low Temperature °F	Mean High Temperature °F	Mean Low Temperature °F	Mean High Temperature °F
January	20	38	40	61	53	80
February	22	42	43	65	54	78
March	28	51	49	72	52	72
April	38	64	56	78	44	68
May	47	73	65	85	35	57
June	56	81	70	90	34	53
July	61	85	73	92	32	50
August	60	83	72	92	34	54
September	52	76	67	88	38	60
October	41	65	57	81	42	65
November	33	53	49	72	52	69
December	24	41	42	63	54	79

Task A

Jeremy is planning ahead for his 2015 vacation. He has decided that he'd like to travel to a place where he can enjoy outdoor camping, hiking, and fishing with his Labrador retriever, Sadie. Jeremy's tent is rated for temperatures above freezing (32 °F). Sadie prefers not to be too active when the temperature is over 70°F.

Create a bar graph that shows the average monthly high and low temperatures in each city. Identify where and when Jeremy should go on vacation.

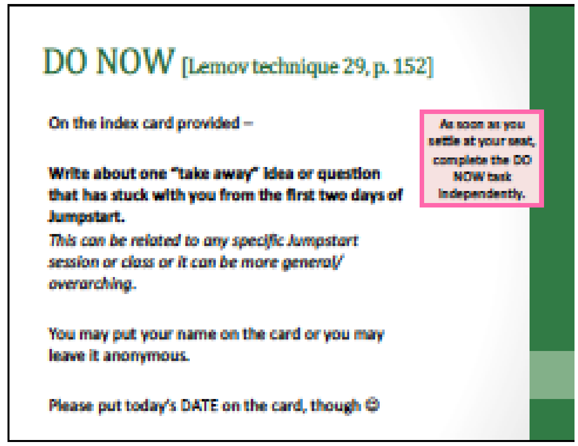
Task B

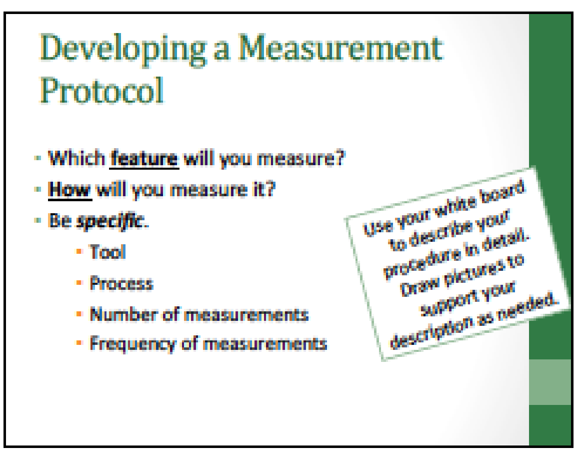
Jeremy is planning ahead for his 2013 vacation. He has decided that he'd like to travel to a place where he can enjoy outdoor camping, hiking, and fishing with his Labrador retriever, Sadie. Jeremy's tent is rated for temperatures above freezing (32 °F). Sadie prefers not to be too active when the temperature is over 70°F.

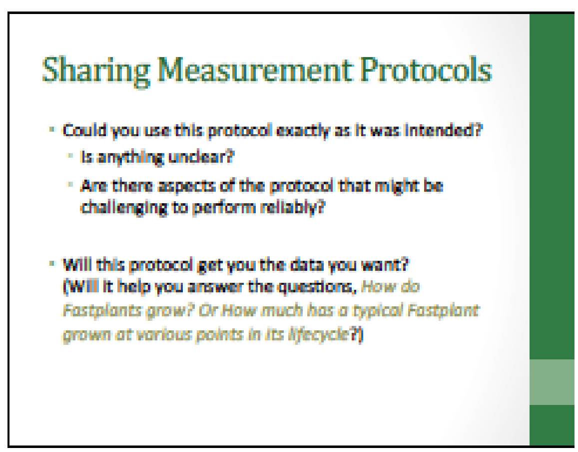
Using the data provided, create a representation that will help you to show which city Jeremy should visit and at what time of year (spring, fall, winter, or summer). You may represent your data in any way you choose. You may represent all or some of the data as long as you can use your representation to justify your recommendations for Jeremy's vacation (where to go and when to go there).

[5] Reprinted with permission from the National Council of Teachers of Mathematics.

Class 2 Slides







Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world.

Identifying opportunities for students to engage in science practices.

STEP BACK

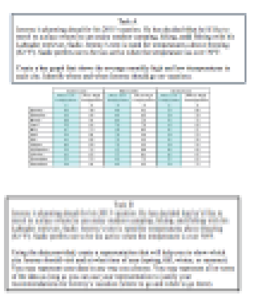
Step Back

1. Asking questions (for science) and defining problems (for engineering)
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.

In which practices did you have an opportunity to engage during the Fastplants task?

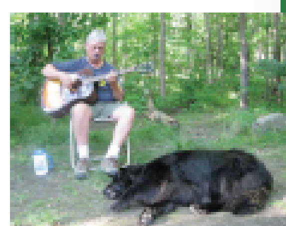
Science Tasks

- Read the two versions of the "Jeremy Vacation" task
- In which practices might students have an opportunity to engage (for version A and version B)?



Jeremy's Vacation

- Which version of the task would present more challenge for students?
- Why? What specific features of the task make it challenging?



Science Tasks

They are not all created equal!

- Engagement in tasks can be "rote" or can place high cognitive demand on students
  - High cognitive demand means that in order to be successful with the task, students really have to think about it!
  - Not algorithmic.

Tomorrow (Thursday)

What are some features of tasks that make them "high cognitive demand" or challenging?

Class 3

Supporting Engagement in Science Learning

In preparation for Class 3, PSTs read Chapter 1 and Chapter 3 of *5 Practices for Orchestrating Productive Science Discussions* (Cartier et al., 2013). This class consisted of a detailed analysis and discussion of High Cognitive Demand Tasks in Science. The tasks instructors used follow. These tasks are Experimentation, Data Analysis/Representation/Interpretation, and Explanation tasks described in Cartier et al. (2013), exemplars of high cognitive demand and low cognitive demand tasks. Using these examples, instructors led an in depth discussion around these tasks and characteristics of high cognitive demand science tasks.

Because textbooks are so widely in science classrooms, instructors discussed with the PSTs the importance of critical analysis of the provided curriculum. Through this analysis, it is important for PSTs to assume the role of an *instructional engineer* and assume the authority to adapt the provided materials as needed in order to make tasks that are cognitively demanding for their students.

Instructors assigned Lesson Plan 1 for homework. The assignment distributed to the PSTs follows the class slides.

Example Tasks Used in Class 3 for High Cognitive Demand Analysis and Discussion [6]

Experimentation Task 1

Context
7th grade Biology

The teacher chose this task because she wanted the students to participate in data collection. Specifically, she wanted them to have an opportunity to make and record measurements over time. She chose Fastplants because she wanted students to learn that there is variation in "normal" growth in a population of plants, but that the general trend can be described by an s-shaped growth curve.

Measuring Fastplant Growth

1. Gently tie a piece of yarn around the base of each plant in your container. Be sure to use a different color yarn for each plant.

2. Prepare a length of measuring string:
   a. Cut a 24-inch segment of white string.
   b. Using a Sharpie marker, place a mark ½-1 inch from one end of the string.

3. Every two days measure the stem length of each plant:
   a. Place the black mark on your measuring string against the bottom of the plant stem. Make sure the black mark is right where the plant stem emerges from the soil.
   b. Gently run the string up the stem, stopping at the base of the highest flower cluster.
   c. Use your fingers to mark (by pinching off) the place where the stem ends.

4. Now use a meter stick to measure the length of the string from the black mark to the place where you have pinched.

5. Record each stem length measurement (in cm) in your data table:

Plant Height (cm)

	Plant 1 Green	Plant 2 Red	Plant 3 Blue	Plant 4 Yellow
Day 4	1.4	1.9	0.92	2.2
Day 6	3.2	3.8	2.4	4.6
Day 8	6.1	6.8	4.5	7.3

[6]Tasks and other materials from Cartier et al. (2013).

Data Representation, Analysis, & Interpretation Task 1

Context	Temperature Patterns
6th grade Earth Science The teacher selected this task in order to give his students an opportunity to create and read bar graphs.	Jeremy is planning ahead for his 2015 vacation. He has decided that he'd like to travel to a place where he can enjoy outdoor camping, hiking, and fishing with his Labrador retriever, Sadie. Jeremy's tent is rated for temperatures above freezing (32 °F). Sadie prefers not to be too active when the temperature is over 70°F. Create a bar graph that shows the average monthly high and low temperatures in each city. Identify where and when Jeremy should go on vacation. (See data for Task A, Fig. 0.2).

	Amber Lake		Bakersville		Chesterton	
	Mean Low Temperature °F	Mean High Temperature °F	Mean Low Temperature °F	Mean High Temperature °F	Mean Low Temperature °F	Mean High Temperature °F
January	20	38	40	61	53	80
February	22	42	43	65	54	78
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October	41	65	57	81	42	65
November	33	53	49	72	52	69
December	24	41	42	63	54	79

Data Representation, Analysis, and Interpretation Task 2

<u>Context</u>
9^{th} grade Biology

The teacher designed this task to provide students with an opportunity to make choices about how to transform data (e.g. calculate the change in mass over time) and represent it in order to show trends that would enable them to answer a specific question. She embedded the task in the context of a unit on respiration and thus highlighted key Learning Goals related to the role of water in plant transpiration.

[task by Helen Snodgrass, KSTF Fellow]

Environmental Factors Impacting Rate of Transpiration

Dear scientists of Prep HS,

We are writing you as fellow scientists in need of some help. At the zoo, our expertise is mainly in the area of animals and we currently have a question about our plants that we hope you can help with.

In different areas of the zoo, plants experience variable growth conditions. Some areas are more humid or shadier than others, etc. We need to develop a plan to provide the correct amount of water to our plants. That watering plan has to take into consideration the rate of transpiration of the plants under different conditions. Our grounds crew has gathered some data about the plants over a 5-day period during which the plants received no water. We would like you to use this data to develop a report about how different environmental growth conditions impact rate of transpiration.

Once we receive your report, we can develop a watering plan that will enable us to keep our zoo habitats thriving! We need to present this data to the Zoo Board at its next meeting. **Please look over the data for any patterns you see and create a graphical representation so that we can show the board members what patterns you have identified. Also, it will be very important to have some written description of what you found out so that our Zoo Board members will be convinced that our watering plan is grounded in good science.**

Thank you for your help. We are looking forward to hearing from you.

Deborah Smith
Director of the Zoo

Variable Condition	Standard Growth Conditions	Mass (g) Day 1	Mass (g) Day 2	Mass (g) Day 3	Mass (g) Day 4	Mass (g) Day 5
---------	64-87°F 75% humidity 8-10 hours of sunlight/day 10 mph winds	16.0	13.2	11.0	9.9	9.0
90% humidity	64-87°F 8-10 hours of sunlight/day 10 mph winds	17.0	16.8	16.6	16.4	15.3
2 hrs of sunlight	64-87°F 75% humidity 10 mph winds	12.9	12.5	11.9	11.4	11.1
40 mph winds	64-87°F 75% humidity 8-10 hours of sunlight/day	16.3	12.6	9.8	7.7	5.1

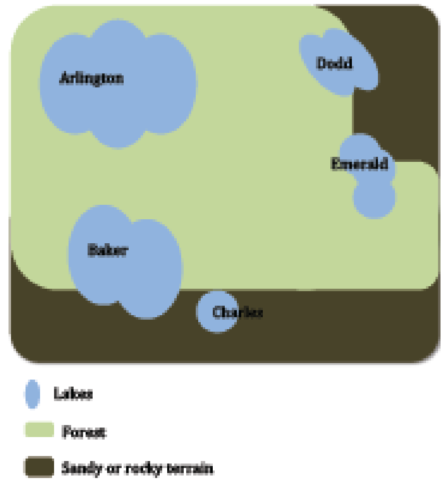
Explanation Task 1

__Context__
5th grade science

The teacher designed this task to provide students with an opportunity to draw on data to make and defend claims. She embedded the task in a unit about ecosystems, anticipating that students would draw upon their understanding of how organisms interact with and are dependent upon living and non-living factors in their environments. She wanted them to build on this knowledge to learn that parasites (or other pollutants in an ecosystem) can be particularly problematic for organisms that are exposed during early stages of development. After the students presented and discussed their claims, she took time to emphasize this new Learning Goal before closing the lesson.

The Frog Problem in Bakersville Park

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



Around Baker, Charles, and Emerald ponds, they have been seeing frogs with too few or too many legs! None of the deformed frogs have been spotted around Arlington or Dodd ponds, though.

Local scientists are wondering: ***what is causing these strange deformities***?

They have two hypotheses:

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

Use the data that the scientists have collected to support or challenge one of the hypotheses.

DATA
Concentration of Chemical Pollutants in Bakersville Park Ponds

	Fertilizer Pollution Level (ppm)	Pesticide Pollution Level (ppm)
Arlington	37	11
Baker	43	17
Charles	34	8
Dodd	41	22
Emerald	28	21

ppm = parts per million

Presence of Tremadode Larvae in Frogs

	number of frogs that were NOT infected	*number of frogs that were infected*	**Percentage** of Frogs Infected by Trematodes
Arlington	24	1	4
Baker	16	9	36
Charles	14	11	44
Dodd	23	2	8
Emerald	15	10	40

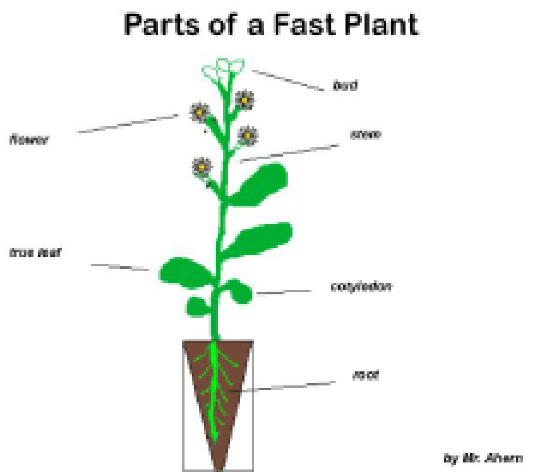
Experimentation Task 2

Studying Fastplant Growth

We know that individual humans vary quite a lot from one another — we are different heights and weights; we have different skin, hair, and eye color; the thickness of our hair varies, etc.

Is there variation in populations of other types of organisms?

- **Would we see variation in a population of plants?**
- **What kind of variation would we see?**
- **How would we measure and describe that variation?**



http://csstechnology.edublogs.org/files/2010/10/fast-plant-20rf8ie.jpg

Over the next few weeks you will be investigating variation in a population of plants called Wisconsin Fastplants. We are going to track ***changes in stem length*** as the plants grow.

Today we will decide how we are going to measure stem length in Fastplants.

SMALL GROUPS
[20 minutes]

1. Obtain a Fastplant from under the grow lights.
2. Select from the available tools:

Measuring tape	Markers	Lego blocks
Bamboo skewers	Colored tape	Pipe cleaners
String	Meter stick	
Scissors	Ruler	

3. Determine how you will use the tool/s you've chosen to measure Fastplant stem length.

4. Write our your measurement protocol in enough detail so that others will be able to use the protocol in a reliable way (i.e. everyone needs to be able to use it exactly the same way).

   Include pictures to help others understand your measurement protocol.

WHOLE CLASS
[20 minutes]

- We will share our protocols with the class and determine whether there are any details missing.
- We will agree on one way of measuring our plants throughout this investigation.

Explanation Task 2

[Students have Styrofoam balls, inflatable globes, a light source, and dry erase boards with markers. They have identified the general pattern of Moon phases that are seen from Earth over the course of a month . . .]

Why does the Moon look the way it does when viewed from Earth? (Why does it change throughout the month?)

Use any of the tools you have available (the globes, Styrofoam balls, light, white boards, or even your own bodies) to provide an explanation. Be prepared to share your explanation with the class.

Explanation Task 3

Why do we see phases of the Moon from Earth? (short answer)

____

____

____

Explanation Task 4

Why do we see phases of the moon during a month?

a. We see only the lit part of the moon as it moves around Earth.
b. Parts of the moon are always in shadow.
c. Eclipses of the moon occur nightly.
d. The moon is smaller when it is farther from the Earth.

Class 3 Slides

Teaching & Learning in Secondary Science 1

Thursday, August 29, 2013

Agenda

- Task Types
- Features of Challenging Tasks
- Strategies to Modify Tasks
- Assignment 1 – Lesson Plan!

Task Types

- Experimentation
  - Design or conduct an investigation
    - Not necessarily an "experiment" – it can be data gathered in a situation where manipulation of variables is not possible
    - Data may be quantitative or qualitative
- Data Representation, Analysis & Interpretation
  - Data may be first- or second-hand
  - Students may be manipulating data themselves or using data that are already transformed or represented in some way to identify patterns
- Explanation
  - Students are providing an explanation for why or how something occurs.
    - Merely justifying or clarifying one's thinking is not the same as providing a scientific explanation.

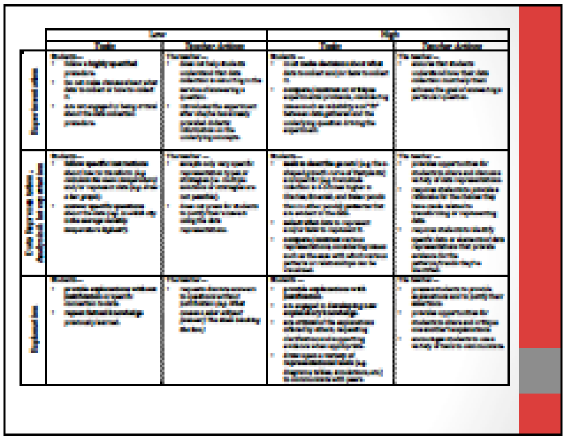
What Makes Tasks Challenging?

EXPERIMENTATION

DATA REPRESENTATION, ANALYSIS AND INTERPRETATION

EXPLANATION

1. **Choose** a category of tasks and **read** the examples provided.
2. **Discuss** with your group members – **what features of this task make it challenging? What are the important differences between challenging and not challenging tasks in this category?**
3. **Repeat** for each category of tasks . . .

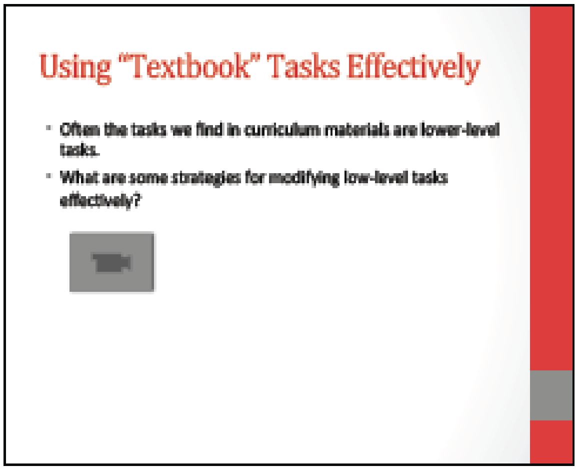


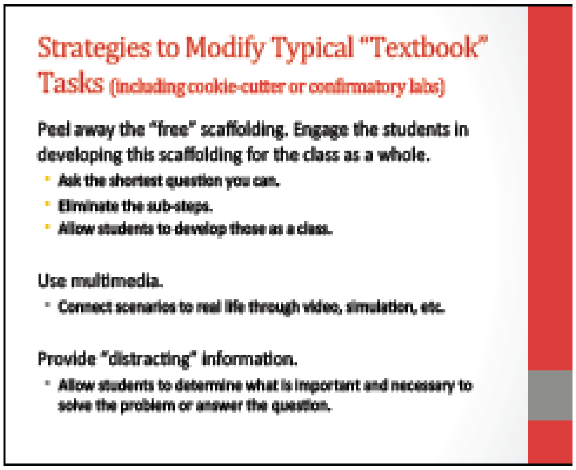
Engineering Tasks That Involve Productive Challenges

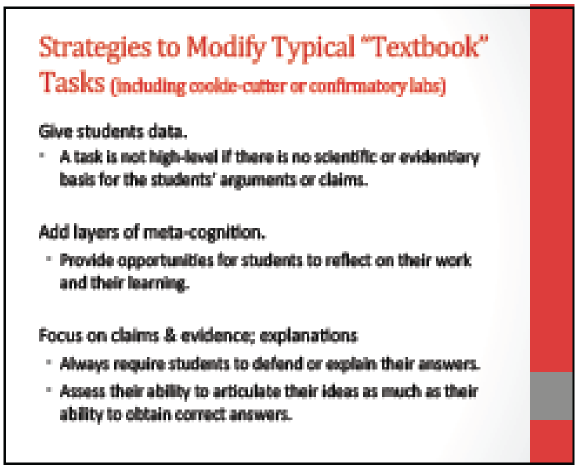
Learners have a limited capacity to handle cognitive demand . . .

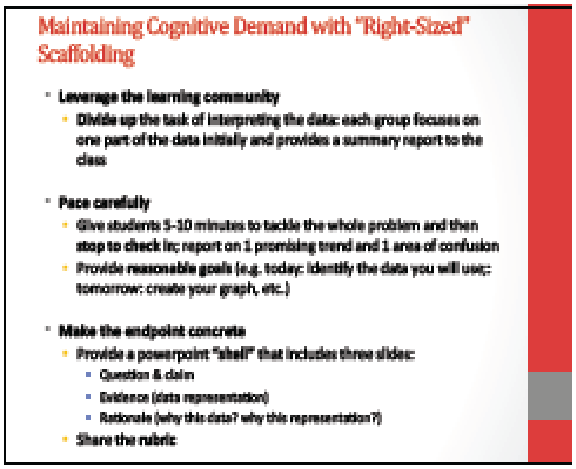
So . . . As ***instructional engineers***, teachers need to –

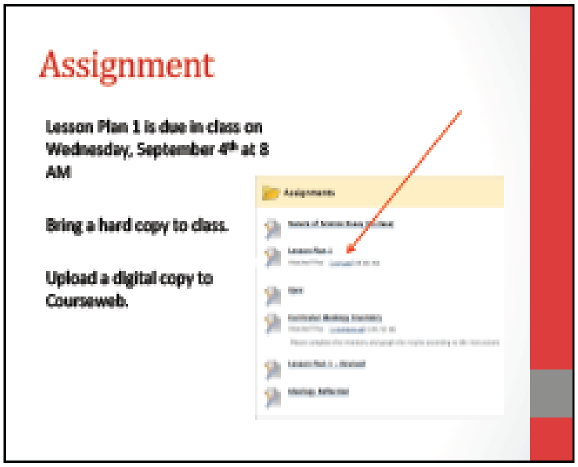
- Analyze tasks with their own students in mind so that they can identify which aspects of those tasks will be challenging.
- Determine which challenges will be productive – that is, contribute to the goals for the lesson.
  - Prepare to support students' engagement in the task, including scaffolds so that students can be successful with challenges.
  - Minimize or eliminate challenges that are not productive (that are not connected to the learning goals of the particular lesson).


Using "Textbook" Tasks Effectively
Often the tasks we find in curriculum materials are lower-level tasks.
What are some strategies for modifying low-level tasks effectively?


Strategies to Modify Typical "Textbook" Tasks (including cookie-cutter or confirmatory labs)
Peel away the "free" scaffolding. Engage the students in developing this scaffolding for the class as a whole.
Ask the shortest question you can.
Eliminate the sub-steps.
Allow students to develop those as a class.
Use multimedia.
Connect scenarios to real life through video, simulation, etc.
Provide "distracting" information.
Allow students to determine what is important and necessary to solve the problem or answer the question.


Strategies to Modify Typical "Textbook" Tasks (including cookie-cutter or confirmatory labs)
Give students data.
A task is not high-level if there is no scientific or evidentiary basis for the students' arguments or claims.
Add layers of meta-cognition.
Provide opportunities for students to reflect on their work and their learning.
Focus on claims & evidence; explanations
Always require students to defend or explain their answers.
Assess their ability to articulate their ideas as much as their ability to obtain correct answers.


Maintaining Cognitive Demand with "Right-Sized" Scaffolding
Leverage the learning community
Divide up the task of interpreting the data: each group focuses on one part of the data initially and provides a summary report to the class
Pace carefully
Give students 5-10 minutes to tackle the whole problem and then stop to check in; report on 1 promising trend and 1 area of confusion
Provide reasonable goals (e.g. today: identify the data you will use; tomorrow: create your graph, etc.)
Make the endpoint concrete
Provide a powerpoint "shell" that includes three slides:
Question & claim
Evidence (data representation)
Rationale (why this data? why this representation?)
Share the rubric


Assignment
Lesson Plan 1 is due in class on Wednesday, September 4th at 8 AM
Bring a hard copy to class.
Upload a digital copy to Courseweb.
Assignments

Teaching & Learning in Science 1
ASSIGNMENT: **Lesson Plan 1**

DUE: **September 4, 2013** (Wednesday, 8:00 AM)
SUMBIT: Digital copy of the lesson plan on Courseweb using the assignments function.
BRING: Bring a hard copy for your own use during class. Make sure this copy is printed single-sided.

Purpose
This assignment will provide you with an opportunity to write a science lesson plan. The work you do on this assignment will be utilized in our class on instructional planning on Wednesday, September 4th.

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

Requirements

1. Write an instructional plan for a lesson in which your students will have an opportunity to engage in *at least one* scientific practice (from the Next Generation Science Standards).
2. Your lesson plan should be a minimum of 2 typed, double-spaced pages long. There is no maximum limit for the length of the plan.
3. The main task in which students engage during the lesson should be challenging in some ways (consider our discussion about challenging tasks during class on Thursday, August 29th).
4. You may use materials (tasks, plans, etc.) that you find on the internet, in curriculum materials, or have obtained from others. If you use prepared materials please be sure to —
    a. Re-type the material, adding or changing things as you see fit.
    b. Provide a complete citation for the source.
    c. Provide a copy of the original material.
5. Set the stage for your lesson—
    a. Tell me what grade level student you are planning for (you can choose).
    b. Tell me whether you are planning for a 45-minute period or an 80-minute block.
6. Write up your lesson plan in whatever format you choose. You are free to use any lesson planning template with which you are familiar or to create your own. **Try to include all the information that you'd find necessary to enable you to teach the lesson.** (In other words, with this lesson plan and the necessary materials for the task you've chosen, you ought to be "good to go" as the lead teacher . . .)

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

General
    Making and justifying claims in science

Earth & Space Science:
    Moon phases

Biological Science:
    Mendelian inheritance of traits

Physical Science:
    Behavior of water at the molecular level

Class 5

Introduction to Lesson Planning

PSTs bring copies of the lesson plan 1 assignments to class. The first part of class involves the PSTs cutting apart the different sections of their lesson plans and examining the similarities and differences between the sections of their group members. After the group work, there is an instructor led discussion regarding important parts of a lesson plan and what a teacher needs to plan and prepare for when planning a high cognitive demand task, such as the Fastplants task, they did last week. The instructors then distribute the Sample Lesson Plan (provided below) and support the PSTs in comparing their plans with this sample plan. Finally, the last part of class involves direct instruction around the various parts of a lesson plan, e.g., Big Idea, Learning Goals, Objectives, etc., and the various resources the PSTs may use in writing those parts of the lesson plan.

The assignment is a revised lesson plan 1. The PSTs are to revise their first lesson plan based on the today's discussion and what they learned today.

Class 5 Slides

TEACHING & LEARNING IN SECONDARY SCIENCE 1
SEPTEMBER 4

Fall 2013

Please sit with your group!

1	2	3	4	5	6
Calvin Kristen Kevin Kady	Mark Thomas Marie	Frank Florence Kelly	Xavier Dana Donna	Bonnie Kris Scott	Nancy Nicole Nicholas

Do Now!

Jot down your group's thoughts somewhere so you can access them a bit later in today's lesson!

- With your group, reflect on the Fastplant task we participated in last week . . .
  - As learners, you had an opportunity to engage in several science practices, including –
  - *Asking questions*
  - *Planning investigations*
  - *Using mathematics and computational thinking*
  - *Obtaining, evaluating, and communicating information*
- What did the instructor have to do ***before you even entered the classroom*** in order to support your learning and engagement in this task?
- What did the instructors do ***during the task*** to support your learning and engagement?

- Ambitious instructional goals demand rigorous planning
  - Engaging students in designing elements of an experimental protocol requires more planning than simply providing them with a protocol to carry out.
  - Engaging students in determining how to transform and represent their data in order to answer a question requires more planning than providing direct instruction about specifically how to transform and represent data.
- **Our expectation is that you will develop ambitious goals for your students, engaging them in challenging cognitive work**

Why do we spend so much time on instructional planning?

Today's Agenda

Components of Instructional Planning

Analyzing Your Preliminary Lesson Plans

Looking at a Sample Lesson Plan

Lesson Plan Rubric

Tools to Support Planning

Standards

Assignments: (1) Revise LP 1; (2) Quiz

Looking at Your Lesson Plans

- Round Robin Sharing of Lesson Plans
  - As you read your group's lesson plans, look for similarities and differences between them.
- Dissecting of Lesson Plans
  - Cut out the distinct parts of your written lesson plans.
  - Put these parts into groups onto your white boards.
    - Explain them. (What information is being conveyed here? What purpose does this information serve?
    - Name them.

Reflecting on the Fast Plant Lesson

What did the teacher have to plan or do before the lesson in order to support your learning and engagement?

Are these planning practices reflected in our list of lesson plan components?

Compare with A Sample Lesson

- Can we see all important components of the lesson represented here?
- Have we left anything out?

The Lesson Plan

Big Idea
Learning Goals
Objectives
Description of Task
Related Standards
Materials Needed
Safety Concerns
Set-Up
Lesson Launch
Support of Lesson Activities
Lesson Close
Assessment
Adaptations and Modifications

Lesson Plan Rubric

- Detailed information about what we expect in these different categories.
- For LP 1 – grade based on YELLOW components only.

Big Ideas!

BIG IDEA

- Describes a core concept in science
- Has the capacity to explain or connect multiple phenomena
- Can't be mastered in a single lesson.

Next Generation Science Standards
http://www.nextgenscience.org/next-generation-science-standards

National Science Digital Library
http://strandmaps.nsdl.org/

PA Standards Aligned System (SAS)
http://www.pdesas.org/

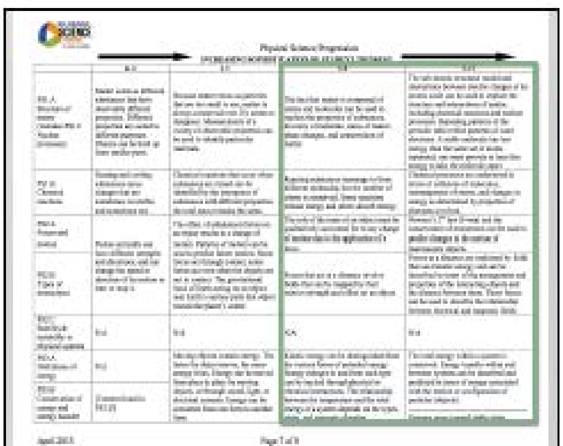
Big Ideas!

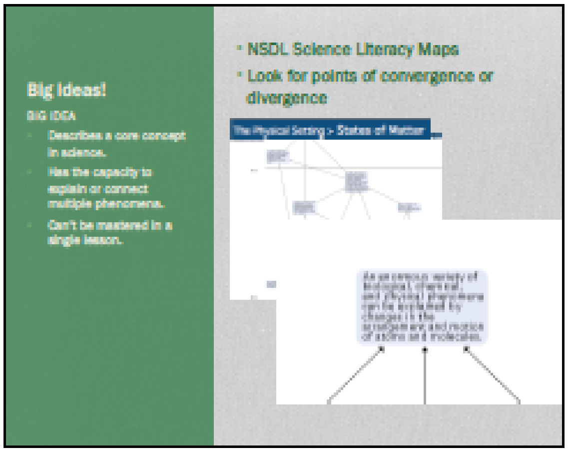
BIG IDEA

- Describes a core concept in science
- Has the capacity to explain or connect multiple phenomena
- Can't be mastered in a single lesson

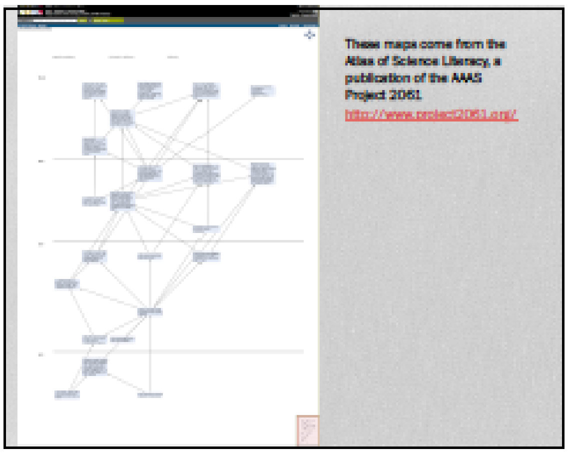
Next Generation Science Standards
http://www.nextgenscience.org/next-generation-science-standards

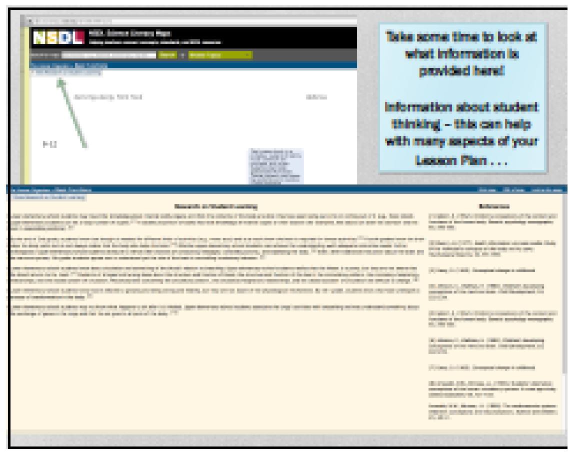
Disciplinary Core Ideas

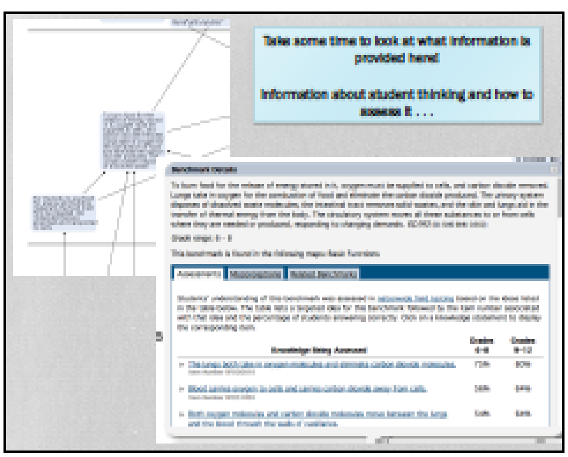


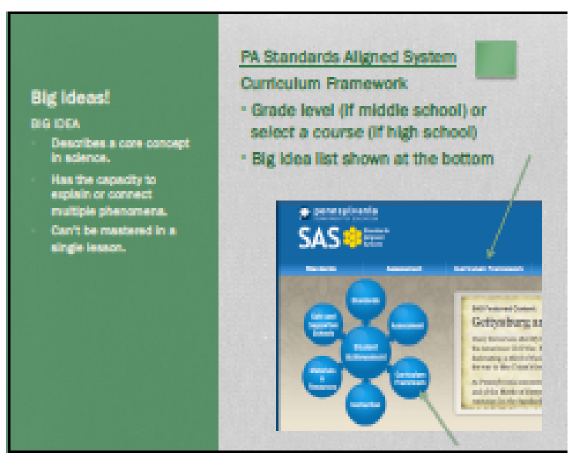

Big Ideas!
BIG IDEA
Describes a core concept in science.
Has the capacity to explain or connect multiple phenomena.
Can't be mastered in a single lesson.
NSDL Science Literacy Maps
Look for points of convergence or divergence
The Physical Setting > States of Matter

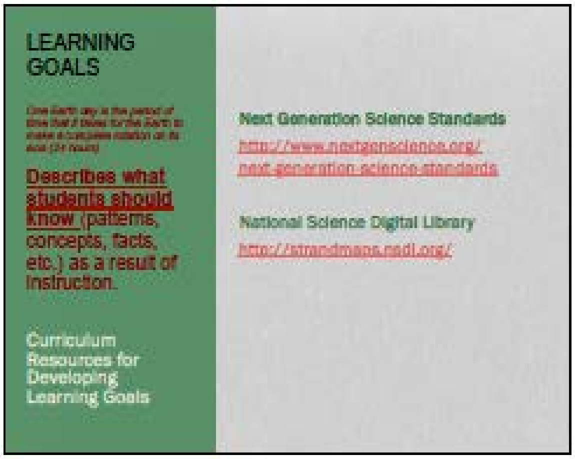

http://nsdl.org/
Science Literacy Maps
View the NSDL Science Literacy Maps

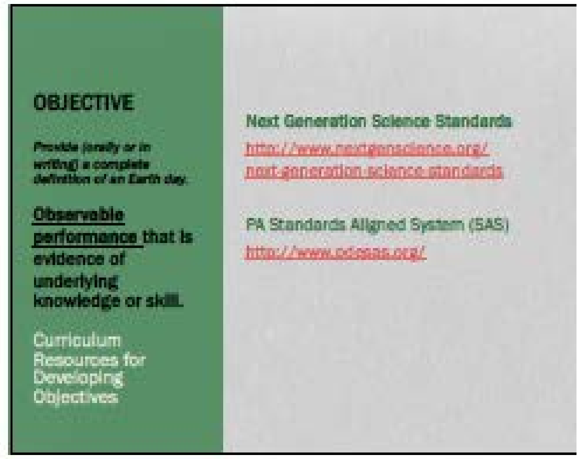

These maps come from the Atlas of Science Literacy, a publication of the AAAS Project 2061.
http://www.project2061.org/

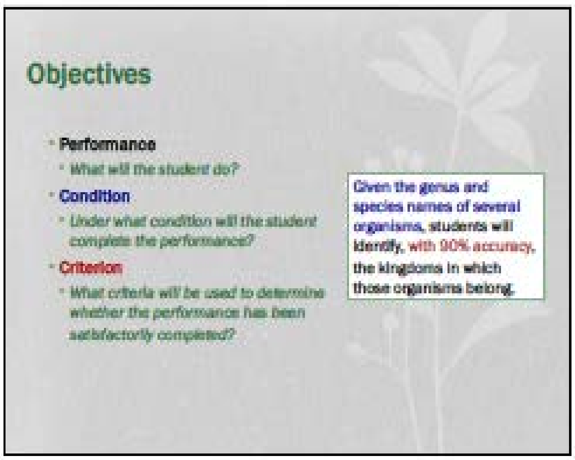

NSDL
Take some time to look at what information is provided here!
Information about student thinking – this can help with many aspects of your Lesson Plan . . .

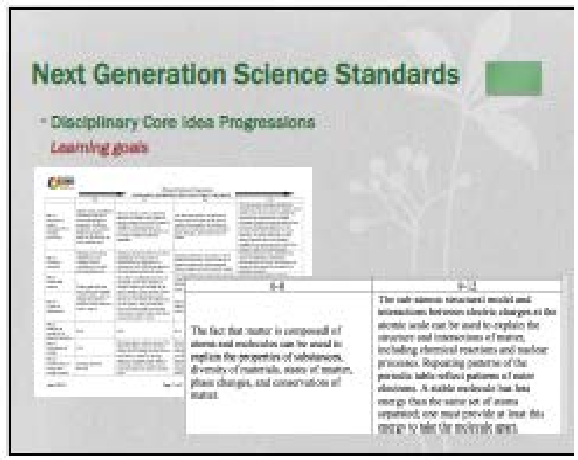

Take some time to look at what information is provided here!
Information about student thinking and how to assess it . . .

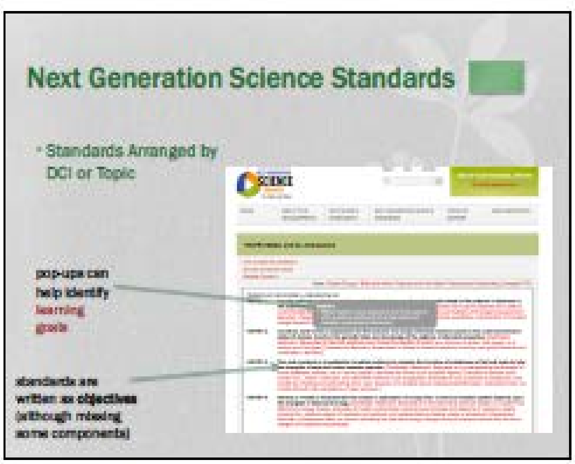

Big Ideas!
BIG IDEA
Describes a core concept in science.
Has the capacity to explain or connect multiple phenomena.
Can't be mastered in a single lesson.
PA Standards Aligned System
Curriculum Framework
Grade level (if middle school) or select a course (if high school)
Big Idea list shown at the bottom
SAS

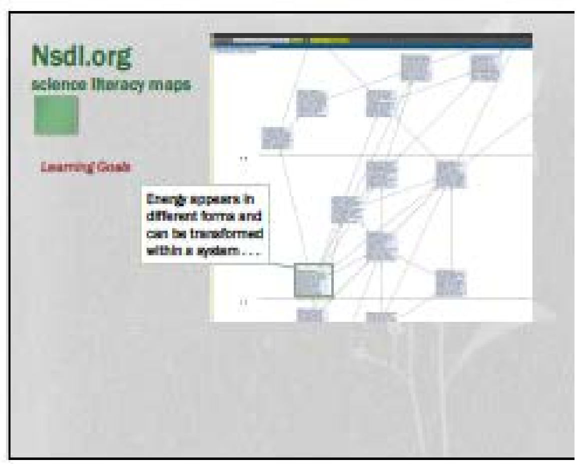

LEARNING GOALS
One Earth day is the period of time that it takes for the Earth to make a complete rotation on its axis (24 hours)
Describes what students should know (patterns, concepts, facts, etc.) as a result of instruction.
Curriculum Resources for Developing Learning Goals
Next Generation Science Standards
http://www.nextgenscience.org/next-generation-science-standards
National Science Digital Library
http://strandmaps.nsdl.org/

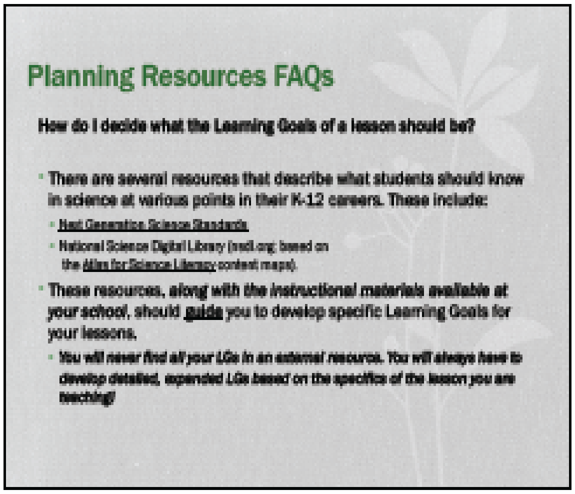

OBJECTIVE
Provide (orally or in writing) a complete definition of an Earth day.
Observable performance that is evidence of underlying knowledge or skill.
Curriculum Resources for Developing Objectives
Next Generation Science Standards
http://www.nextgenscience.org/next-generation-science-standards
PA Standards Aligned System (SAS)
http://www.pdesas.org/

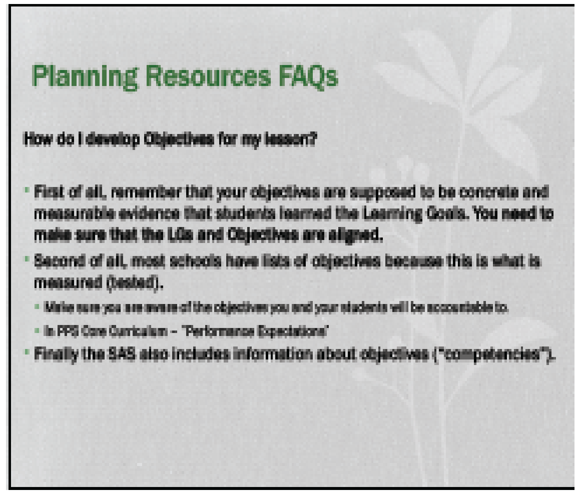

Objectives
Performance
What will the student do?
Condition
Under what condition will the student complete the performance?
Criterion
What criteria will be used to determine whether the performance has been satisfactorily completed?
Given the genus and species names of several organisms, students will identify, with 90% accuracy, the kingdoms in which those organisms belong.


Next Generation Science Standards
Disciplinary Core Idea Progressions
Learning goals
6-8
9-12


Next Generation Science Standards
Standards Arranged by DCI or Topic
pop-ups can help identify learning goals
standards are written as objectives (although missing some components)


Nsdl.org
science literacy maps
Learning Goals
Energy appears in different forms and can be transformed within a system . . .


Planning Resources FAQs
How do I decide what the Learning Goals of a lesson should be?
There are several resources that describe what students should know in science at various points in their K-12 careers. These include:
Next Generation Science Standards
National Science Digital Library (nsdl.org; based on the Atlas for Science Literacy content maps).
These resources, along with the instructional materials available at your school, should guide you to develop specific Learning Goals for your lessons.
You will never find all your LGs in an external resource. You will always have to develop detailed, expanded LGs based on the specifics of the lesson you are teaching!


Planning Resources FAQs
How do I develop Objectives for my lesson?
First of all, remember that your objectives are supposed to be concrete and measurable evidence that students learned the Learning Goals. You need to make sure that the LGs and Objectives are aligned.
Second of all, most schools have lists of objectives because this is what is measured (tested).
Make sure you are aware of the objectives you and your students will be accountable to.
In PPS Core Curriculum – "Performance Expectations"
Finally the SAS also includes information about objectives ("competencies").

Sample Lesson Plan

*Provided to PSTs after lesson planning discussion during Class 5 in order to prepare for the Revised Lesson Plan 1 Assignment.

Lesson Plan

Date: March 11, 2009 *Course/Section:* Biology-9 Block A *Topic:* Classification in Biology

Big Idea [*What is the overarching **Big disciplinary Idea** that this lesson is drawing upon or building toward?* See Core Ideas in the NGSS or Big Ideas on the PA SAS.]
Scientists often develop tools to identify and study patterns in the natural world. A taxonomic system is one such tool. Another is a system for classifying organisms. A third example is the periodic table (a tool for visualizing patterns in the physical features and behaviors of atoms).

Learning Goals [*What will students **know** at the end of this lesson?*]

1. Scientists classify (or group) living things because they want to be able to describe and ask questions about how they are related.
2. Different ways of categorizing or grouping objects or organisms allow scientists to notice different patterns and to answer different kinds of questions.
3. Early classification in Biology was based mostly on obvious features like body shape, size, whether something had feathers or hair, etc.
4. Modern Biologists have more powerful tools for studying organisms now and the most effective way of determining how living things are related is to look at the sequence of their DNA.

Objectives [*What will students **be able to do** at the end of the lesson? What they can do should be evidence that they know what you intended for them to learn . . .]*

1. Given a group of diverse objects, students will be able to organize them into categories that are mutually exclusive and hierarchical.
2. Students will be able to use their classification scheme to determine the appropriate place for new objects (e.g. a metal washer, a glass marble).
3. Working independently, students will be able explain why multiple classification schemes might exist (e.g. because they are developed with different purposes in mind and because they are developed by human beings).

Related Standards [*What **PA Standards** will you touch upon in this lesson?]*

S11.A.1.1 Analyze and explain the nature of science in the search for understanding the natural world.

Materials Needed [*What **materials** do you need for this lesson? Include things like representational tools (Powerpoint slides, etc.), handouts, manipulative, laboratory materials, etc.*]

For **each** student **group**:

1. One 2-gallon plastic zipper bag containing items for the sorting task
    a. markers, crayons, pencil colors, and tubes of paint in various colors
    b. paper of different texture, size, and color
    c. rulers (1 wood, 1 plastic)
    d. scissors (1 pair regular scissors, 1 pair with rounded ends)
    e. glue or glue stick
    f. beads and buttons (some metal, some wood, some plastic)
    g. thread
    h. bills and receipts
    i. spare change
    j. breath mints, gum, candy bars

2. A large tray for containing the items once removed from the baggie.
3. A dry erase board, markers, and eraser
4. Post-it notes
5. Index card with a "purpose" (different groups will have different "purposes")

For **each student**:

1. Science note sheet.
2. Exit slip

For the **teacher**:

1. Powerpoint slides.
2. Digital camera.

Safety Concerns [*What **safety issues** do you and students need to be aware of during this lesson? Include information about **how/when** you intend to let students know about these issues.*]

The main safety issues are:

- Students may want to eat the candy, mints, etc. During the activity launch, I will make sure to warn them that these materials are NOT HYGENIC as they have been handled by many students. They should NOT put anything in their mouths in any science class.
- Students should take care not to poke themselves or others with the scissors. I will instruct them to leave all objects on the tray at all times. They can move them from one area of the tray to another, but they should remain on the tray at all times. This should also alleviate the last safety concern . . .
- Students may drop small items like beads that could pose a slipping/tripping hazard. They will be instructed to pick up any dropped objects immediately.

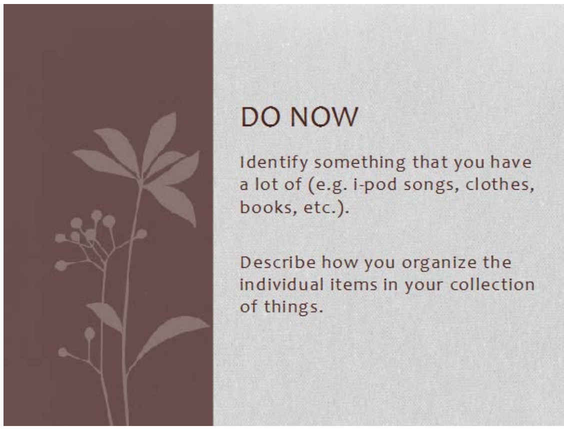
Set Up [*How will you have materials **set up** at the beginning of the lesson?*]

When students enter class, they know to take out their science notebooks and complete the ***Do Now*** prompt from the Powerpoint. I will have the Do Now slide projected when they enter the classroom.

I will also have the sorting materials (in 6 baggies, one per group) placed on the side table. Each baggie will be labeled with a group number (students are already in lab groups, so they know their numbers). The stack of trays will be on the side table near the baggies.

White boards, markers, and post-it notes are already at the group tables when students enter the room. (These materials are always on the tables.)

Lesson Opening *[How will you begin this lesson? Be specific about how you will activate relevant prior knowledge, connect to previous lessons, etc.]*



7 minutes

The Do Now slide will serve to open the lesson:

Once students have ~3 minutes to complete the Do Now, I will ask for volunteers to share their responses.

I expect students to talk about how they organize their clothes by season or by types (pants, sweaters, underwear, etc.); how they organize their music by artist or genre; and how they organize their books by size or use (school-related or pleasure reading, etc.).

I will solicit and make alternative categorization suggestions where necessary to prompt discussion.

After a few examples, I will ask, "Why do we organize things?"

I expect students to say things like "because my parents make me" and "because it makes it easier to find stuff we need."

I will then prompt, "We are going to complete a task today where we have to create a system to organize a pile of stuff. We all have the same piles of stuff, but our systems will probably be different."

Support of Lesson Activities

(1) LAUNCH *[How will you launch this activity? Be specific about what you will say to students, how you will let them know the* ***purpose*** *of the activity, what they are* ***expected*** *to do, how much time they'll have, etc. Be clear about how you will give them the necessary* ***directions and materials*** *to participate successfully in the activity.]*

5 minutes I will tell students:

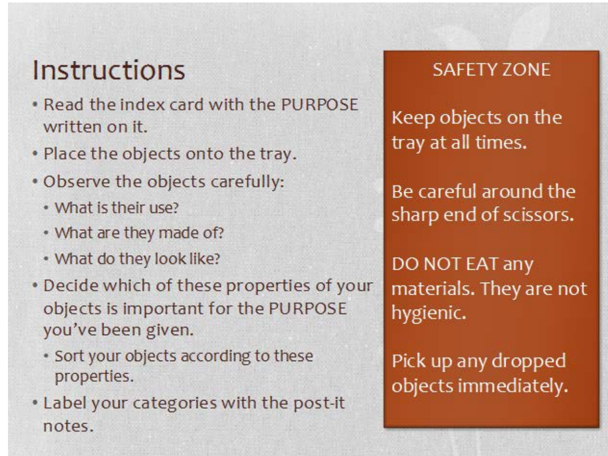
- Our first activity today is going to be a sorting task. We are doing this so we can practice the kind of thinking that goes into developing a system to sort things—this is what scientists have to do when they develop similar systems. Before we talk about how Biologists sort things, we're going to so some similar work ourselves.
- Every group is going to get a baggie of stuff and you'll have **15 minutes** to come to agreement with your group members about how to sort it.
- To figure out how you want to sort, you will have to do two things: (1) read your index card that has the PURPOSE written on it; and (2) make careful observations of your objects-pay attention to what they look like, what they're made of, what they're used for, etc.

- To sort your objects, move them around into piles on your tray.
- Use the post-it notes to label what the different groups mean or contain.
- You can use the white boards, too, if you want to add more information or draw a diagram.
- After 15 minutes we will have a class discussion.

Pause for questions.

- Okay, let's review our Safety Zone reminders. (I will call on volunteers to read these from the slide.)

- When I tell you to, I want the tallest student in your group to go to the side table and retrieve the baggie with your group's number on it and one tray.
- Begin working as soon as your group receives your materials. We are starting at (time) so you will have until (time) to complete this part of the activity.
- Okay, "go."



Throughout the launch, I will use Slide 2 as a guide and will leave it projected during the task as a visual reminder to students.

(2) WORK TIME [*How will you* ***support students' work and thinking*** *during the activity? What will you be doing and saying? What will students be doing and saying? How will you* ***help students connect their ideas to the specific learning goals*** *of the lesson?*]

group sort: 15 minutes
class discussion: 10 minutes
notes: 5 minutes

group sort

I will have 6 groups and three different PURPOSE cards. Therefore, there will be two groups working on each purpose.

As students work, I will circulate and ask them to explain the basis of their sorting systems. There are some features that I want to highlight:

Hierarchical ordering systems (nested categories)

If I don't see a hierarchical system, I will push at least one group to consider this. For example, I might see a group of students who are sorting materials for an elementary teacher. These students might put the markers, paints, pencils, and crayons together. I might ask, "Suppose you are teaching 7-year-olds. Would you want to store all these materials where students could access them independently? Would some of them require more supervision than others?" This question might prompt the students to consider that all these coloring materials might be in a big group, but that they might separate the group further by having pencils and crayons stored in an accessible location but having markers and paints stored in a location only the teacher can get to. (This is similar to what I expect will arise in our Do Now conversation:

Students might have their music organized by genre, but then within a genre they will also have categories for individual artists and the albums of individual artists will be listed alphabetically, etc.)

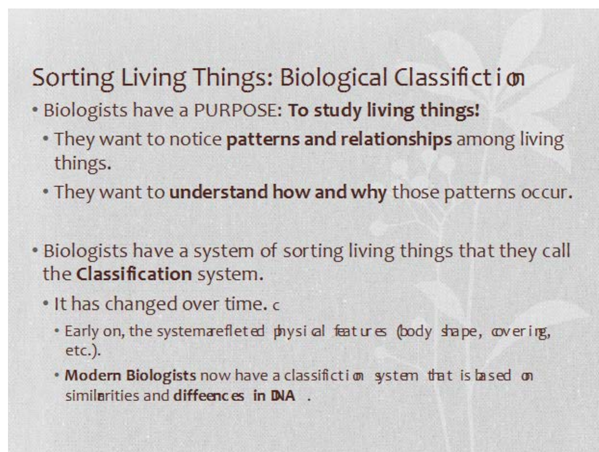
Mutually exclusive categories

If I see an item that seems like it might fit into more than one category, I will ask students about that. For example, students might have a category for red things and a category for wooden things. Which category would a red, wooden button go into? This is another way of helping them develop a hierarchical system. But it is also an opportunity to make explicit the idea that categories are only useful if they are definitive.

Categories should connect to the purpose

I do not expect to see identical sorting schemes across all 6 groups. One thing I will try to emphasize in my questioning is the way the categories are useful to the people who will be using them. For example, a moving company might want to know where objects are found in a house so they know how to pack them and label the boxes; or they might want to know which items are breakable so they know to pack them carefully. A teacher would want to keep track of materials that are used every day vs. those that are taken out only for special activities; a craft store owner would probably want to group materials according to their probability of being used together (e.g. string and beads would be in a similar location). I will ask questions about the NEEDS of the users of the sorting systems to help students realize these possible different ways of sorting.

class discussion



Because we have so little time (48 minutes), my students know that I will not call on every group to share during every activity. I keep track of student participation in my notes, so I know which students have had few opportunities to speak lately and which have had many. I will try to take this into account when drawing on examples from the activity during the class discussion.

I will begin by asking generally, "What did your group think about when you developed your sorting categories?"

I will solicit a few answers from the students, focusing on (or drawing out) the idea that they thought about both the objects and the needs of the users of the sorting scheme.

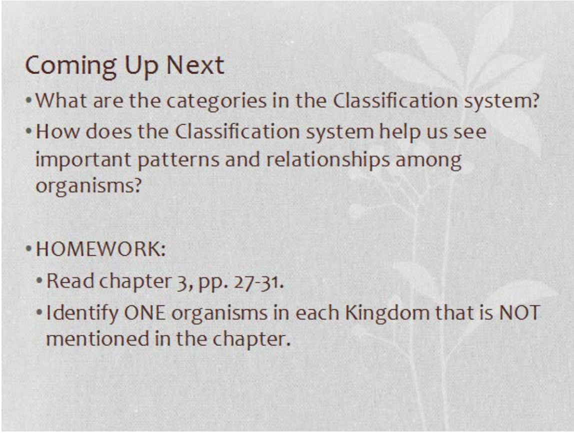
Then I will ask two groups who had the same purpose but different categories to compare/contrast their schemes. I might point out a few similarities and differences that are of interest to me. I will ask why they think these differences occurred. I will try to highlight the idea that people are complex and think in different ways and any time you have human beings doing things, you can expect some messiness. But if we took time to communicate and share our ideas, we might agree on one best way to approach the sorting.

Finally, I will highlight the differences across groups and connect this to the PURPOSE of the USERS.

To close this part of the lesson, I will hold up an item (e.g. metal washer or glass marble) and ask students to use their sorting system to place this item. This will serve as a quick check that students can use the sorting system and an opportunity to point out that when scientists discover new things, sometimes they "fit" into their systems and sometimes the systems need to be changed to accommodate the new organisms.

notes

I will use the Powerpoint slide to give students notes (these build on biology ideas we have covered in the first unit on the needs of living things--- but I am connecting these ideas about living things to categories/classification). Students record their notes in their science notebooks.



Lesson Close [*How will you close the lesson? How will you help students know what the **important "take away" ideas** were? How will you let them know what is **coming next**?*]

5 minutes

I will present slide 4, letting them know what we will study tomorrow and also their homework assignment (this is posted on the class website so I don't hand out copies of homework---students know to do this in their notebooks).

I will hand out copies of the exit slip and give students the remaining minutes to complete it. Students submit their exit slips by dropping them into the marked basket on my desk as they exit the classroom.

Assessment [*What will **students do and say** during the lesson (or after it) that will let you know that they did/didn't achieve the lesson **objectives**?*]

Objective	When Assessed	How Assessed
Students will be able to organize a group of diverse objects into categories that are mutually exclusive and hierarchical.	During the group sorting task.	I will notice the students' categories as I circulate during the small group activity. I will ask questions about the basis for their categories and the rationale for placing certain objects into various categories. I will be looking for students to acknowledge when categories are not exclusive and to propose solutions. I will be looking for students to propose ways to "nest" or organize categories to reflect a hierarchy.
Students will be able to use their classification scheme to determine the appropriate place for new objects (e.g. a metal washer, a glass marble).	During the whole class discussion following the sorting task.	I will quickly scan the room to see where the groups would place this new object (I will prompt them to point). This will give me a sense of how students can use their categories and whether they can recognize deficiencies in them.
Students will be able explain why multiple classification schemes might exist (e.g. because they are developed with different purposes in mind and because they are developed by human beings).	In the exit slip.	I expect students to mention at least two of the following: 1. Sometimes scientists find new information that doesn't fit with their old schemes and they need to change them. 2. Scientists are people and they will come up with different ways to think about problems. 3. Scientists might have different purposes for classification systems and so there might be more than one.

Resources

Index cards for sorting task

Purpose:

Your classification system needs to be used by a CRAFT STORE OWNER to help her set up her store shelves.

Purpose:

Your classification system needs to be used by an ELEMENTARY SCHOOL TEACHER to organize her new classroom.

Purpose:

Your classification system needs to be used by a MOVING COMPANY to pack a family's belongings and unpack them in their new house.

Exit Slip

Name: ____
March 11, 2009

Think about the sorting activity we did today and connect to the following question:

Why might scientists develop more than one Classification scheme to sort living things?

Your answer should be 2-3 sentences long.

TEACHING AND LEARNING II
FALL 2013

Teaching & Learning in Secondary Science II is a 4-credit course offered during weeks 3-16 of fall term (September 9 – December 13). The course is designed to help PSTs develop the capacity to design lessons that will enable secondary science students to learn core science ideas while engaging in disciplinary practices. The instructors focus on in-depth coverage of high-leverage practices, including —

- selecting or designing cognitively demanding tasks
- supporting classroom discourse through various talk strategies (e.g. revoicing, tossing, questioning, etc.)
- developing and/or selecting robust tools (e.g. representations) to support learner engagement
- utilizing the Five Practices Model to plan for and support student engagement in task-based discussions

PSTs have opportunities to design lessons and receive detailed feedback from course instructors. They also have opportunities to engage in micro-teaching episodes, practicing various teaching strategies with their peers acting as learners. Finally, PSTs collaborate with one another to provide feedback on lesson planning, enactment, and reflection during the last part of the term.

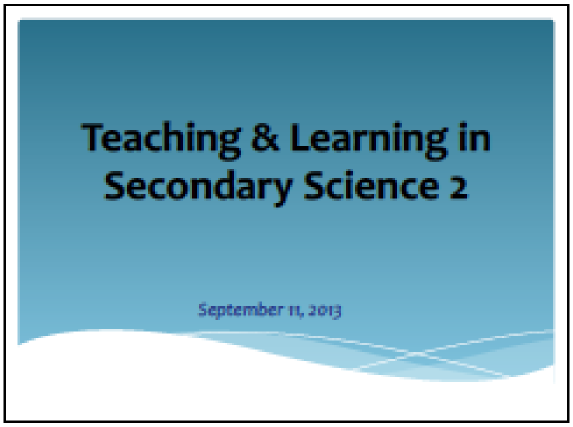
Class 1

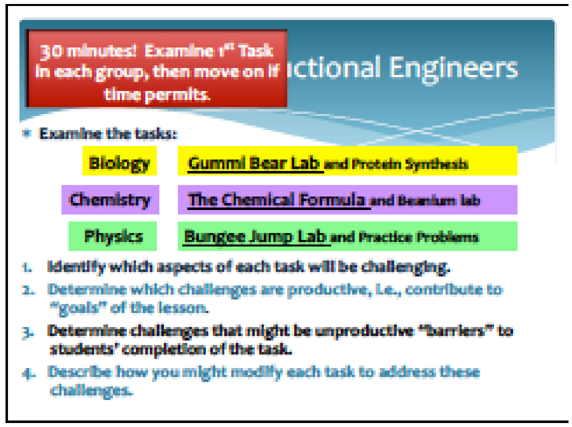
This first class of Teaching and Learning II involved three main parts: task selection, anatomy of a lesson, and micro-teaching episode. What follows is a description of each, including the instructional materials used during class.

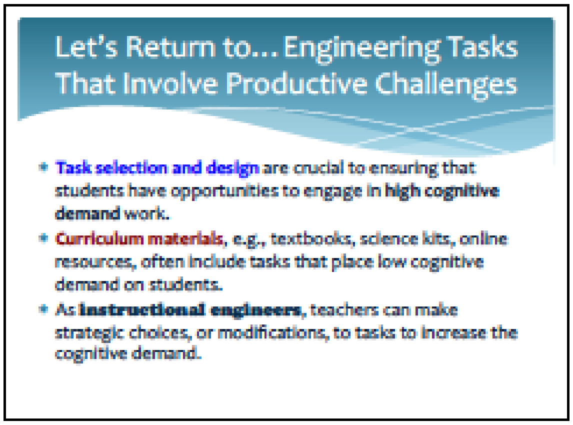
Part 1: Task Selection

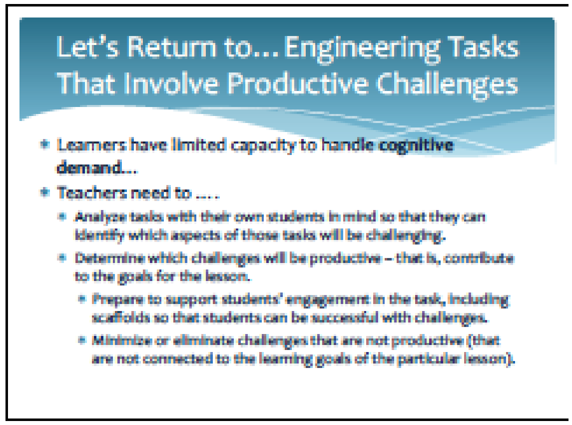
In preparation for class today, the PSTs read Chapter 1 of *5 Practices for Orchestrating Productive Science Discussions* (Cartier et al., 2013). This first part of Class 1 is a continuation of the concepts and ideas discussed surrounding high demand tasks in science in Teaching & Learning I. The instructors provide three science tasks (see below). The PSTs examine the tasks and determine the cognitively challenging parts, the unproductive barriers, and how they would modify each task. The main goals of this task are: (1) to provide the PSTs with an opportunity to engage in instructional engineering by modifying tasks; (2) to introduce the PSTs to scaffolding, maintaining demand, and unproductive barriers to task completion. What follows is a copy of the slides used in class as well as the example tasks.

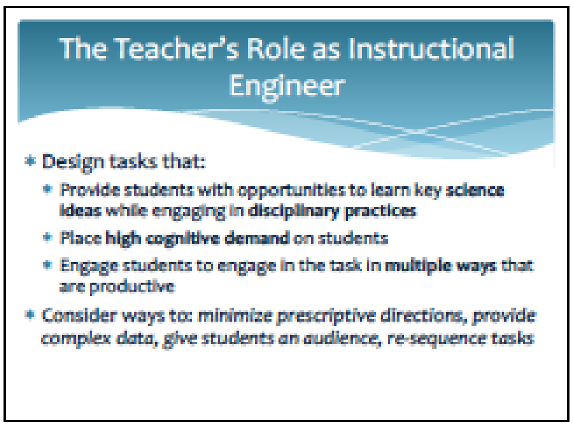
Task Selection Slides











Example Biology Task[7]

Gummy Bear Lab: Cell Transport

Today we will be investigating the transport of materials into and out of a "cell," which will be represented by a Gummy Bear! We will be placing Gummy Bears in different concentrations of salt, sugar, distilled water, and tap water solutions.

GOAL: You and your group members must accomplish the goal of **measuring the change between the gummy bear before and after it is placed in solution – it is up to you to decide the best way to measure this. You will then create a data chart representing your findings.**

(1) Pre-Lab Questions

- **What are Gummy Bears made of?**

- **When a Gummy Bear is placed in water, where do you think the water will go?**

- **If there is salt or sugar in the solution of water, how might this affect where the water goes?**

- **Define these terms:**
  - **Solute**
  - **Solvent**
  - **Solution**
  - **Concentration**
  - **Osmosis**
  - **Diffusion**

- **Fill in the blanks: Particles always move from an area of __________ concentration to an area of __________ concentration.**

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[7] Task from Kristin Germinario, Knowles Science Teaching Foundation Fellow

(2) Hypotheses (Written in an "if… then" statement). Create a hypothesis for each scenario, and identify the CONTROL(s) in the experiment by labeling then with CONTROL in capital letters in the chart below.

Gummy Bears in 100ml tap water:
Gummy Bears in 100ml distilled water:
Gummy Bears in 100ml tap water with 5 grams salt
Gummy Bears in 100ml tap water with 10 grams salt
Gummy Bears in 100ml tap water with 15 grams salt
Gummy Bears in 100ml tap water with 5g sugar
Gummy Bears in 100ml tap water with 10g sugar
Gummy Bears in 100ml tap water with 15g sugar

Materials (per lab group):

- 6 beakers
- 6 Gummy Bears
- tap water
- distilled water
- salt
- sugar
- stir rod
- ruler
- balance
- measuring spoon
- wax pencil

Procedure:

1. Obtain all materials.
2. Label all beakers with solution, your names, and your period.
3. Measure your bears (use data tables; use the **metric system**).
4. Prepare solutions in beakers and add bears (one in each solution). Let the bears sit overnight.
5. One or two days later, **carefully** remove bears and measure (use data tables).

Data Collection:

For your data, use percent change to calculate the change in the bears for whichever measurements you choose to use. To calculate percent change:

$$\frac{\text{After} - \text{Before}}{\text{Before}} \times 100 = \%\ \text{change}$$

Data Tables: Create your data tables in the space below to record your data for each type of solution used. Make one data table for each beaker's results.

Analysis:

I. Graphs: Determine how your group will most effectively graphically represent your data so that your classmates can interpret it. Create your graph on poster paper in class.

II. Question:

1) Did the tap water gummy bear differ from the gummy bear placed in distilled water? What is present in tap water that may have affected these results? Write your response below.

III. Conclusion:

In 1 to 2 paragraphs, explain how this lab allowed you to demonstrate **osmosis,** and make sure to reference your results in your explanation. Write your response below.

Chemistry Task[8]

2B: The Chemical Formula

What is a chemical formula, and how is it used?

Paper, glass, plastic, metal, skin, leaves, etc. are all matter. Although different substances are made of different combinations of elements, there are only 92 elements on Earth from which all substances are made. In fact, only six elements make up almost everything around us. How does such incredible variety come from only a few elements? Compare elements to letters in the alphabet. How do so many words come from only 26 letters? The answer for matter is very similar, and the chemical formula is how we "spell" all the different kinds of matter with the same few elements.

Materials
- Molecular model kit
- Calculator
- Periodic table

Part 1: Setting up your model

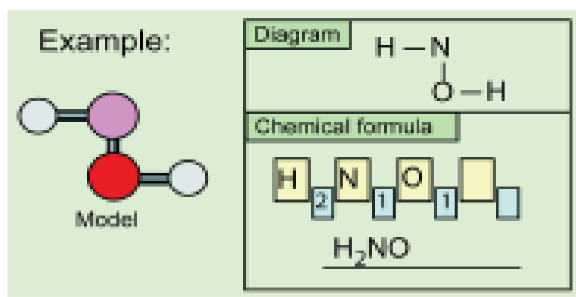
Look at the molecular model kit. Assign colors to the different atoms, and write them down in the table on the right. Make sure you have at least the following four: carbon, oxygen, hydrogen, and nitrogen.

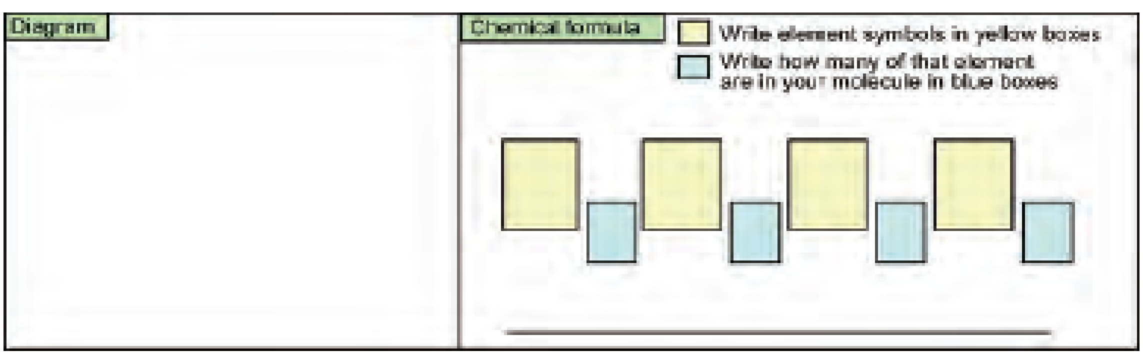
One color in particular should be assigned to a specific element. Which one and why?

Color	Element
black	
red	
white	
green	
yellow	
blue	
purple	

Part 2: Making some models and "spelling" them

1. Pick any four atoms. Use the plastic bonds to connect them.
2. Draw the molecule you have made in the diagram below.
3. Use the yellow and blue boxes to work out the chemical formula for your molecule.
4. Write the completed formula on the line.

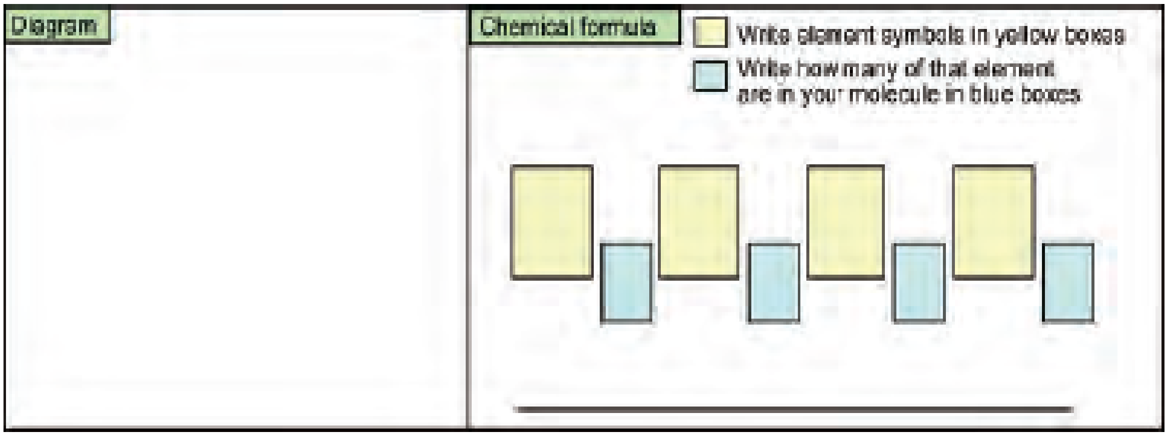




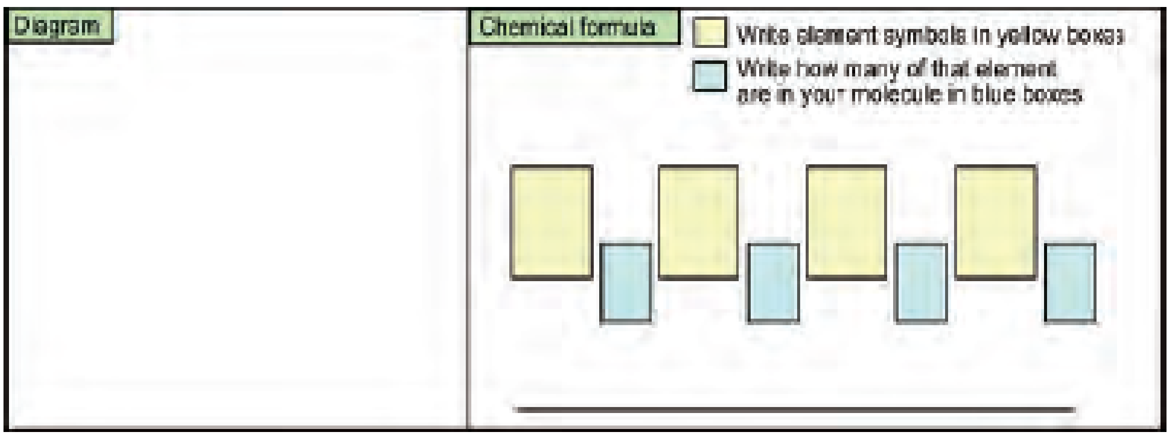
[8] Task from *A Natural Approach to Chemistry* by Hsu, Chaniotakis, & Damelin (1998) Reprinted with permission from LAB-AIDS, Inc.

Part 3: Bigger molecules

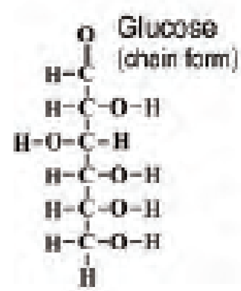
1. Using six atoms, build a molecule with two pairs. A pair is two of the same atom.



2. Using six atoms, build a molecule that has three of the same type of atom



Part 4: Reflecting on what you learned



a. How many atoms in total are there in a glucose molecule?

b. Write the chemical formula for glucose.

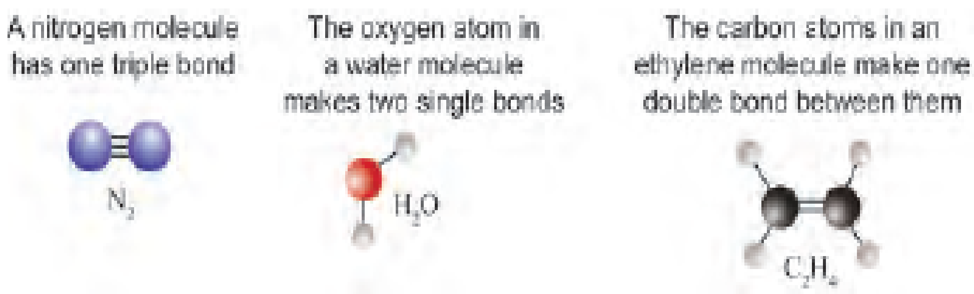
c. Methane has the chemical formula CH_4. Draw a possible chemical diagram for a methane molecule. (Hint: Carbon makes four bonds with other atoms.)

d. Write a chemical formula for a molecule that has four hydrogen atoms, two carbon atoms, and two oxygen atoms.

Part 5: Rules for bonding atoms

In most situations, elements tend to form a specific number of bonds when they make molecules. For example, each carbon atom needs to make four bonds, a nitrogen atom needs to make three, and an oxygen atom needs to make two. This is one of the most important ways the elements are different from each other. They are different *because* they form different numbers of bonds with other elements.

Molecules can have single bonds, double bonds, and even triple bonds! Here are some examples of each.



Let's reassign the colors and set up the rules for bonding a few elements

		Element	Number of bonds
	black	carbon	4
	red	oxygen	2
	white	hydrogen	1
	green	chlorine	1
	yellow	sulfur	2
	blue	ritrogen	3
	purple	sodium	1

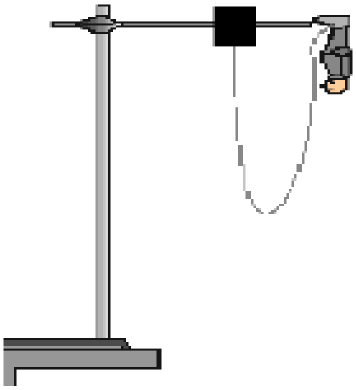
1. Build one possible structure for each of the following molecules. Make sure you follow the rules for how many bonds connect each atom.
2. Draw a possible structural diagram for each molecule you build. There may be many possible structures for each molecule.
3. Leave the "formula mass" lines blank until the next step.

NH_3 **Formula mass** ____________	Diagram
CO_2 **Formula mass** ____________	Diagram

Physics Task[9]

Bungee Jump Lab

Setup: The bungee jumper has a string with a rubber band attached to it. For the first jump hook the string to the force sensor. For the second ju hook the rubber band to the force sensor. (For both jumps be sure that someone holds the base of the stand.)



LabQuest Setup:

1. Turn on the LabQuest screen and click on the graph icon.
2. Tap **Graph**, then **Graph Options**
3. Set: **Left**: 0 **Right**: 1.5
   Top: 15 **Bottom**: 0 (click ok)
4. Use triangle button on the right side to start the sensor for jumps.

Jump #1

1. Hook the string loop to the force sensor,
2. Release the jumper and hit the triangle button at the same time. (Hold the base of the stand.)
3. Copy the first curve of the graph on your lab sheet.

Jump #2

1. Hook the rubber band loop to the force sensor,
2. Release the jumper and hit the triangle button at the same time. (Hold the base of the stand.)
3. Copy the first curve of the graph on your lab sheet.

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[9] Adapted from http://www2.vernier.com/sample_labs/PWV-07-LABQ-bungee_jump.pdf

Bungee Jump Lab

Jump #1

Jump #2

Describe the shape of each graph.

Jump #1
What is the Force (max) and time (range of curve)?

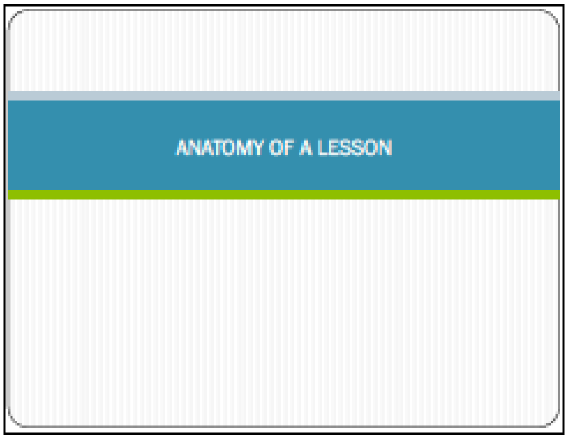
Jump #2
What is the Force (max) and time (range of curve)?

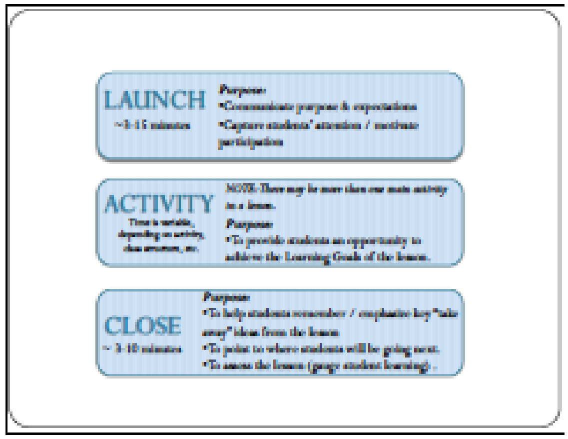
Explain why the two jumps were different.

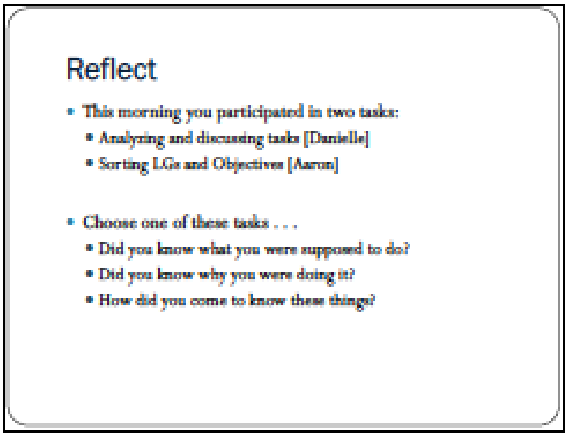
Part 2: Anatomy of a Lesson and Micro-teaching Episode - **Launch**

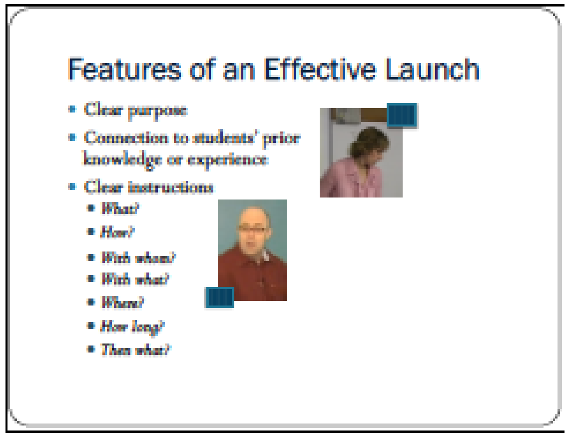
Part 2 of Class 1 provided PSTs with an opportunity to examine representations of a "good" and "bad" launch by analyzing videos of expert teachers. After this analysis, PSTs learned about the different parts of a lesson: launch, activity, and close. Finally, the PSTs participated in a role-play micro-teaching episode in which they each had the opportunity to practice a launch in front of their peers. Following this practice, a culminating discussion identified the characteristics of a good launch.

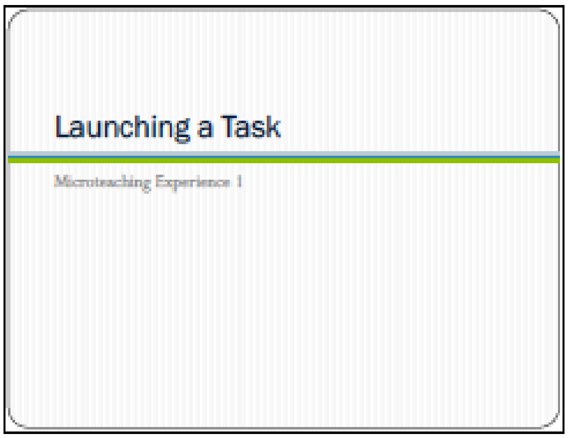
Anatomy of a Lesson Slides

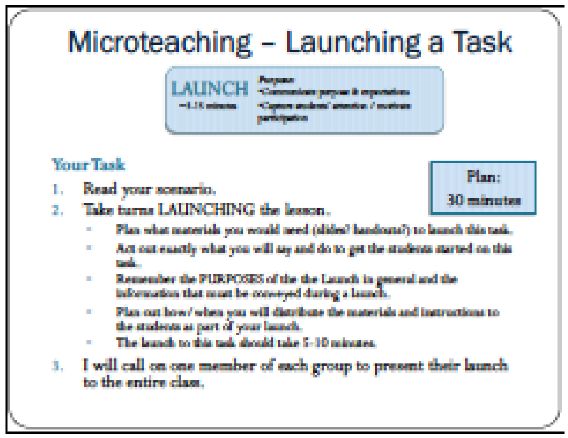












<u>Class 3</u>

<u>Anticipating & Getting Ready to Monitor</u>

In preparation for Class 3, the PSTs read Chapters 2 and 3 of *5 Practices for Orchestrating Productive Science Discussions* (Cartier et al., 2013). After some direct instruction and review of the Five Practices model, the PSTs approximate the practice of anticipating using the Frog Task. During this time, PSTs anticipate the various ways students might approach the task, stumbling blocks, and unproductive barriers they would want to minimize.

Following a discussion of their anticipations on the frog task, the instructors model representations of monitoring using the Kinetic Molecular Theory of Water Task in order to provide the PSTs with an understanding of what it means to elicit students' thinking through questioning versus tutoring. The instructors then provide the PSTs with the "Orchestrating a Discussion Guide" (see below), which they will use for the remainder of the Five Practices role-play, which focuses on the Kinetic Molecular Theory of Water. Next, each group of PSTs acting as students during the role play are provided with their "Student Models with Student Thinking" in order to prepare for their student roles. Using the monitoring tool and student models provided, the PSTs prepare for their role at teachers by planning questions they will ask the student groups during their monitoring micro-practice episode. Finally, each pair of PSTs take turns playing the role of teacher and monitors students using their monitoring tool and ask the questions they planned with the goal of eliciting the student thinking behind the models (see below) in order to prepare for the discussion during the next class. For the next class, each pair of PSTs plans for their KMT discussion using the selecting, sequencing, and connecting guide in their "Orchestrating a Discussion" packets.

Class 3 Slides

ORCHESTRATING PRODUCTIVE DISCUSSION IN A SCIENCE CLASSROOM

TEACHING & LEARNING IN SECONDARY SCIENCE 2
SEPTEMBER 25, 2013

AGENDA

MORNING SESSION (8-11)

- Feedback on Representational Tools
- Orchestrating Productive Discussion in a Science Classroom
- Overview
  - "Productive" Discussion
  - The Five Practices Model
    - Is this "learner-centered?"
- A Deeper Look
  - Anticipating

AFTERNOON SESSION (2-4)

- Monitoring (and Eliciting)

EVENING SESSION (4:30-7:00)

- Practicing
  - Monitor during the KMT activity

REPRESENTATIONAL TOOLS

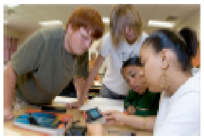
Very interesting set of tools that were selected:

- Make sure you think very hard about how students will actually interact with these tools and what work this does towards your LG and objectives.
- Remember to consider the distractions that can be associated with some tools

Some resources to consider:

- Phet - http://phet.colorado.edu/
- Wise - http://wise.berkeley.edu/webapp/pages/teacher-tools.html
- Khan - http://www.khanacademy.org/

PRODUCTIVE CLASSROOM TALK



[turn & talk – 3 minutes]

If you entered a classroom where "productive talk" was taking place, what would you notice and hear?

Discussion is —

focused upon and directed by students' ideas.

explicitly connecting to disciplinary concepts and/or skills.

THE FIVE PRACTICES MODEL

Originally developed in mathematics (Smith and Stein, 2011).

- SET LEARNING GOALS
- SELECT/DESIGN TASK
  - Students produce artifacts that reveal their thinking and can be made public
  - Task places high cognitive demand on students
  - Multiple approaches, interpretations, or solutions are possible
  - Students often work in pairs or collaborative groups

THE FIVE PRACTICES MODEL

1. ANTICIPATE student ideas related to the task and potential ways students might solve or engage with the task
2. MONITOR students' thinking and work during the task
3. SELECT examples of student work to use in whole class discussion
4. SEQUENCE the order in which you want to discuss the student work examples
5. CONNECT plan questions that will elicit key ideas and support connections between ideas and to key disciplinary concepts

HOW DO THE FIVE PRACTICES FIT IN WITH DAILY ACTIVITY STRUCTURES?

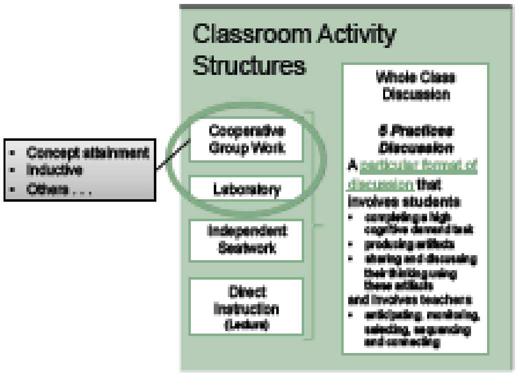
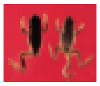


TABLE TALK . . .

Is orchestrated discussion (using the five practices model) consistent with <u>student-centered</u> practice?

- Consider the role that students and teachers play in this type of discussion.
- Consider the learning goals – the "destination" of the discussion – and how the class arrives at that destination.
- *Use excerpts from the cases of Kelly Davis and Nathan Gates to support your assertions.*

5P - ANTICIPATING



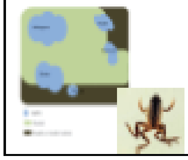
Context:

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

LGs

Scientists use various mathematical processes and representational tools to notice patterns in data and to share their results with others.

Scientists must provide evidence to support the claims that they make.

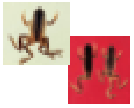


OBJECTIVES

Working in collaborative groups, students will be able to use appropriate mathematical tools (e.g. calculating mean) and representational strategies to identify and show patterns in data.

During the whole-class discussion, students will provide and/or request appropriate evidence to support claims.

THE FROG TASK



Which of the two hypotheses do you support?

What specific data support your conclusion?

Be prepared to convince your peers of your claims. *Include some representation of data in your presentation.*

YOUR TASK – ANTICIPATE!

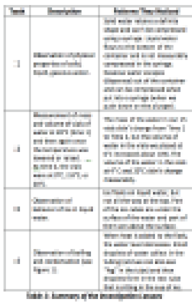
- **Anticipate students' engagement with the problem—beyond "misconceptions" to a view of how students would engage with the whole problem . . .**
  - What are the various ways you can imagine a student responding to this task (What would he/she represent? Which hypothesis would he/she support? What evidence would he/she use to do this?)?
  - What would students first notice?
  - What would they fail to pay attention to?
  - What prior knowledge or experiences would serve as a lens for them to notice things and/or make sense of them?
  - What assumptions would they make?
  - What would a frustrated or disengaged student do (Is there an "easy way out" of this task)?

5P - MONITORING

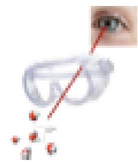
An example . . .

First we need to set the stage . . .

THE CONTEXT



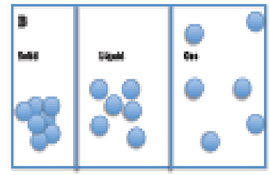
Using your magic science goggles, look at the particles that make up the water and draw what you see. What are they like and how are they behaving? How does this enable you to explain the patterns we saw?



5P - MONITORING

FISHBOWL

Two instructors will be students in this scenario. They have produced "model B" – pictured on the right – in response to the task.



Danielle will be the teacher.

Pay close attention to the way in which the teacher and students interact in these two instances of "monitoring."

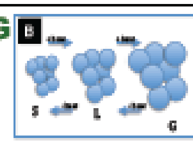
MONITORING

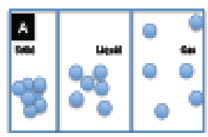
Read:
Chapter 7 Five Practices
pp. 117-119 (Lesson 3)

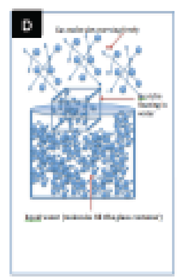
TUTOR	ELICITOR
Goal is to ensure that the students reached the target answer	Goal is to understand students' thinking
Focus on stumbling blocks, misconceptions, what was missing	Focus on building blocks
Spends considerable time with one or two groups, ignoring others	Moves efficiently from group to group
Minimizes cognitive demand of task through direct instruction	Maintains cognitive demand of task through redirection

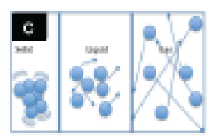
MONITORING

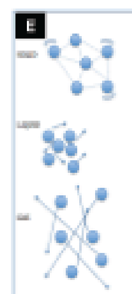
Design a monitoring tool that you might use during KMT task.











Consider how this tool would help you to notice important features of these (and other) models.

MONITOR

Consider the models that students produced (A – E).

What questions might you want to ask to elicit their thinking?

What questions might you ask to enable them to make progress during the task?

TOOLS AVAILABLE

- Summary of data table.
- Marbles (magnetic and non magnetic)
- White boards and markers.

PRACTICE!

MONITOR & ELICIT

"Teachers"

Each teacher pair will have 15 minutes to circulate to the different groups and monitor.

Stay together – move from group to group as a unit.

Use your monitoring tool.

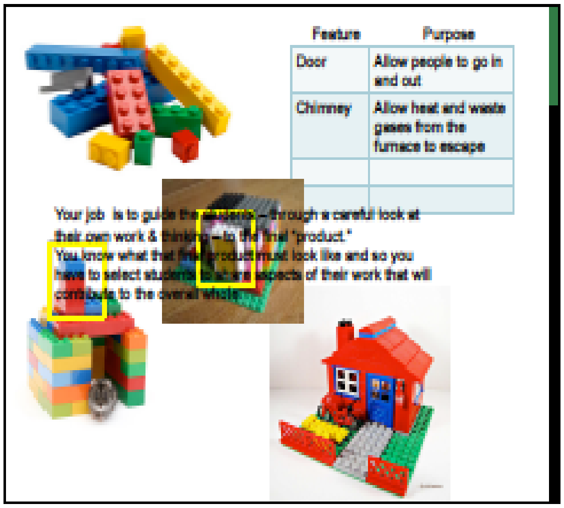
Remember to keep track/take notes as you circulate.

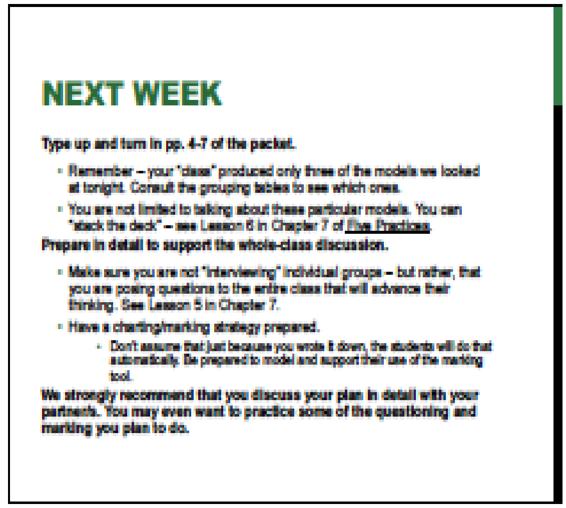
"Students"

When the teachers come to your group, do your best to represent the thinking of the students who constructed your model.

It is okay to respond (to "learn") based on what the teachers say when they are in your groups. But try to start off with the thinking that is represented in your role-play card.

Avoid "misbehavior" – remain on task!


Feature
Purpose
Door
Allow people to go in and out
Chimney
Allow heat and waste gases from the furnace to escape
Your job is to guide the ... through a careful look at
their own work & ... "product."
You know what that ... must look like and so you
have to select students ... aspects of their work that will
... to the overall whole.


NEXT WEEK
Type up and turn in pp. 4-7 of the packet.
Remember – your "class" produced only three of the models we looked at tonight. Consult the grouping tables to see which ones.
You are not limited to talking about these particular models. You can "stack the deck" – see Lesson 6 in Chapter 7 of Five Practices.
Prepare in detail to support the whole-class discussion.
Make sure you are not "interviewing" individual groups – but rather, that you are posing questions to the entire class that will advance their thinking. See Lesson 5 in Chapter 7.
Have a charting/marking strategy prepared.
Don't assume that just because you wrote it down, the students will do that automatically. Be prepared to model and support their use of the marking tool.
We strongly recommend that you discuss your plan in detail with your partners. You may even want to practice some of the questioning and marking you plan to do.

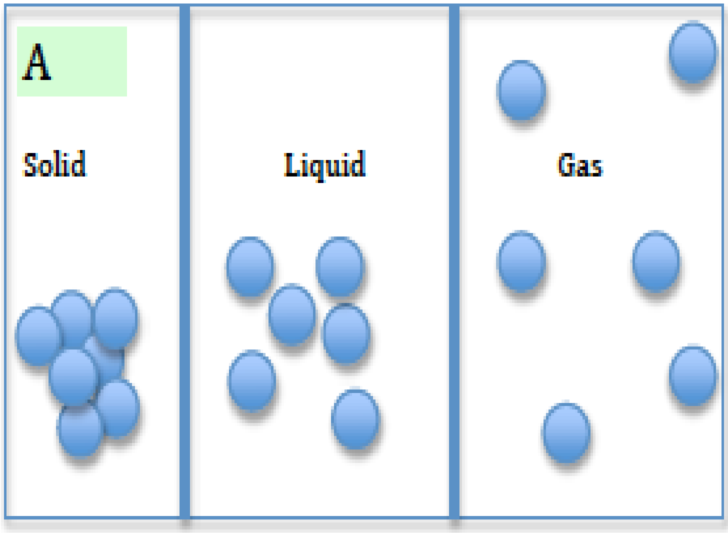
Prepared Student Models with Examples of Student Thinking

What Group A said about their model—

Our model shows how solids are packed together and liquids are not as packed. But the gases are spaced out more.

We were thinking about how the gas in the plunger—the syringe thing—was able to be compressed. We put it in there and squeezed and the plunger went down. So we think that's because the molecules have all this space or air between them and when you compress them they are moving closer together. But like a solid you can't push them closer together because they're already as close as possible. That's why solids keep their shape — you can't move the molecules around.

We really weren't sure about the liquid molecules. We couldn't compress them — or compress the liquid in the syringe. But we think they're not stuck together like in a solid.



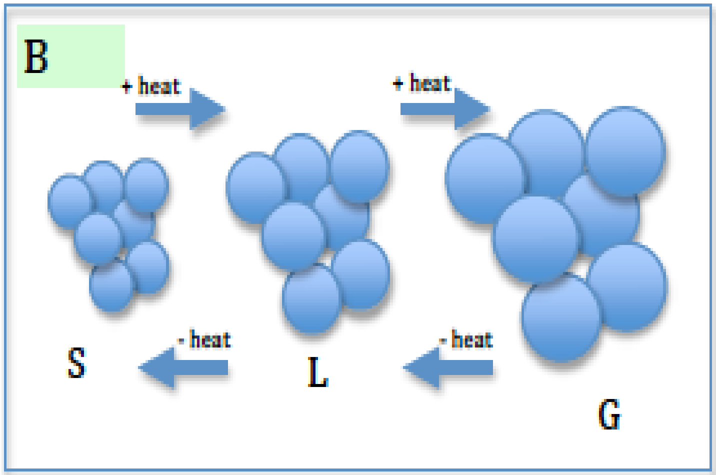
What Group B said about their model—

We showed like the melting and freezing and stuff. So it's melting when it goes from solid to liquid. And it's freezing when it goes from liquid to solid. And when it freezes you take away heat. But when add heat, like when it goes from liquid to gas, you add heat and that is when it boils.

And we also showed how the molecules of water take up more space when they get hot.

That's like when metal expands when it is heated. I think that's why you put jars under hot water when you can't get the lids off. 'Cuz that makes the metal in the lid spread out or loosen up.

So when we did our experiment we said that the gas expanded. And that's what we showed. That when you add heat, it expands.

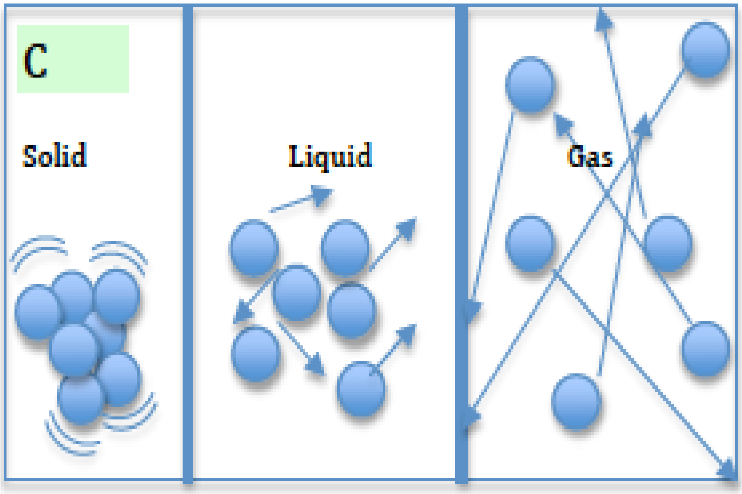


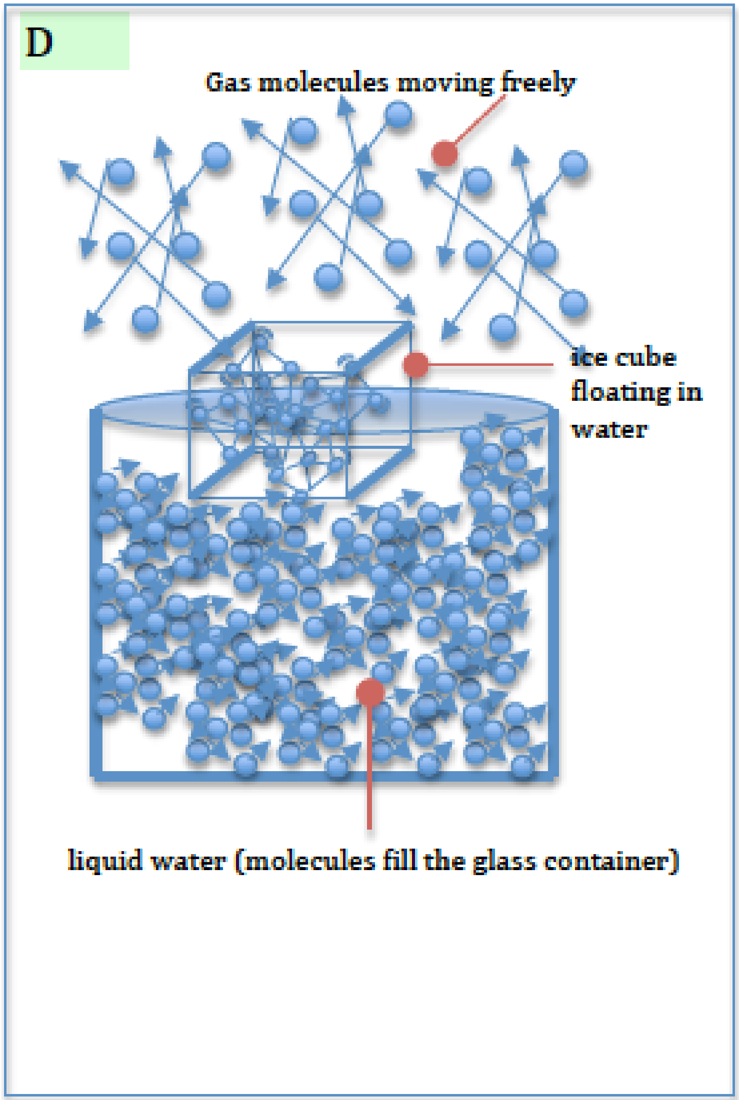
What Group C said about their model—

They're always moving. We showed that they were moving in the solid, but not a lot, that's why there are just little squiggles. And then in the liquid they move more and in the gas they move a lot. That's why there are long arrows.

And that explains why the solid is hard and has a shape but the gas is all over the place and doesn't have any real shape. Like we saw in the experiment.

Plus we saw that you could squeeze the gas in the thing, like when you put pressure on it, and get it to be smaller. Like the plunger thing went down. But we couldn't do that with the solid and the liquid. Couldn't get them to take up less space. And that's because the gas molecules are far apart so you can push them closer together with the plunger.





What Group D said about their model—

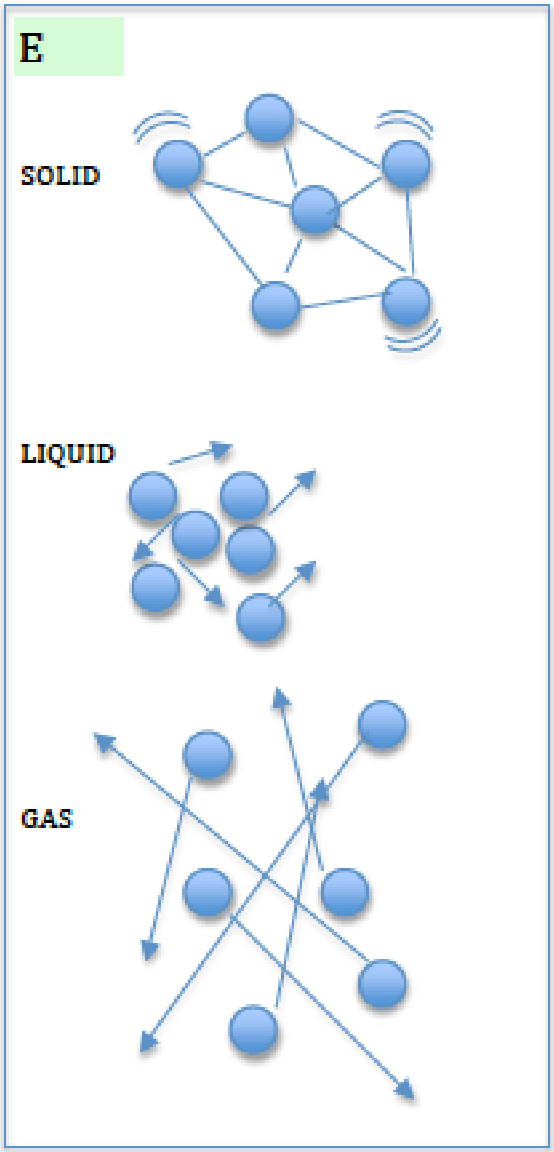
Okay, so at first we drew a whole different thing. We had the solid molecules all packed together and the gas ones spread out. And we had water in between. But then [student name] said that didn't make sense because we saw how the water expanded when it froze. It took up more space.

So we figured that the molecules have to spread out and push away from each other. That's what we showed with the dotted lines here.

But we have no real idea about why they do that. We just think it makes sense with what we saw.

And we showed how ice would float this way because it's going to not be as dense as the water because there are less molecules.

Oh, and our arrows are showing how the molecules are moving around. They're all moving, but not the same.



What Group E said about their model—

Our model shows that the molecules in water change how they move in each state. In the solid state, water molecules are vibrating. In the liquid state, they are moving a little more, but not as much as in the gas state.

This model helps us explain why gases don't have a definite volume and take up so much space. They move randomly and a lot. But liquids are moving only a little bit and so they just take up the space of the container they're in. In a solid, the molecules only move by vibrating. Plus in the solid state they are held together by some kind of bond or force. This is what makes the solid stay together so strongly.

Our model also shows how the solid takes up more space than the liquid. This is because the bonds actually push the molecules apart further. This is like when you take two magnets and hold them near each other. If you hold them so that the north ends are near each other, you get repulsion. That's what is happening in the bonds here.

ORCHESTRATE A DISCUSSION USING THE "FIVE PRACTICES[1]"

PLANNING

Scenario:
You are teaching an integrated science course to 8th graders. The students have completed several lessons, all part of a unit on Kinetic Molecular Theory.

In the days leading up to this lesson, students participated in 4 experimental hands-on tasks:

Task	Description	Patterns They Noticed
1	Observation of physical properties of solid, liquid, gaseous water.	Solid water retains a definite shape and can't be compressed using a syringe. Liquid water flows to the bottom of the container and is not measurably compressed in the syringe. Gaseous water escapes (disperses) out of the container and can be compressed when put into a syringe (when we push down on the plunger).
2	Measurement of mass and volume of vials of water at 20°C (time 1) and then again once the temperature was lowered or raised . . . At time 2, the vials were at 0°C, 2.8°C, or 20°C.	The mass of the water in our 15 vials didn't change from Time 1 to Time 2, but the volume of water in the vials we placed at 0°C increased about 10%. The volume of the water in the vials at 4° C and 20°C didn't change measurably.
3	Observation of behavior of ice in liquid water.	Ice floats on liquid water, but not all the way at the top. Part of the ice cubes are under the surface of the water and part of them are above the surface.
4	Observation of boiling and condensation (see Figure 1).	When heat is added to the flask, the water level decreases. Small droplets of water collect in the tubing (and we can also see "fog" in the tube) and then

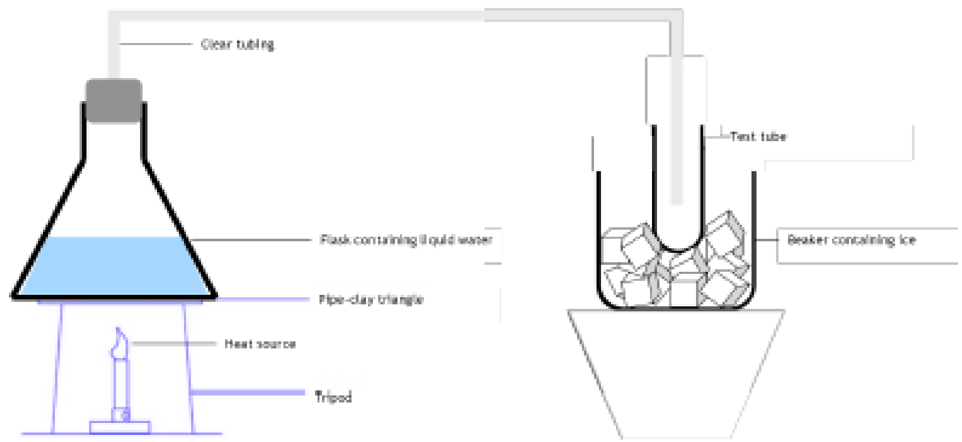


Figure 1: Experiment 4

1

		droplets form in the test tube that is sitting in the cup of ice.

Table 1: Summary of the Investigation Lessons

Following the investigation lessons, you summarized the patterns (using a table similar to the one on page 1) with the students and then put them into groups. You gave them the following instructions:

Imagine that you have a pair of Magic Science Glasses[2]*. You put on your Magic Science Glasses and you look at the glass of water. But instead of the water, you see the pieces that make up the water, the particles.*

I want you to put on your Magic Science Glasses and "look" at the solid, liquid, and gaseous water that we've been experimenting with. I want you to use what you see about how these particles are behaving and what they look like to explain all those patterns that we noticed while we were investigating.

Keep our patterns table in mind as you do this task.

In your groups, you are going to DRAW what you see when you put your Magic Science Glasses on. Use the white boards to do this. I'll give you 20 minutes and then we are going to share our ideas and see if we can come up with one model that explains all of what we saw.

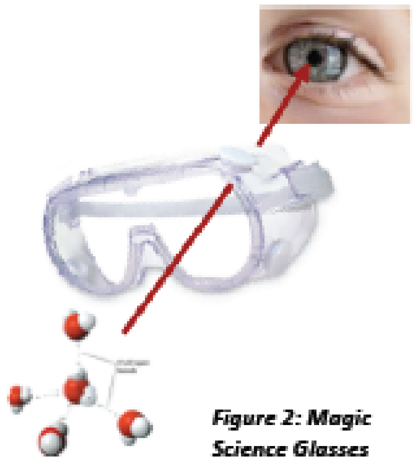


Figure 2: Magic Science Glasses

The students work in 5 different groups (3 students per group). Collectively, the students produce 3 *different* models (attached to this handout).

Your Planning Task:

Imagine that students drew their models and then the class ended. You now have a set of student models in front of you and you're preparing for class tomorrow.

Your task is to **prepare to support the discussion that will take place during the next lesson** – the purpose of this next lesson is to develop a consensus (and canonical) explanation of the molecular nature and behavior of water than can account for the observed patterns.

You will do this preparation work by following the FIVE PRACTICES that we read about in the 5 Practices book.

NOTE: You will need to make use of the specific **Learning Goals** and **Common Misconceptions** related to this lesson (see Tables 2 & 3) to do this planning work.

[2] Matter & Molecules curriculum. ©1998, Institute for Research on Teaching, College of Education, Michigan State University

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

Table 2: Learning Goals

COMMON STUMBLING BLOCKS
B1: Molecules in a solid are not moving at all.
B2: The observable properties of states of matter are attributed to individual particles. (e.g. solid molecules are rigid; liquid molecules are squishy; liquid molecules expand to form gas molecules, etc.)
B3: The molecules in liquid water are farther apart on average than the molecules in solid water.

Table 3: Common Misconceptions

PLANNING STEP 1: You need to **MONITOR**. In other words, you need to *notice* which of the important ideas (both correct and incorrect) are evident in each model. You can use the table below to record what you notice or you can use a monitoring tool of your own design. Please be sure that your tool clearly captures the target LGs and potential misconceptions that are apparent in each model.

TABLE 4

STUDENT MODEL	**IDEAS** **LGs or misconceptions evident in the Student Model (visually evident and/or evident through monitoring 9/25/13)** **[use the LG and M numerical designations from Tables 2 & 3 to indicate what you've noticed in each student model]**

PLANNING STEP 2: Based on which ideas may be accessed through discussion of the different models (what you've noticed and recorded in your monitoring tool), choose which group you will ask to present their model first, who will go next, etc. In other words, **SELECT and SEQUENCE** the students' models in preparation for the discussion. List the models (in order) that you will have the students present during the class discussion. (You do not need to use all three models. Also, you are not limited to these models – read Lesson 5 in Chapter 7 of the Five Practices book about "stacking the deck" and consider whether you wish to introduce any additional models during the discussion.)

________ ________ ________

Provide a brief **rationale** for why you chose the models you did and why you intend to discuss them in the order you specified.

PLANNING STEP 3: Plan specific questions you[3] will ask each group to **CONNECT** across models. You questions should (1) draw out the important LGs and Misconceptions you want to talk about with each model; and (2) help students make connections from model to model and across the entire group of models. Plan how you will orchestrate the discussion such that the key LGs surface.

Be sure to refer to the examples of marking/charting from the Five Practices book and consult the rubric (pg. 9) for specific types of questions and talk moves that we expect you to use during the discussion. Also consult Chapter 7, lesson 4 – plan ways to engage the whole class in the discussion and avoid having one-on-one interviews with presenters!

TABLE 5

STUDENT MODEL	**STUDENT IDEAS** you want to draw out & emphasize	**QUESTIONS YOU WOULD ASK** Include specific questions about individual models as well as comparison questions. Include specific statements or questions you plan to make in order to transition from one model to the next.	**CHARTING/MARKING** *noticings and connections between ideas that you intend to mark in some way*

[3] NOTE: Since you are working with a partner for this task, you must BOTH participate in all aspects of it. That means co-planning and co-participation in discussion. You both need to ask questions, revoice, help to represent/chart ideas, etc. In your planning, be as clear as possible about who is going to do what during which part(s) of the lesson so that when you enact it, it is as seamless as possible.

STUDENT MODEL	**STUDENT IDEAS** you want to draw out & emphasize	**QUESTIONS YOU WOULD ASK** Include specific questions about individual models as well as comparison questions. Include specific statements or questions you plan to make in order to transition from one model to the next.	**CHARTING/MARKING** *noticings and connections between ideas that you intend to mark in some way*

ENACTING THE DISCUSSION

Wednesday, October 2

In class on Wednesday, October 2nd you will engage your classmates—playing the role of 8th grade students who developed the water models contained in this packet—in a discussion.

The discussion will occur following the collaborative group task (we role-played this on 9/25) in which students developed their initial explanatory models. By the time the discussion and close are finished, students should have achieved the Learning Goals of the lesson (see Table 2).

During the discussion, your job is to surface key ideas and student thinking so that the whole class can understand and build on them. And you must use particular questioning and talk moves to shape the discussion such that students can build toward the target LGs.

On October 2nd, you will have 15 minutes to conduct your discussion.

We will videotape your performance. This is very important, as you will be using this information in your final reflection.

We will provide feedback on your select/sequence/connect performance using the following rubric—

REFLECTION & CLOSE

Scenario:

You are teaching an integrated science course to 8th graders. The students just completed the discussion portion of the lesson in which you focus on developing the molecular explanation for the behavior of water (this is what you did in class on 10/2/13).

Based upon what occurred during this lesson — what was said and what you wrote down or documented during the discussion — you must now lead a 15-minute CLOSE.

To get ready for this close, answer the questions that follow:

1. What information is on the board / chart paper / overhead, etc. right now (at the end of the discussion)? Sketch this as closely as possible to how it actually looks (use the video as a reference).

2. What are the key ideas that emerged during the discussion and who was responsible for saying them?

3. Are there any LGs from the lesson that were NOT addressed in the discussion or not adequately addressed? If so, which ones are they?

4. Describe how you plan to orchestrate the close. Your close must—
   - Ensure that you have highlighted all of the main LGs from the lesson.
   - Provide instruction for any LGs not adequately addressed to this point.
   - Draw upon appropriate visual tools (either the stuff already on the board, etc. or new stuff or a combination).

Your description of the close should include specific details about **questions** you will ask, (and to whom you'll direct the questions), **what you will "mark" or write down**, what **visuals or tools** you plan to use, any **instruction** you plan to deliver, and **how long** you expect each portion of the close to take.

<u>Class 4</u>

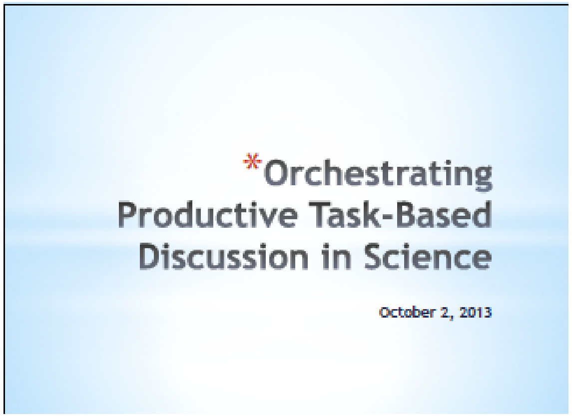
<u>Monitoring, Selecting, Sequencing & Connecting and Microteaching Practice - **Connecting**</u>

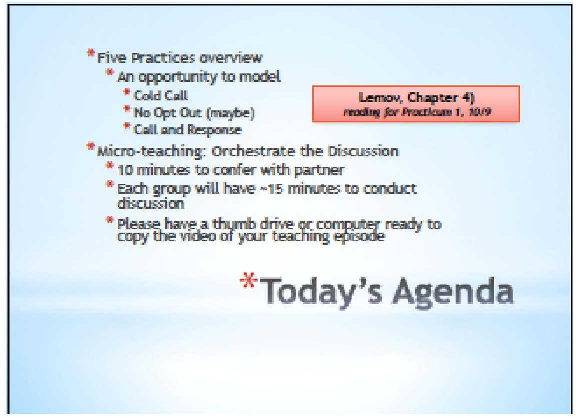
In preparation for Class 4, the PSTs read Chapters 4 and 5 of *5 Practices for Orchestrating Productive Science Discussions* (Cartier et al., 2013). Today's class begins with the PSTs approximating orchestrating a whole class discussion about the KMT of water. Each group had 16-18 minutes for discussion. Each PST gave feedback after each episode using the "noticing and wondering tool" (see below). At the end of the session, the instructors led an overall discussion, summarizing moves that were effective and things PSTs should be mindful of for their next micro-teaching episode.

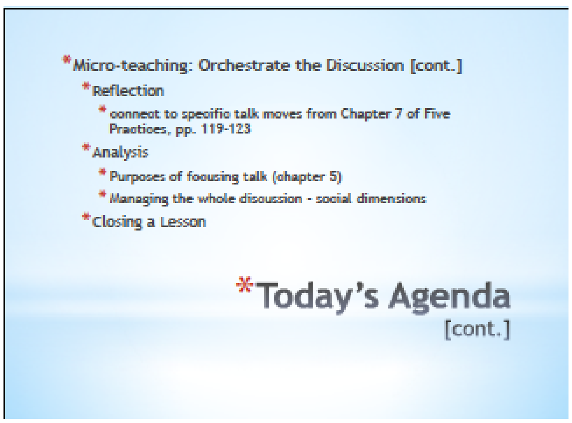
Following the micro-teaching, the instructors provided the PSTs an opportunity to reflect on their teaching. Calling attention to Chapter 7, pp. 119-123, of *5 Practices for Orchestrating Productive Science Discussions* (Cartier et al., 2013) the instructors ask the PSTs to use the ideas presenting in this chapter as a frame to analyze and reflect on their instruction. By focusing on their planned storyline the PSTs answered the following questions: (1) what types of talk support the emerging storyline and make it accessible to students? (2) What types of talk makes student thinking visible? (3) What types of talk guides student thinking in productive directions? (4) What types of talk directs student thinking to what matters?

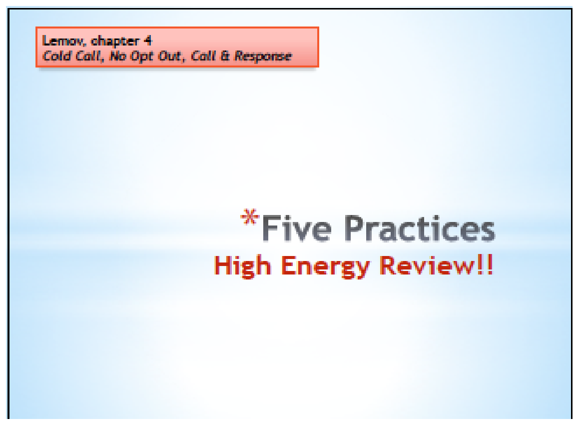
Finally, the instructors reviewed a lesson arc and a lesson close and assigned the final page of the "Orchestrating a Discussion Guide" where the PSTs plan a lesson close to their enacted discussion. After this class, the instructors assigned Instructional Performance 1 and later Instructional Performance 2. Each assignment follows the instructional materials for this class.

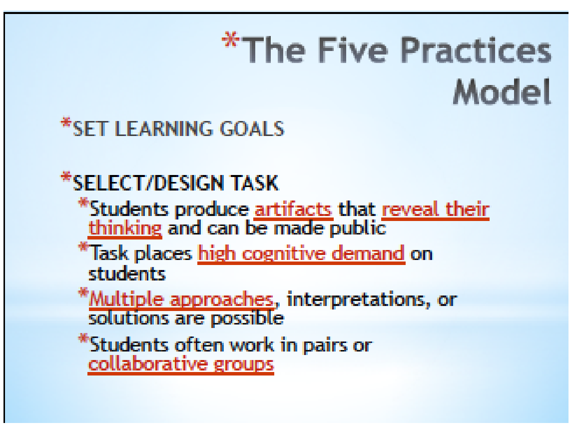
<u>Class 4 Slides</u>

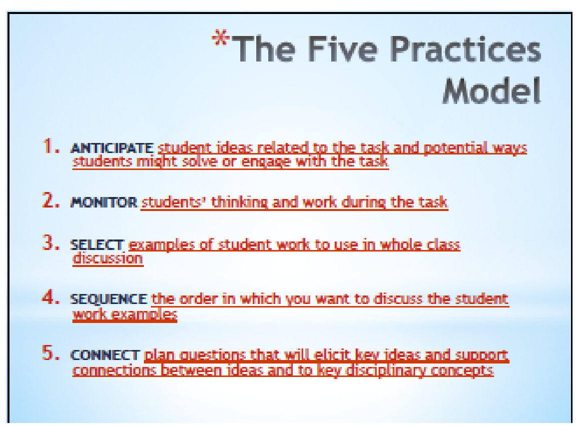












*Micro-Teaching

Orchestrate a Discussion

Read pp. 119-123

* To what extent did you
  - Revoice
  - Prompt students to revoice
  - Mark
  - Draw on tools or routines to support every student's engagement in the discussion

* To what extent would this type of talk have helped to advance the learning goals of the lesson?

*Reflect

* Looking at your planning document, what parts or thinking did you do prior to today around:
  - How you would revoice students ideas
  - Prompts and moves to get students to revoice ideas
  - How you would mark students work, or have them mark their own work
  - Draw on tools or routines to support every student's engagement in the discussion
* How did this part(s) of the lesson plan or thinking help in your facilitation today (positive and negative)?
* What changes in your planning do you think are necessary to better support the class discussion?

*Analyzing the Discussion

* REVIEW the videotape from this morning

* To what extent did you *engage* in talk that
  - Made student thinking visible
  - Guided student thinking in productive directions (toward the overall "storyline" - coherent, connected LGs)
  - Directed students' attention to key features of the target explanation

See Five Practices, Chapter 5 for examples of these types of talk . . .

* To what extent did you *plan* for this talk?

*Analyzing the Discussion

*Closing the Lesson

LAUNCH
~3-15 minutes

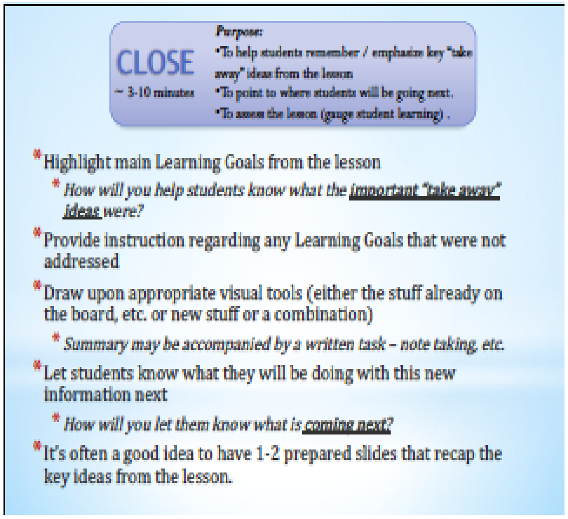
Purpose:
•Communicate purpose & expectations
•Capture students' attention / motivate participation

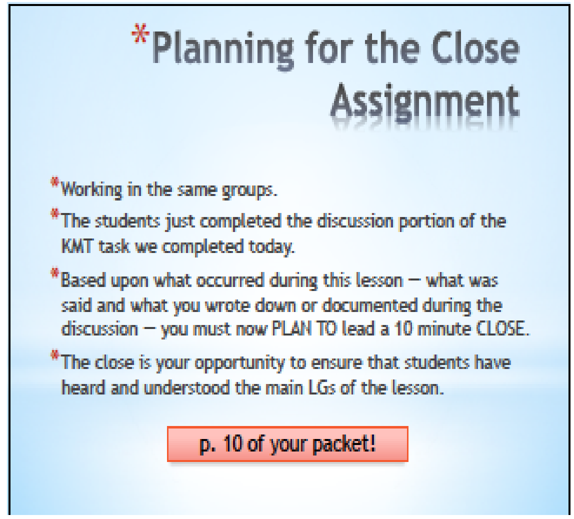
ACTIVITY
Time is variable, depending on activity, class structure, etc.

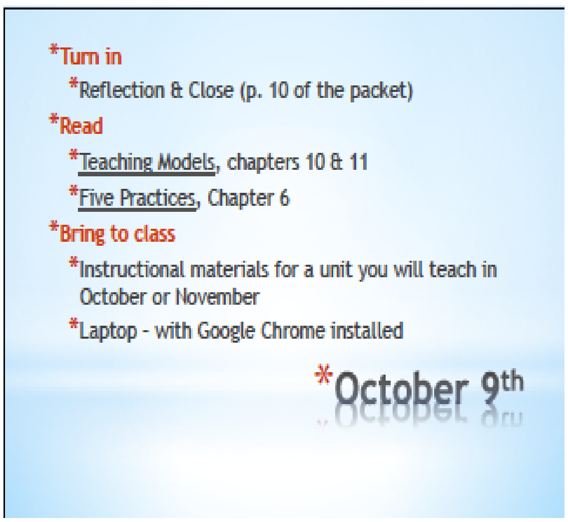
NOTE: There may be more than one main activity in a lesson.
Purpose:
•To provide students an opportunity to achieve the Learning Goals of the lesson.

CLOSE
~ 3-10 minutes

Purpose:
•To help students remember / emphasize key "take away" ideas from the lesson
•To point to where students will be going next.
•To assess the lesson (gauge student learning) .


CLOSE
~ 3-10 minutes
Purpose:
•To help students remember / emphasize key "take away" ideas from the lesson
•To point to where students will be going next.
•To assess the lesson (gauge student learning) .
*Highlight main Learning Goals from the lesson
*How will you help students know what the important "take away" ideas were?
*Provide instruction regarding any Learning Goals that were not addressed
*Draw upon appropriate visual tools (either the stuff already on the board, etc. or new stuff or a combination)
*Summary may be accompanied by a written task – note taking, etc.
*Let students know what they will be doing with this new information next
*How will you let them know what is coming next?
*It's often a good idea to have 1-2 prepared slides that recap the key ideas from the lesson.


*Planning for the Close Assignment
*Working in the same groups.
*The students just completed the discussion portion of the KMT task we completed today.
*Based upon what occurred during this lesson – what was said and what you wrote down or documented during the discussion – you must now PLAN TO lead a 10 minute CLOSE.
*The close is your opportunity to ensure that students have heard and understood the main LGs of the lesson.
p. 10 of your packet!


*Turn in
*Reflection & Close (p. 10 of the packet)
*Read
*Teaching Models, chapters 10 & 11
*Five Practices, Chapter 6
*Bring to class
*Instructional materials for a unit you will teach in October or November
*Laptop - with Google Chrome installed
*October 9th

Noticing and Wondering Tool

WHOLE CLASS DISCUSSION
Formative Feedback

	I noticed . . .	I wondered . . .
Talk that served to make students' thinking visible . . .		
Talk that served to guide students' thinking in productive directions (i.e. directions consistent with achievement of the LGs) . . .		
Talk that explicitly highlighted or called attention to important features of the target explanation . . .		

	I noticed . . .	I wondered . . .
Use of specific talk moves such as • Teacher Revoicing • Student Revoicing • Marking		
The teacher taking on the role of facilitator (vs. interviewer) by engaging all students in the discussion . . .		
Teacher's use of tools to support student engagement in the lesson . . .		

<u>Instructional Performance 1 Instructional Guide</u>

Instructional Performance #1: Lead a Discussion

Important Dates

Please attempt to complete this assignment by October 30th.

If you are unable to complete all of the documentation (artifact packet) by this date, just let me know – but do strive to have the lesson taught by October 30th.

Reminders

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

- Once you have scheduled the lesson, let your Field Supervisor know ASAP. Some Field Supervisors have to observe 4 different students, so your scheduled lesson MUST fit within that overall schedule.

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

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

Your Teaching Task

You will lead a **<u>discussion</u>** in the class. The discussion should be ***at least*** 25 minutes long.

Your lesson must involve:

Students drawing upon work that they completed in a previous high cognitive demand task.

For example,

- In an earlier task (either earlier the same day or on a prior day), students drew models to explain the patterns of the behavior of water. During the discussion portion of this lesson, the students will focus on these models.

- In an earlier task (either earlier the same day or on a prior day), students developed protocols to measure plant growth. During the discussion portion of this lesson, the students will focus on these protocols.

- In an earlier task (either earlier the same day or on a prior day), students examined second-hand data related to Moon phases and sought to identify patterns. In the discussion portion of this lesson, students will share and develop a consensus description of the key patterns from the data.

Students engaging in actual ***discussion*** (not simply *presentation*). Thus, —

- Students should know your expectations for their verbal participation as well as active, respectful listening.

- Students should have opportunities to add to, challenge, question, etc. what others have said.

- You will need to prepare in advance for ways to get the students to engage with one another. That is, I don't want you to ask a question, get an answer, ask another question, etc. The students should be talking roughly 75% of the time.

    a) Some questions you may want to be prepared to ask: Does everyone agree with . . . ? Can someone add on to that idea or say it in a different way? Can you repeat what [student] said? Etc.

    b) Be sure to use tossing and revoicing (teacher revoicing as well as student revoicing) to support engagement in the discussion.

    c) Also draw on Cold Call and other strategies to ensure that you are involving the entire class in the thinking work and not just relying on the "presenters" and volunteers.

Use of a marking tool.

- This might be a whole class level tool (e.g. you completing a chart on the board) or an individual note-taking tool. You may use it consistently throughout the discussion or only at the lesson close.

Preparing to Teach

Work with your mentor teacher to identify a topic / lesson where you can incorporate this discussion. KEEP IN MIND that you will likely need two consecutive days – one day for students to complete the high cognitive demand task and a subsequent day for them to discuss their work as a class.

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

Write a Lesson Plan.

- Your Lesson Plan should address all of the requirements described in the standard rubric.
- Your lesson must have a Launch, Work Time (Discussion) and Close.
- Include sufficient detail to enable you to support the discussion, similarly to the way you planned for the KMT discussion in our T&L in Science class.

Discuss your lesson plan with your mentor teacher and/or field supervisor and make any revisions as per his/her suggestions. It is also a VERY GOOD IDEA to get feedback on the high cognitive demand task and the lesson in which you intend to complete this work. So, in other words, your Field Supervisor is only coming to see the discussion – but the previous lesson, in which students actually produced work worthy of discussion – is vitally important, too. Your supervisor can help you shape this task so that it is more likely to lead to productive discussion!

Upload your lesson plan to the Lesson Planning tool **no later than 24 hours** before you plan to teach the lesson.

On The Day That You Teach

Arrive at your school early and make sure everything is ready to go. It is best if you prepare materials (slides, handouts, etc.) the day before at the latest. Have a hard copy of your lesson plan ready to hand to your Field Supervisor when s/he arrives to view your lesson. Also provide your Field Supervisor with the folder with video permission records (if applicable). Finally, provide the Field Supervisor with the video camera or smart phone if you are going to record the lesson. Set aside some time in your schedule for a post-lesson conference with your Field Supervisor.

Reflecting on Teaching

Reflection Questions

Answer these questions (typed) drawing on any evidence you have from the lesson, including your own observations, feedback from the Mentor and Field Supervisor, and written artifacts produced by the students.

1) Did students achieve the desired Learning Goals? To answer this question, draw from specific evidence (things students said and/or produced, such as an exit slip). Put copies of relevant student work in the 4th section of your packet.

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

3a) Did students seem able to engage in the discussion (according to the rules/expectations you provided)? What aspects of participating in the discussion seemed to challenge your students the most? What aspects of the discussion were easiest for them?

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

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

4b) What elements of the task were problematic?

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

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

5b) To what extent do you feel you succeeded at leading the discussion (promoting students' engagement) and not stepping in and "telling?" Provide specific examples of where you felt you did a good job and where you would have done something differently if you could go back and do it again.

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

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

Documenting Practice

You will submit the **Instructional Performance Packet** to your Practicum instructor **in hard copy** on October 30th.

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

(1) Lesson Plan

(2) Instructional Materials

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

Also include a copy of the high cognitive demand task that students completed prior to the discussion. Include data tables and any other materials that students used during this task.

(3) Student Work

Include copies of the work that students produced during the high cognitive demand task (the artifacts that you used to anchor your discussion).

(4) Feedback

In this section place a copy of your Field Supervisor's and Mentor's feedback.

(5) Reflection

Put a copy of the answered Reflection Questions here.

Include copies of whatever evidence is pertinent (e.g. exit slips, etc. See Reflections Questions for clarification here).

<u>Instructional Performance 2 Instructional Guide</u>

Instructional Performance #2: Lead a Discussion

Important Dates

Final packet is due on Monday, December 16th.

Reminders

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

- Once you have scheduled the lesson, let your Field Supervisor know ASAP. Some Field Supervisors have to observe 4 different students, so your scheduled lesson MUST fit within that overall schedule.

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

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

Your Teaching Task

You will lead a **<u>discussion</u>** in the class. The discussion should be ***at least*** 25 minutes long.

Your lesson must involve:

Students drawing upon work that they completed in a previous high cognitive demand task.

For example,

- In an earlier task (either earlier the same day or on a prior day), students drew models to explain the patterns of the behavior of water. During the discussion portion of this lesson, the students will focus on these models.

- In an earlier task (either earlier the same day or on a prior day), students developed protocols to measure plant growth. During the discussion portion of this lesson, the students will focus on these protocols.

- In an earlier task (either earlier the same day or on a prior day), students examined second-hand data related to moon phases and sought to identify patterns. In the discussion portion of this lesson, students will share and develop a consensus description of the key patterns from the data.

Students engaging in actual ***discussion*** (not simply *presentation*). Thus, —

- Students should know your expectations for their verbal participation as well as active, respectful listening.

- Students should have opportunities to add to, challenge, question, etc. what others have said.

- You will need to prepare in advance for ways to get the students to engage with one another. That is, I don't want you to ask a question, get an answer, ask another question, etc. The students should be talking roughly 75% of the time.

    d) Some questions you may want to be prepared to ask: Does everyone agree with . . . ? Can someone add on to that idea or say it in a different way? Can you repeat what [student] said? Etc.

    e) Be sure to use tossing and revoicing (teacher revoicing as well as student revoicing) to support engagement in the discussion.

    f) Also draw on Cold Call and other strategies to ensure that you are involving the entire class in the thinking work and not just relying on the "presenters" and volunteers.

Use of a marking tool.

- This might be a whole class level tool (e.g. you completing a chart on the board) or an individual note-taking tool. You may use it consistently throughout the discussion or only at the lesson close.

Preparing to Teach

Work with your mentor teacher to identify a topic / lesson where you can incorporate this discussion. KEEP IN MIND that you will likely need two consecutive days – one day for students to complete the high cognitive demand task and a subsequent day for them to discuss their work as a class.

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

Write a Lesson Plan.

- Your Lesson Plan should address all of the requirements described in the standard rubric.
- Your lesson must have a Launch, Work Time (Discussion) and Close.
- Include sufficient detail to enable you to support the discussion, similarly to the way you planned for the KMT discussion in our T&L in Science class.

Discuss your lesson plan with your mentor teacher and/or field supervisor and make any revisions as per his/her suggestions. It is also a VERY GOOD IDEA to get feedback on the high cognitive demand task and the lesson in which you intend to complete this work. So, in other words, your Field Supervisor is only coming to see the discussion – but the previous lesson, in which students actually produced work worthy of discussion – is vitally important, too. Your supervisor can help you shape this task so that it is more likely to lead to productive discussion!

Upload your lesson plan to the Lesson Planning tool **no later than 24 hours** before you plan to teach the lesson.

On The Day That You Teach

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

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

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

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

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

Reflecting on Teaching

Reflection Questions

Answer these questions (typed) drawing on any evidence you have from the lesson, including your own observations, feedback from the Mentor and Field Supervisor, and written artifacts produced by the students.

1) Did students achieve the desired Learning Goals? To answer this question, draw from specific evidence (things students said and/or produced, such as an exit slip). Put copies of relevant student work in the 4th section of your packet.

2a) Did students seem able to engage in the discussion (according to the rules/expectations you provided)? What aspects of participating in the discussion seemed to challenge your students the most? What aspects of the discussion were easiest for them?

2b) How can you help the students get better at engaging in this type of discussion?

3a) What elements of the high cognitive demand task (that they completed prior to the discussion) were most productive in terms of eliciting productive thinking and responses from the students?

3b) What elements of the task were problematic?

3c) Would you change the task if you were to do this again? If so, in what ways?

4a) How comfortable were you leading the discussion? Did you feel nervous or relaxed?

4b) To what extent do you feel you succeeded at leading the discussion (promoting students' engagement) and not stepping in and "telling?" Provide specific examples of where you felt you did a good job and where you would have done something differently if you could go back and do it again.

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

6) Reflect on your work supporting classroom discussion throughout this semester. In what ways have your skills as a facilitator grown? In what ways has your students' capacity to engage in this work developed? What are your goals for yourself and your students as you move into the new term?

Documenting Practice

You will submit the **Instructional Performance Packet** to your Practicum instructor **in hard copy** on December 16th.

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

(1) Lesson Plan

(2) Instructional Materials

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

Also include a copy of the high cognitive demand task that students completed prior to the discussion. Include data tables and any other materials that students used during this task.

(3) Student Work

Include copies of the work that students produced during the high cognitive demand task (the artifacts that you used to anchor your discussion).

(4) Feedback

In this section place a copy of your Field Supervisor's and Mentor's feedback.

(5) Reflection

Put a copy of the answered Reflection Questions here.

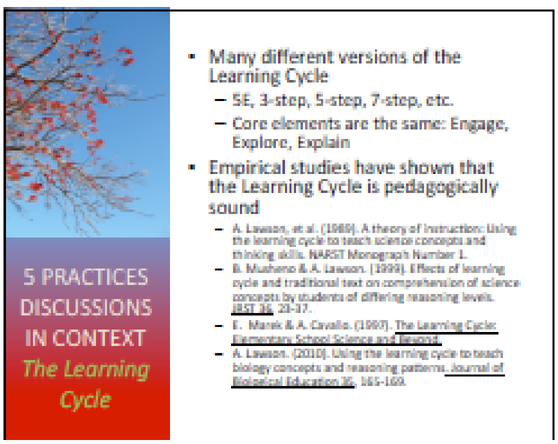
Include copies of whatever evidence is pertinent (e.g. exit slips, etc. See Reflections Questions for clarification here).

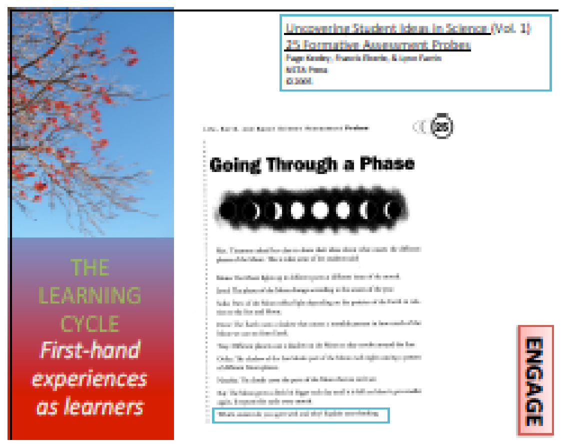
Class 5

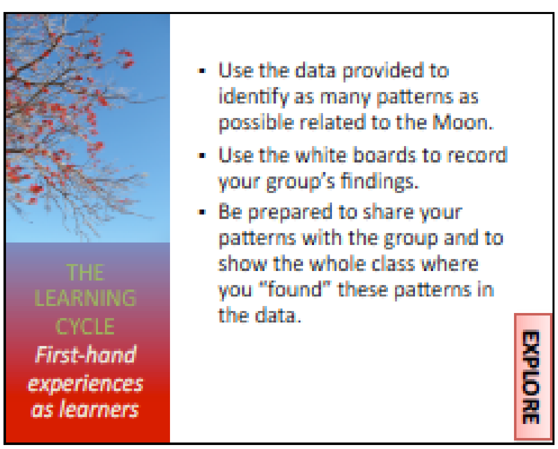
Learning Cycle

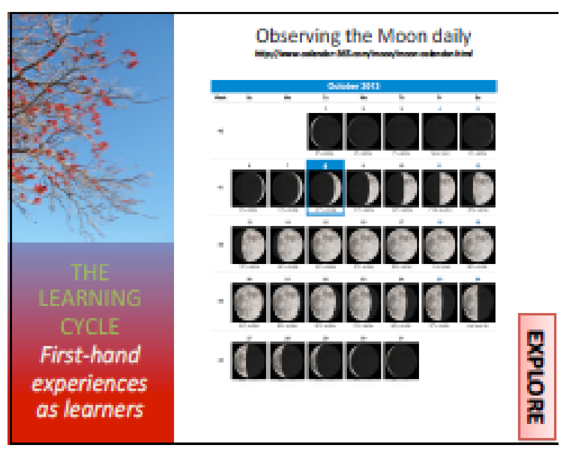
In preparation for Class 5, the PSTs read Chapters 6 of *5 Practices for Orchestrating Productive Science Discussions* (Cartier et al., 2013). Class 5 involved a detailed examination of the Learning Cycle. Through direct instruction, the instructors review the Learning Cycle. The PSTs then engage in a portion of a Moon Phase Learning Cycle. Each group of PSTs received a different piece of data and identified as many patterns as possible related to the moon. Following the small group work, the PSTs shared the patterns they noticed with the class. Finally, the instructors provide examples of Learning Cycles “in action” as well as examples in which a teacher embeds a Five Practices discussion in different phases of a Learning Cycle depending on the teacher’s learning goals. What follows are the slides used in class, which include the various moon phase data given to the PST groups.

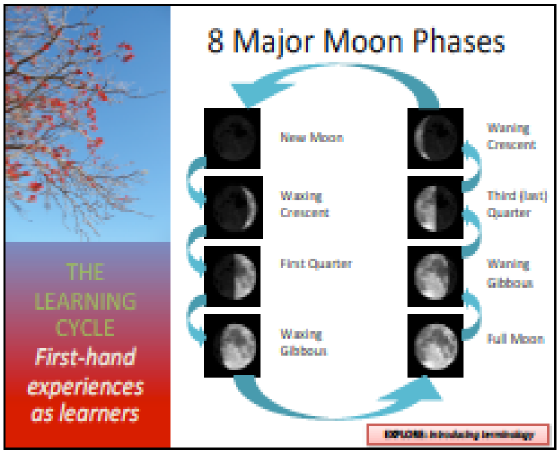
Class 5 Slides

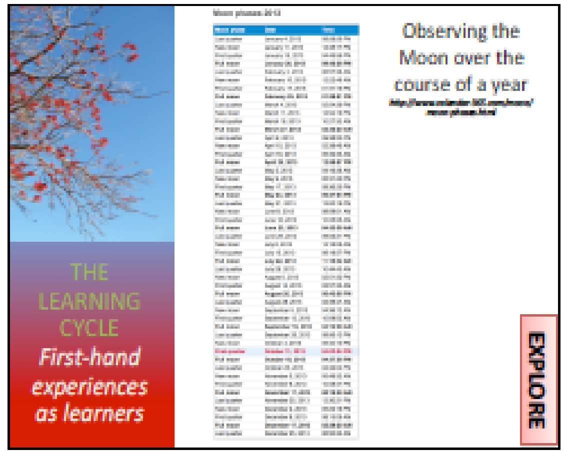


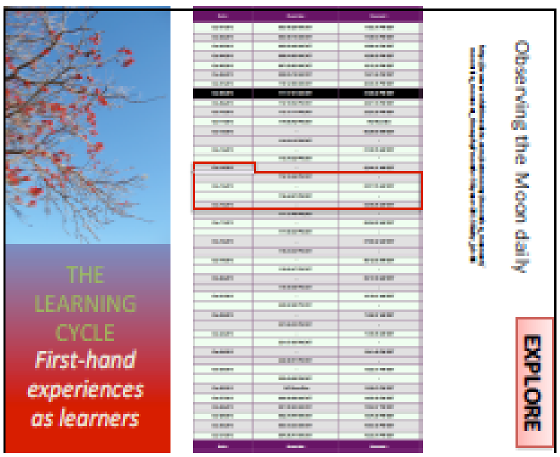


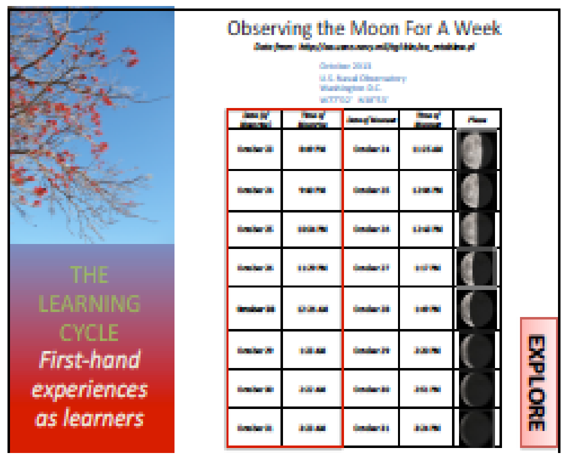


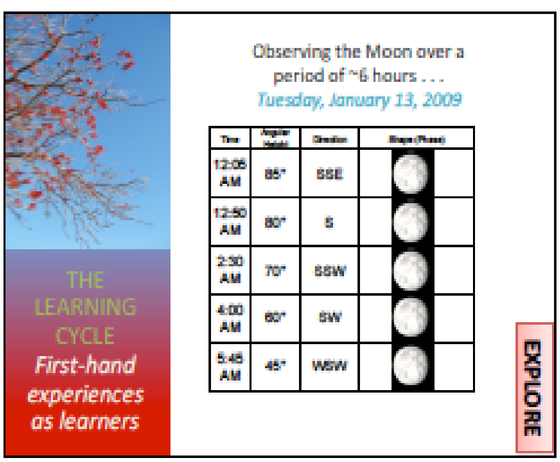


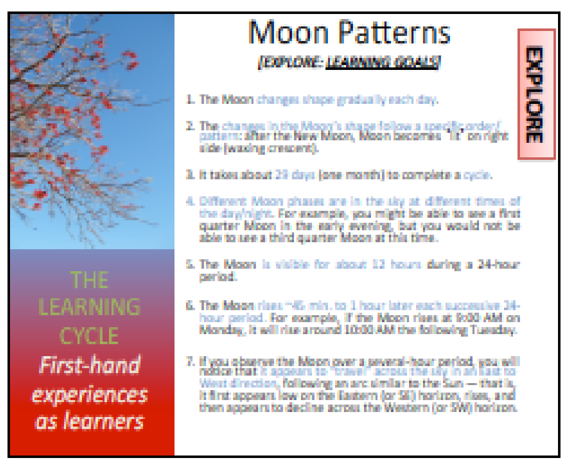

8 Major Moon Phases
New Moon
Waxing Crescent
First Quarter
Waxing Gibbous
Waning Crescent
Third (last) Quarter
Waning Gibbous
Full Moon
THE LEARNING CYCLE
First-hand experiences as learners
EXPLORE: Introducing terminology

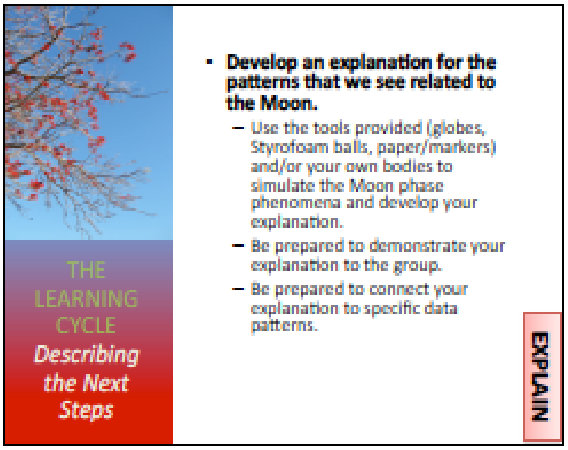

Observing the Moon over the course of a year
THE LEARNING CYCLE
First-hand experiences as learners
EXPLORE

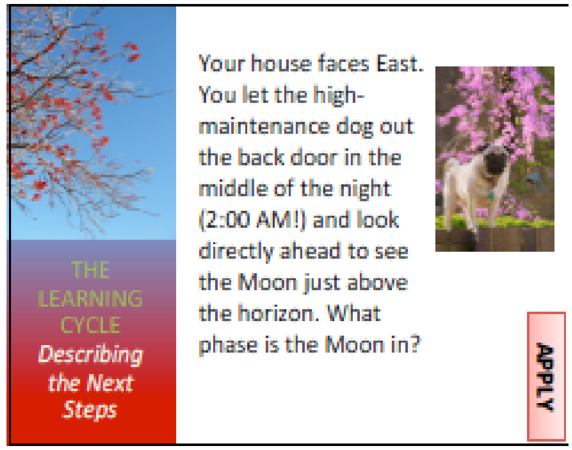

Observing the Moon daily
THE LEARNING CYCLE
First-hand experiences as learners
EXPLORE

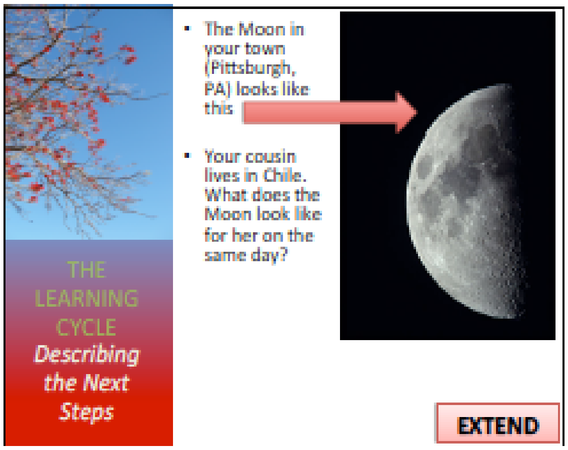

Observing the Moon For A Week
THE LEARNING CYCLE
First-hand experiences as learners
EXPLORE

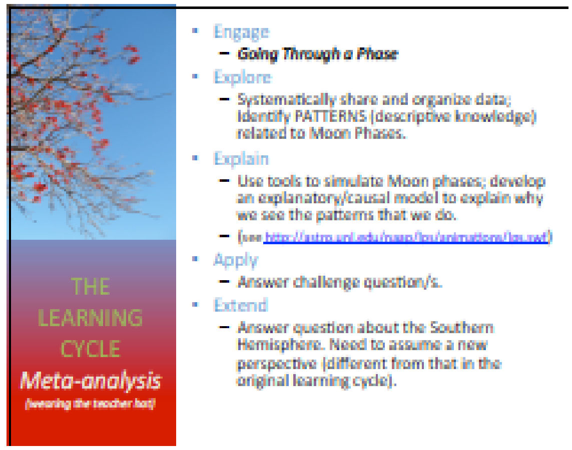

Observing the Moon over a period of ~6 hours . . .
Tuesday, January 13, 2009
Time
Direction
Shape (Phase)
12:05 AM
85°
SSE
12:50 AM
80°
S
2:30 AM
70°
SSW
4:00 AM
60°
SW
5:45 AM
45°
WSW
THE LEARNING CYCLE
First-hand experiences as learners
EXPLORE


Moon Patterns
[EXPLORE: LEARNING GOALS]
1. The Moon changes shape gradually each day.
2. The changes in the Moon's shape follow a specific order/ pattern: After the New Moon, Moon becomes "lit" on right side (waxing crescent).
3. It takes about 29 days (one month) to complete a cycle.
4. Different Moon phases are in the sky at different times of the day/night. For example, you might be able to see a first quarter Moon in the early evening, but you would not be able to see a third quarter Moon at this time.
5. The Moon is visible for about 12 hours during a 24-hour period.
6. The Moon rises ~45 min. to 1 hour later each successive 24-hour period. For example, if the Moon rises at 9:00 AM on Monday, it will rise around 10:00 AM the following Tuesday.
7. If you observe the Moon over a several-hour period, you will notice that it appears to "travel" across the sky in an East to West direction, following an arc similar to the Sun — that is, it first appears low on the Eastern (or SE) horizon, rises, and then appears to decline across the Western (or SW) horizon.
THE LEARNING CYCLE
First-hand experiences as learners
EXPLORE



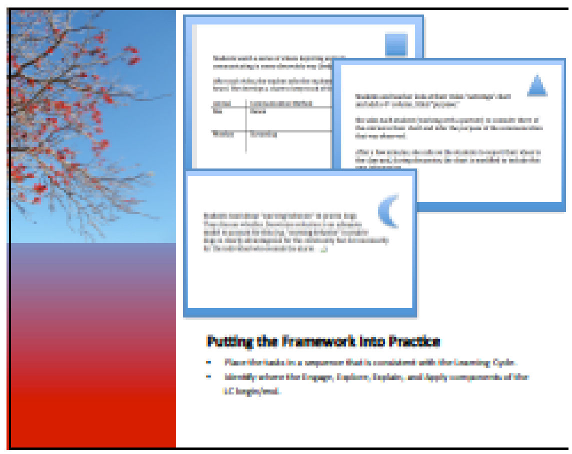


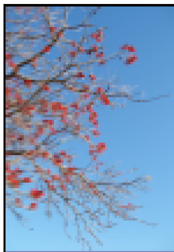




The Learning Cycle in Science

Engage	*Purpose is for teachers to—* • Motivate learners to want to find out about the topic of study. • Find out about or "surface" learners' relevant prior knowledge and experiences.
Explore	*Purpose is for students to—* • Investigate the topic by collecting first- or second-hand **data.** • Use a variety of representations to identify and describe **patterns** in data.
Explain	*Purpose is for students to—* • Develop an **explanation** that can account for the patterns previously identified and/or connects to broader (more general) ideas in science. • Engage in community **discourse** about explanations; compare and critique ideas. • **Come to understand** the accepted (canonical) explanation for the phenomena/patterns.
Apply	*Purpose is for students to—* • **Use** new knowledge to predict or explain novel phenomena.
Extend	*Purpose is for students to—* • **Use & revise existing knowledge** to make sense of new phenomena.



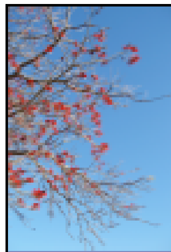


THE LEARNING CYCLE
Meta-analysis
(wearing the teacher hat)

- Learning Cycle structure enables teachers to design opportunities for students to engage in the 8 Practices highlighted in the <u>K-12 Science Education Framework.</u>

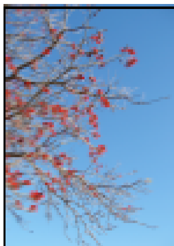
NGSS Science Practice	Learning Cycle stage			
	ENGAGE	EXPLORE	EXPLAIN	APPLY
CSP 1: Asking questions	√			√
CSP 2: Developing and using models			√	√
CSP 3: Planning and carrying out investigations		√		
CSP 4: Analyzing and interpreting data		√	√	
CSP 5: Using mathematics and computational thinking		√		
CSP 6: Constructing explanations			√	√
CSP 7: Engaging in argument from evidence			√	√
CSP 8: Obtaining, evaluating, and communicating information		√	√	√

Fig. 4.1: Opportunities for students to engage in the Next Generation Science Standards practices (Achieve, Inc., 2013) throughout the stages of the Learning Cycle



THE LEARNING CYCLE
Meta-analysis
(wearing the teacher hat)

- The organization of the LC supports/scaffolds learners as they develop new knowledge and skills while engaging in key science practices.
- The LC structure supports teachers as they develop "lesson arcs" (a series of activities that are tightly linked conceptually); this leads to increased instructional coherence for students.



Talk About It

Where should a "Five Practices Discussion" happen within the overall context of a Learning Cycle?

What are some of the things teachers need to consider when making this design choice?

(Look back at Mrs. Duncan, chapter 6.)

Task type	Learning Cycle stage			
	ENGAGE	EXPLORE	EXPLAIN	APPLY
Experimentation		√		
Data Representation, Analysis, and Interpretation		√	√	√
Explanation			√	√

Fig. 6.1: Alignment between Learning Cycle stages and task types described in chapter 3

Challenging and "Five Practice Discussion – worthy" tasks can fit into any of the LC stages. It is usually most worth investing the time to use this activity structure (5PD) in Explore, Explain, or Apply.

SUMMARY
Sequencing Tasks in a Lesson Arc

Examples . . .

BEHAVIOR OF WATER

DAY 1

<u>ENGAGE</u>

Turn & Talk / Class Discussion

Potholes and frozen water pipes . . .

<u>EXPLORE</u>

Provide mass/volume data from day before (T_1); students collect mass/volume data for T_2

Data displayed in whole class chart – key patterns noted (mass remains the same; volume increases)

DAY 2

<u>EXPLAIN</u>

Provide marbles and magnetic marbles to groups

Interactive lecture about the unique properties of water (H-bonding)

<u>APPLY / EXTEND</u>

Students play the role of "expert" in litigation about poor construction materials – is the cement to blame?

Day 2 – research & planning

Day 3 - presentations

5P DISUCSSION
Explanation

SUMMARY
Sequencing Tasks in a Lesson Arc

Examples . . .

FAST PLANTS

DAY 1

<u>ENGAGE</u>

Observe different plants; list characteristics

<u>EXPLORE</u>

- Provide protocol to the class for gathering stem length data
- In small groups, propose format for data table; teacher approves data tables for each group
- Students gather data for first measurement

DAY 3-15

<u>EXPLORE</u>

Students gather data every 2-3 days for first few minutes of class

DAY 17

Sts construct representations of the data – focused on supporting an answer to "What does the growth of a *typical* Fastplant look like?"

Day 18

Sts share/critique representations

Summarize patterns of "typical" growth *5P DISUCSSION*
Data Representation & Analysis

SUMMARY
Sequencing Tasks in a Lesson Arc

Examples . . .

FAST PLANTS

DAY 3-15

<u>EXPLORE</u>

Students gather data every 2-3 days for first few minutes of class

DAY 17

Sts construct representations of the data – focused on supporting an answer to "What does the growth of a *typical* Fastplant look like?"

Day 18

Sts share/critique representations

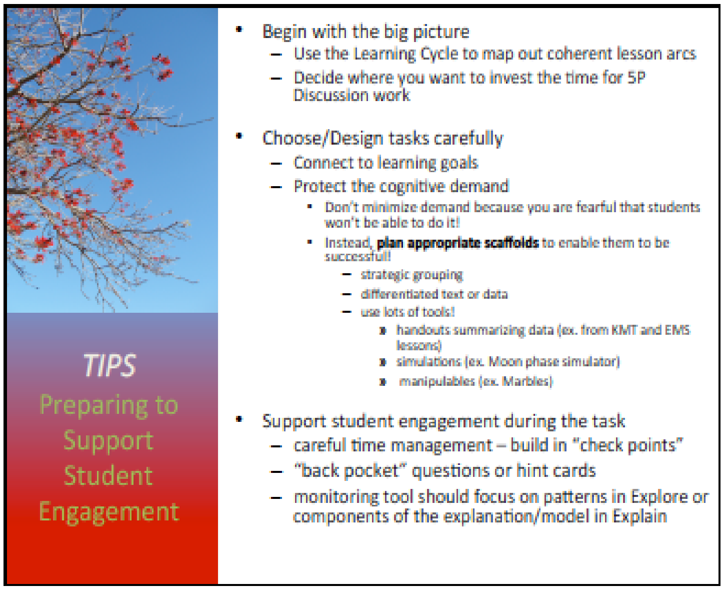
Summarize patterns of "typical" growth *5P DISUCSSION*
Data Representation & Analysis

DAY 19

<u>EXPLAIN</u>

Sts read section of text about plant life cycle

Interactive lecture to tie typical growth curves to plant's energy needs during life cycle


TIPS
Preparing to Support Student Engagement
Begin with the big picture
Use the Learning Cycle to map out coherent lesson arcs
Decide where you want to invest the time for 5P Discussion work
Choose/Design tasks carefully
Connect to learning goals
Protect the cognitive demand
Don't minimize demand because you are fearful that students won't be able to do it!
Instead, plan appropriate scaffolds to enable them to be successful!
strategic grouping
differentiated text or data
use lots of tools!
handouts summarizing data (ex. from KMT and EMS lessons)
simulations (ex. Moon phase simulator)
manipulables (ex. Marbles)
Support student engagement during the task
careful time management – build in "check points"
"back pocket" questions or hint cards
monitoring tool should focus on patterns in Explore or components of the explanation/model in Explain

TEACHING AND LEARNING III
SPRING 2014

Teaching & Learning in Secondary Science III is a 3-credit course offered during the spring semester (Jan-Apr). The course was designed to help PSTs refine their skills for designing, implementing, and reflecting upon lessons in which adolescent students engage in cognitively challenging tasks and participate in robust classroom discussions. The course also focused on the role of assessment, both formative and summative, in providing teachers and students with useful information and guidance to support the learning process. What follows is a description of each course session on which this study focuses, instructional materials from each session, and pertinent assignments.

At the beginning of the semester, the instructors provided the PSTs with the Instructional Guide for Instructional Performances 3 and 4. The guide distributed is below. As you will see, it is similar to the guides distributed during the fall semester.

Instructional Performance 3 and 4 Instructional Guide

Instructional Performances #3 and #4: Lead a Five Practices Discussion

Important Dates

Instructional Performance 3:

1. Final Artifact Packet due by **2/5/2014**
2. **Bring hard copy of artifact packet to class on 2/5/2014**

Instructional Performance 2:

1. Final Artifact Packet due by **3/19/2014**
2. **Bring hard copy of artifact packet to class on 3/19/2014**

Reminders

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

- Once you have scheduled the lesson, let your Field Supervisor know ASAP. Some Field Supervisors have to observe 4 different students, so your scheduled lesson MUST fit within that overall schedule.
- ***Supervisors are required to observe one (1) of these 5 Practices lessons.***
- ***You must have feedback from your supervisor or mentor accompany each artifact packet.***

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

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

Your Teaching Task

You will lead a Five Practices **discussion** in the class. The discussion should be ***at least*** 25 minutes long.

Your lesson must involve:

Students drawing upon work that they completed in a previous high cognitive demand task.
For example,

- In an earlier task (either earlier the same day or on a prior day), students drew models to explain the patterns of the behavior of water. During the discussion portion of this lesson, the students will focus on these models.

- In an earlier task (either earlier the same day or on a prior day), students developed protocols to measure plant growth. During the discussion portion of this lesson, the students will focus on these protocols.

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Students engaging in actual ***discussion*** (not simply *presentation*). Thus, —

- Students should know your expectations for their verbal participation as well as active, respectful listening.

- Students should have opportunities to add to, challenge, question, etc. what others have said.

- You will need to prepare in advance for ways to get the students to engage with one another. That is, I don't want you to ask a question, get an answer, ask another question, etc. The students should be talking roughly 75% of the time.

    g) Some questions you may want to be prepared to ask: Does everyone agree with . . . ? Can someone add on to that idea or say it in a different way? Can you repeat what [student] said? Etc.

    h) Be sure to use tossing and revoicing (teacher revoicing as well as student revoicing) to support engagement in the discussion.

    i) Also draw on Cold Call and other strategies to ensure that you are involving the entire class in the thinking work and not just relying on the "presenters" and volunteers.

Use of a marking tool.

- This might be a whole class level tool (e.g. you completing a chart on the board) or an individual note-taking tool. You may use it consistently throughout the discussion or only at the lesson close.

Preparing to Teach

Work with your mentor teacher to identify a topic / lesson where you can incorporate this discussion. KEEP IN MIND that you will likely need two consecutive days – one day for students to complete the high cognitive demand task and a subsequent day for them to discuss their work as a class.

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

Write a Lesson Plan.

- Your Lesson Plan should address all of the requirements described in the standard rubric.
- Your lesson must have a Launch, Work Time (Discussion) and Close.
- Include sufficient detail to enable you to support the discussion, similarly to the way you planned for the KMT discussion in our T&L in Science class.

Discuss your lesson plan with your mentor teacher and/or field supervisor and make any revisions as per his/her suggestions. It is also a VERY GOOD IDEA to get feedback on the high cognitive demand task and the lesson in which you intend to complete this work. So, in other words, your Field Supervisor is only coming to see the discussion – but the previous lesson, in which students actually produced work worthy of discussion – is vitally important, too. Your supervisor can help you shape this task so that it is more likely to lead to productive discussion!

Upload your lesson plan to the Lesson Planning tool **no later than 24 hours** before you plan to teach the lesson.

Reflecting on Teaching

Reflection Questions

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

1) Did students achieve the desired Learning Goals? To answer this question, draw from specific evidence (things students said and/or produced, such as an exit slip). Put copies of relevant student work in the 4th section of your packet and be sure to provide clear evidence of how that student work indicates students met the goals of the lesson.

2a) Did students seem able to engage in the discussion (according to the rules/expectations you provided)? What aspects of participating in the discussion seemed to challenge your students the most? What aspects of the discussion were easiest for them?

2b) How can you help the students get better at engaging in this type of discussion?

3a) What elements of the high cognitive demand task (that they completed prior to the discussion) were most productive in terms of eliciting productive thinking and responses from the students?

3b) What elements of the task were problematic?

3c) Would you change the task if you were to do this again? If so, in what ways?

4a) How comfortable were you leading the discussion? Did you feel nervous or relaxed?

4b) To what extent do you feel you succeeded at leading the discussion (promoting students' engagement) and not stepping in and "telling?" Provide specific examples of where you felt you did a good job and where you would have done something differently if you could go back and do it again.

5) Describe the role that **planning** using the Five Practices Model played in your ability to conduct this lesson.

6) Reflect on your work supporting classroom discussion throughout this semester. In what ways have your skills as a facilitator grown? In what ways has your students' capacity to engage in this work developed? What are your goals for yourself and your students as you move into the new term?

Documenting Practice

You will submit the **Instructional Performance Packet** to your Seminar instructor **<u>in hard copy</u>** on February 5th, 2014 for Lesson #3 and March 19, 2014 for Lesson # 4

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

(1) Lesson Plan

(2) Instructional Materials

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

Also include a copy of the high cognitive demand task that students completed prior to the discussion. Include data tables and any other materials that students used during this task.

(3) Student Work

Include copies of the work that students produced during the high cognitive demand task (the artifacts that you used to anchor your discussion).

(4) Feedback

In this section place a copy of your Field Supervisor's and/or Mentor's feedback.

(5) Reflection

Put a copy of the answered Reflection Questions here.

Include copies of whatever evidence is pertinent (e.g. exit slips, etc. See Reflections Questions for clarification here).

Class 2

The Learning Cycle

During Class 2, PSTs revisit the Learning Cycle by engaging as students in a Physics Learning Cycle: "The Ramp Activity." The instructor provided a scenario to students where they are building a ramp system to determine, "How does the length of the board affect how fast the ball moves?" The PSTs then worked on answering this question using the provided materials. As the PSTs work in their small groups, the instructor models monitoring for the students. Once the PSTs completed the task, there was a short discussion regarding their findings for the remaining minutes of the period. What follows are the slides used in class.

Class 2 Slides

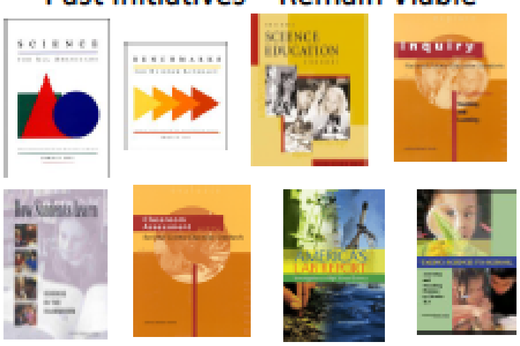
The Learning Cycle

Teaching & Learning in Secondary Science 3
Spring 2014

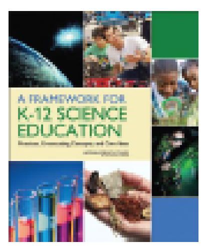
Agenda

- 4:30 p.m. - Introduction
- 4:45 p.m. - Introduce the Learning Cycle
- 5:00 p.m. - Engage in Learning Cycle
- 5:30 p.m. - Break
- 5:50 p.m. - Report Results
- 6:15 p.m. – Making Sense of the Learning Cycle

Past Initiatives – Remain Viable



Next Generation Science Standards



Science and Engineering Practices

Practice	Description
1	Asking questions (for science) and defining problems (for engineering)
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

The Second Dimension—Seven Crosscutting Concepts

- 1. Patterns
- 2. Cause and Effect: Mechanism and Explanation
- 3. Scale, Proportion, and Quantity
- 4. Systems and System Models
- 5. Energy and Matter: Flows, Cycles, and Conservation
- 6. Structure and Function
- 7. Stability and Change

Disciplinary Core Ideas

Physical Sciences
PS 1: Matter and its interactions
PS 2: Motion and stability: Forces and interactions
PS 3: Energy
PS 4: Waves and their applications in technologies for information transfer

Earth and Space Sciences
ESS 1: Earth's place in the universe
ESS 2: Earth's systems
ESS 3: Earth and human activity

Life Sciences
LS 1: From molecules to organisms: Structures and processes
LS 2: Ecosystems: Interactions, energy, and dynamics
LS 3: Heredity: Inheritance and variation of traits
LS 4: Biological evolution: Unity and diversity

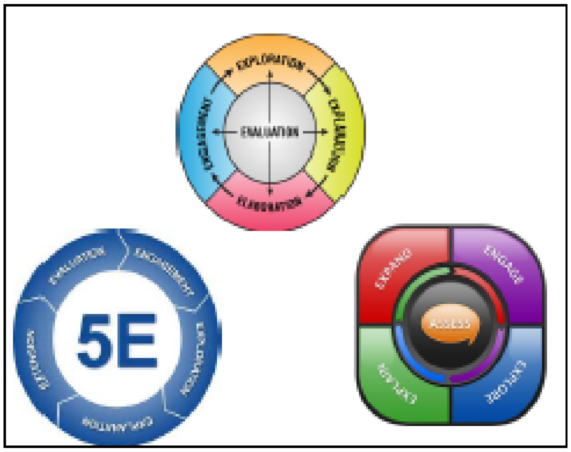
Engineering, Technology, and the Applications of Science
ETS 1: Engineering design
ETS 2: Links among engineering, technology, science, and society

Essential Features of Classroom Inquiry and Their Variations

Less ——— Learner Self-Direction ——— More
More ——— Direction from Teacher or Material ——— Less

FEATURE				
1. **Learner engages in scientifically oriented questions**	A. Learner engages in question provided by teacher, materials, or other source	B. Learner sharpens or clarifies question provided by teacher, materials, or other source	C. Learner selects among questions, poses new questions	D. Learner poses a question
2. **Learner gives priority to evidence in responding to questions**	A. Learner given data and told how to analyze	B. Learner given data and asked to analyze	C. Learner directed to collect certain data	D. Learner determines what constitutes evidence and collects it
3. **Learner formulates explanations from evidence**	A. Learner provided with evidence	B. Learner given possible ways to use evidence to formulate explanation	C. Learner guided in process of formulating explanations from evidence	D. Learner formulates explanation after summarizing evidence
4. **Learner connects explanations to scientific knowledge**	A. Learner given all connections	B. Learner given possible connections	C. Learner directed toward areas and sources of scientific knowledge	D. Learner independently examines other resources and forms the links to explanations
5. **Learner communicates and justifies explanations**	A. Learner given steps and procedures for communication	B. Learner provided broad guidelines to use to sharpen communication	C. Learner coached in development of communication	D. Learner forms reasonable and logical argument to communicate explanations

Source: National Research Council. 2000. Inquiry and the National Science Education Standards: A Guide for Teaching and Learning. Washington, DC: National Academy Press, P. 29



The Learning Cycle

Engage	*Purpose is for teachers to—* • Motivate learners to want to find out about the topic of study. • Find out about or "surface" learners' relevant prior knowledge and experiences.
Explore	*Purpose is for students to—* • Investigate the topic by collecting first- or second-hand **data.** • Use a variety of representations to identify and describe **patterns** in data.
Explain	*Purpose is for students to—* • Develop an **explanation** that can account for the patterns previously identified and/or connects to broader (more general) ideas in science. • Engage in community **discourse** about explanations; compare and critique ideas. • **Come to understand** the accepted (canonical) explanation for the phenomena/patterns.
Apply	*Purpose is for students to—* • **Use new knowledge** to predict or explain novel phenomena.
Extend	*Purpose is for students to—* • **Use & revise existing knowledge** to make sense of new phenomena.

Learning Cycle and SEPs

NGSS Science Practice	Learning Cycle stage			
	ENGAGE	EXPLORE	EXPLAIN	APPLY
(SP 1) Asking questions	√			√
(SP 2) Developing and using models			√	√
(SP 3) Planning and carrying out investigations		√		
(SP 4) Analyzing and interpreting data		√	√	
(SP 5) Using mathematics and computational thinking		√		
(SP 6) Constructing explanations			√	√
(SP 7) Engaging in argument from evidence			√	√
(SP 8) Obtaining, evaluating, and communicating information		√	√	√

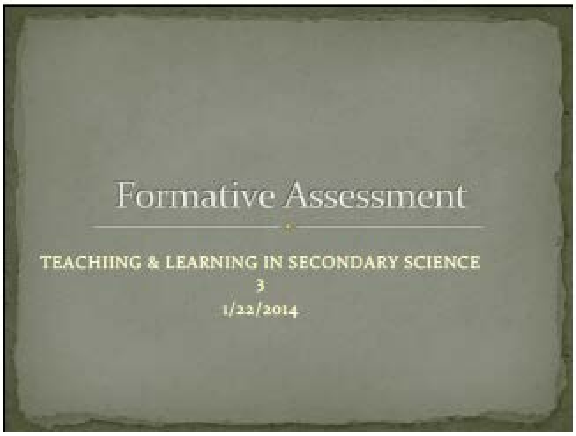
Fig. 6.2 Opportunities for students to engage in the Next Generation Science Standards practices (Achieve, Inc., 2013) throughout the stages of the Learning Cycle

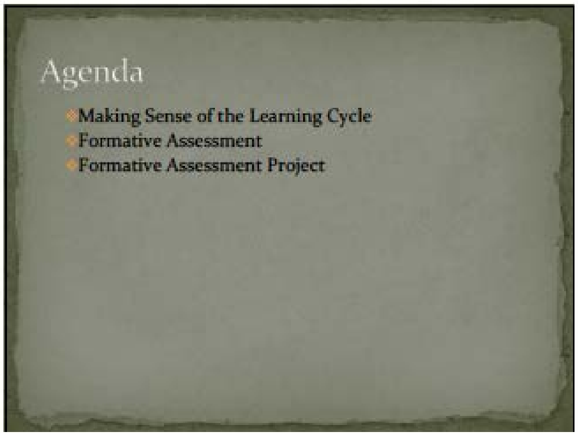
Class 3

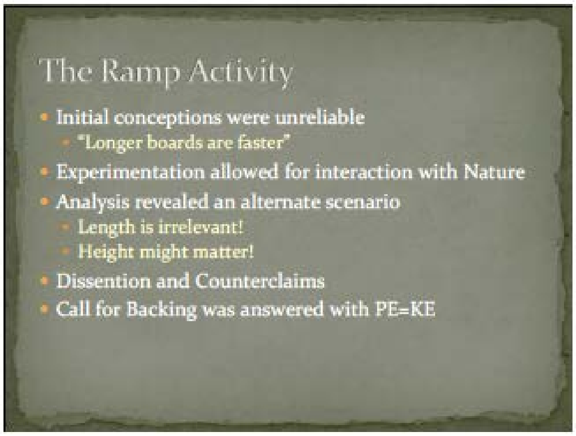
Formative Assessment

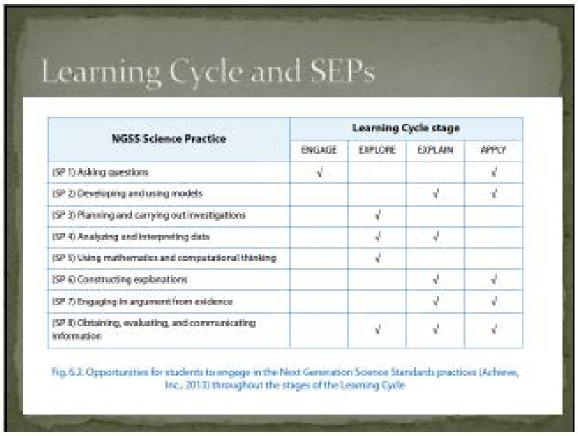
Class 3 involved an analysis of the task and Learning Cycle presented in Class 2. During the discussion, the PSTs unpack the necessary teacher preparation and teacher moves during the student work time. By examining expert modeling in detail, the instructors hoped that the PSTs would gain a better understanding of the Five Practices Model and how to plan for and enact these types of discussions in their classrooms. In addition, this session focused on formative assessment and the various monitoring tools the teacher can use to assess student thinking and understanding. This class provided the PSTs with an opportunity to examine various types of monitoring tools for formative assessment and how they might use these tools in their own classrooms.

Class 3 Slides



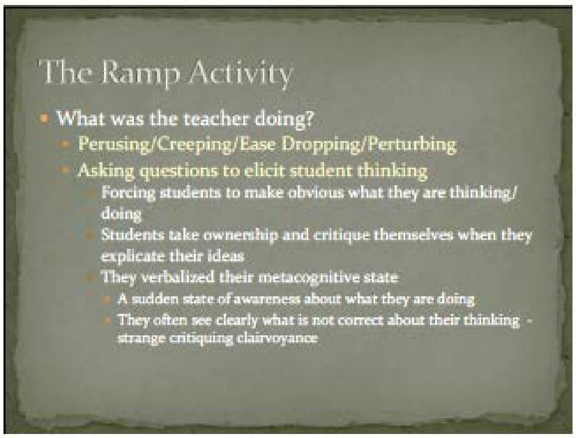


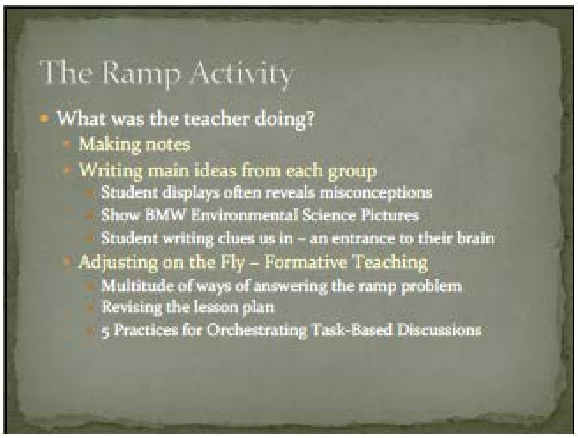




NGSS Science Practice	Learning Cycle stage			
	ENGAGE	EXPLORE	EXPLAIN	APPLY
(SP 1) Asking questions	√			√
(SP 2) Developing and using models			√	√
(SP 3) Planning and carrying out investigations		√		
(SP 4) Analyzing and interpreting data		√	√	
(SP 5) Using mathematics and computational thinking		√		
(SP 6) Constructing explanations			√	√
(SP 7) Engaging in argument from evidence			√	√
(SP 8) Obtaining, evaluating, and communicating information		√	√	√

Fig. 6.2. Opportunities for students to engage in the Next Generation Science Standards practices (Achieve, Inc., 2013) throughout the stages of the Learning Cycle





5 Practices for Orchestrating Productive Task-Based Discussions

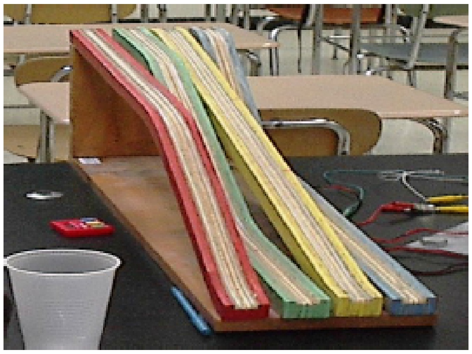
- **Anticipating** – how students are likely to respond to a task
- **Monitoring** –what students actually do as they work on the tasks in pairs or small groups
- **Selecting** – particular students to present their work during the whole-class discussion
- **Sequencing** – the student work or products that will be displayed in a specific order
- **Connecting** different students' responses and connecting the responses to key scientific ideas

Getting Real

- Anticipating
  - Students play the school game well
    - They are going to think about the previous activities
    - They will connect what you have said to activities
    - Play the opposite game
- Monitoring
  - Walking, listening, and watching what they are drawing or writing
  - Making mental notes of different ways of thinking about the problem
- Selecting
  - Which particular students should present their work

Getting Real

- Sequencing
  - The conversation can stop if a sound, well articulated description is given
    - Choosing a group with the most obvious answer is often useful
      - They have support from other students who also are thinking in a similar manner
      - They share the risk with their peers
- Connecting
  - It is important to share the credit and point out what each group contributed
  - But then it is important to point out the superior points that allowed for arriving at the best scientific explanation



Student	1st Law	2nd Law	Thinking about how to view the problem	Drawing Picture	Simplifying Problem	Limitations
Tony						
Rebecca						
Alex						
Paul						
Maggie						
Trish						
Doug						
Ray						
Tim						
Sky						
Joe						
Chris						
Todd						
Lexi						
Jenny						
Kristen						
Jake						
Mary						
Randy						
Larry						
Moon						

Assessment for Learning

- Assess First - Let it Guide Instruction
- Assessing Last - Too Late!
- Misconceptions will remain unless uncovered
  - Students often play the game of school
    - They avoid the cognitive work
    - Teachers must engineer lessons that help to expose student thinking
    - Teachers must have PCK

Assessment

- Summative testing is for ranking - not learning
- Formative Assessment is for learning
  - FA can double the learning!
  - Use halfway testing
  - Determine what the performance is first and design lessons to align to those outcomes

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Ice-cubes are added to a glass of water. What happens to the level of the water as the ice-cubes melt?

A. The level of the water drops
B. The level of the water stays the same
C. The level of the water increases
D. You need more information to be sure

Techniques for Formative Assessment

- Continuous Assessment
  - Red Cup, Green Cup
  - Small White Boards
  - A B C D E Cards
- Assessing on the fly
  - Dialogic Discourse
    - Engaging in authentic conversations
    - Unscripted
    - Not Monologic
    - Shared epistemic authority
    - Accountable Talk

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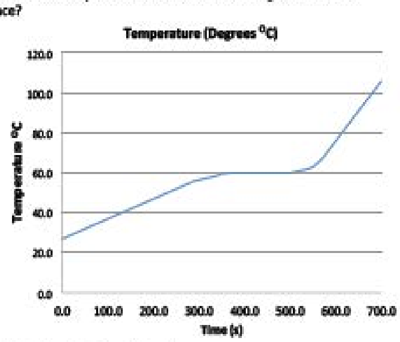
8. The purpose of generators in a power plant is to transform energy from
(A) chemical to electrical
(B) electrical to chemical
(C) mechanical to chemical
(D) mechanical to electrical

A sample of a pure solid substance is heated at a constant rate and its temperature recorded as a function of time. A graph of the data is shown below. At about what temperature is the heat added being used to melt the substance?

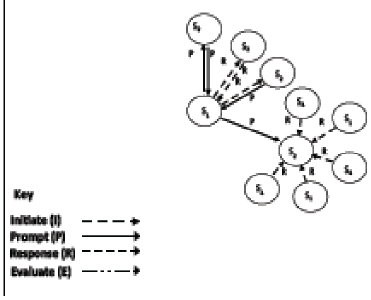
(A) 25°C
(B) 40°C
(C) 53°C
(D) 60°C
(E) 105°C



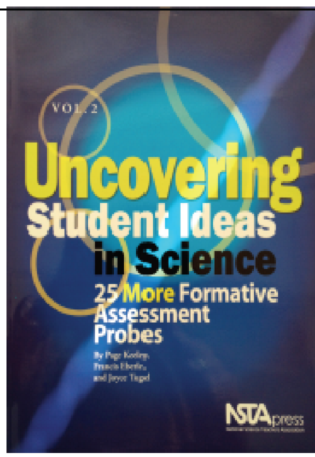
Building a Tool

- Use NGSS
  - Tension in Mixed Messages
- Use L, M, H
  - Or 1, 2, 3, 4, 5
  - 1-10
  - Create Corresponding Rubric
    - Students must know expectations
    - Justify grades

True Dialogue



Student	Mass vs. Weight	Tension is same through rope	Equal and Opposite Forces	Thinking about how to view the problem	Simplifying the Problem	Mathematical Operations
Tony						
Rebecca						
Alex						
Paul						
Maggie						
Trish						
Doug						
Ray						
Tim						
Sky						
Joe						
Chris						
Todd						
Lexi						
Jenny						
Kristen						
Jake						
Mary						
Randy						
Larry						



Long Term Project – Features and Evaluation Tool

Feature of Inquiry	Example of Feature	Codes, Comments, and Justification E - Enacted R - Reported
Scientifically Oriented Question	Student-scientists pose, refine, and evaluate scientific questions	
Scientific Claims	Student-scientists make scientific claims in an attempt to construct explanations of natural phenomena	
Problematizing the Question	Student-scientists problematize the question by making observations obvious, asking open questions, drawing diagrams, or attempting something, often while brainstorming	
Measurement Protocols	Student-scientists operationally define variables and determine how best to measure each	
Arrangement of Materials to View Nature's Behavior	Student-scientists determine how to arrange materials so as to view and capture nature's behavior (ex. design an experiment, make or use a model (physical, pictorial, mathematical, analogical, computer, etc.)]	
Variables	Student-scientists, when possible, vary only one variable why holding all other variables constant	

Long Term Project – Features and Evaluation Tool

Feature of Inquiry	Example of Feature	Codes, Comments, and Justification E - Enacted R - Reported
Minimizing Systematic and Random Errors	Student-scientists demonstrate concern for minimizing unwanted sources of variation, attempt to eliminate this variation, and determine what error is acceptable	
Collection of Data	Student-scientists determine what data is sufficient for testing the claim(s) as well as how to collect it, how much needs to be collected, and when it should be collected.	
Displaying Data to See Patterns	Student-scientists determine how best to display data to make patterns apparent and to make a convincing case for their claim	
Communicating and Justifying Explanations Publicly	Student-scientists determine what information to present to their peers, how to present it, and what are reasonable and logical arguments to justify their explanations	
Data Interpreted Through Models	Student-scientists use, create, refine and compare models to link data and explanations	

Long Term Project – Features and Evaluation Tool

Feature of Inquiry	Example of Feature	Codes, Comments, and Justification E - Enacted R - Reported
Examining and Critiquing Others Claims	Student-scientists debate the alignment of claims with natures behavior using their own data, alternative theories, models, or explanations	
Working Through Nitty-Gritty Issues	Student-scientists solve problems using creativity and logical thinking, while persevering through resistance from nature and each other	

Class 4

High Demand Tasks

The instructors divided Class 4 into two parts: High Demand Tasks and Unit Plan Work Time. Because the unit plan is not a part of this study, what follows is a description of the high demand task analysis and discussion. As you can see from the Class 4 slides below, the PSTs revisit the Learning Cycle by designing a task they might use in an assigned phase of the Learning Cycle and the role formative assessment has in that phase. After a detailed discussion related to their designed tasks, the PSTs then examine their own tasks brought in for homework. As a group, they prepare to present and discuss that task to the class, including where it might fit in the Learning Cycle, the features that make it cognitively demanding, modifications to increase cognitive demand, and ways to maintain cognitive demand during instruction.

Class 4 Slides

Teaching & Learning in Secondary Science 3

January 29 (Class 4)

High Cognitive Demand Tasks

Unit Planning – Workshop Time

Agenda

- Instructional Design in the context of the Learning Cycle
  - Important features of challenging learning tasks in LC stages
  - Strategies and resources for selection or design of learning tasks and formative assessment tasks/opportunities
- Unit Planning
  - GOAL: sketch out the unit
    - Major LGs and Objectives
    - Estimate of instructional days with major topics addressed
    - Location of Learning Cycle in overall unit
  - Work plan – who needs to do what when?
    - *Make sure that research about student thinking is high on your list of priorities!*

Designing for the Learning Cycle

Your Task

1. Summarize the LC stage you've been assigned.
2. Describe how you would go about finding or designing instructional tasks that "fit" within this stage of the LC.
   - Be explicit about key features of the tasks.
   - Suggest specific resources.
3. Describe the role of formative assessment during this stage of the LC.

Key Resources

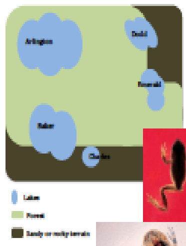
- Chapter 1, figure 1.8 from Five Practices
- Chapter 6 from the Five Practices
- Learning Cycle slides (posted in January 15th folder on courseweb)
- Notes from last week's class
- Keeley books on formative assessment probes

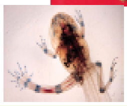
Your Instructional Tasks

Examine the instructional task/s you brought with you to class today. Choose 1 to focus your discussion as a team.

Discuss:

1. Where might this task fit in the LC? Why?
2. What are the features of this task that contribute to high cognitive demand?
3. In what ways might the task be modified to increase cognitive demand?
4. What do you need to do ***during instruction*** to ensure that you are maintaining the cognitive demand and not minimizing it?



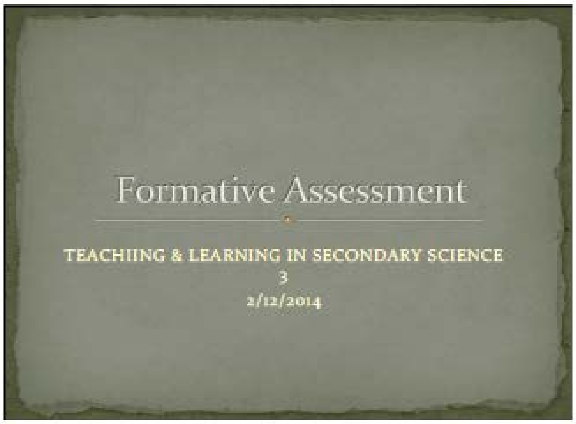


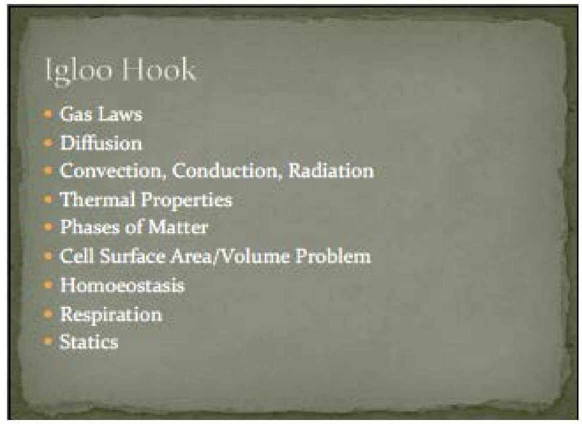
Class 6

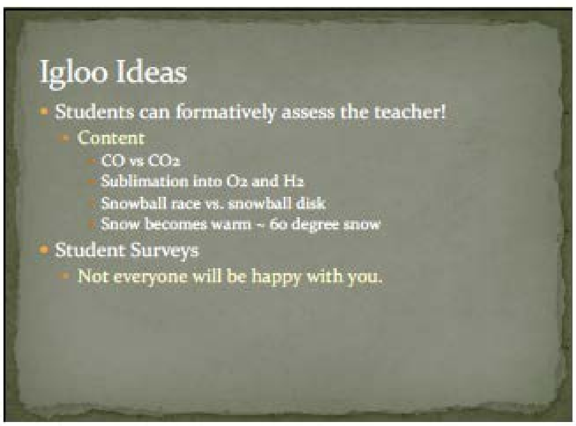
Formative Assessment

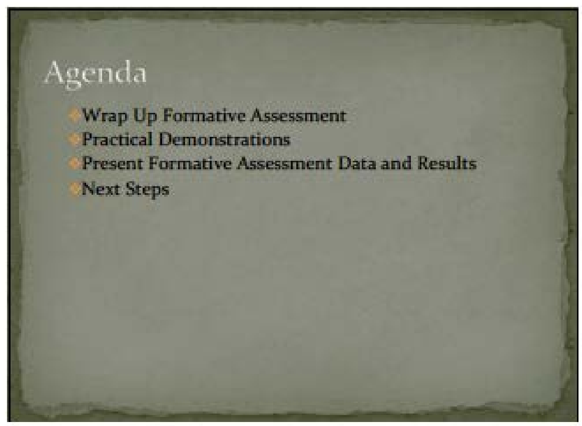
In Class 6, the PSTs revisit formative assessment and discuss the discovered affordances and drawbacks of various types they used over the past few weeks. Initially, the instructor describes various ways to engage all learners through different types of scenarios and lesson engagements. After discussing the importance of a good “hook” in providing access for all learners, the instructor uses direct instruction to review formative assessment and it’s use within the Learning Cycle and the Five Practices Model. The goal of this class was to provide a closure to these topics so that the PSTs can begin to incorporate them into their unit plans. The slides used to guide instruction follow.

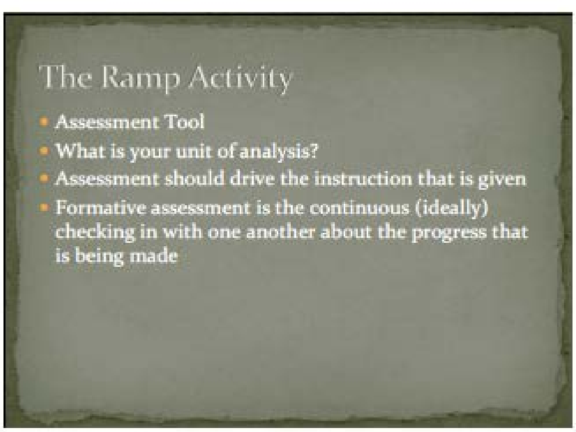
Class 6 Slides

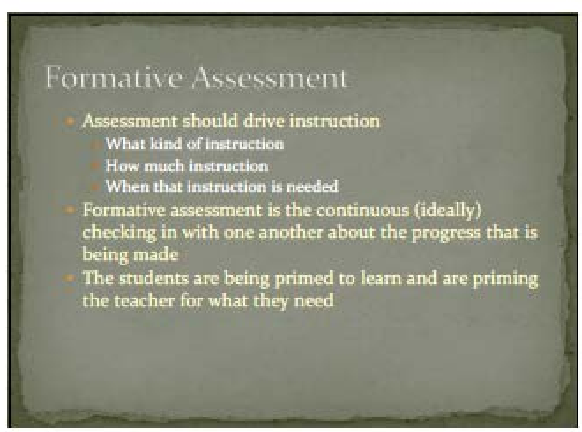












So Now What?

- Once you have data about what students know, don't know, or can and can not do…
- Now is the time to implement instruction
- If students know derivatives, there is no need to waste their time
  - Either skip it or go deeper
  - It may be time to clean-up misconceptions
    - You may be able to do a couple at a time
  - If issues are not addressed, they often will not improve
    - End of the year tests depend on instruction to alter students ideas

Why Quick Quizzes

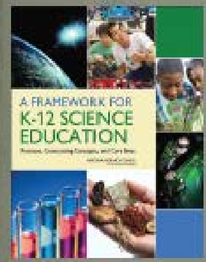
- ½ sheets of paper are cheap, small, and recyclable
- Provide a receipt or record of participation
  - students show up and then leave
- Captures thinking at a particular time
- Students get to move and talk to others
  - positive physical energy
- Electronic versions may be better
  - A, B, C, D buttons that record responses
  - Email can work
- Motivation to learn – Students are now ready to learn
- Tap into competitiveness and cooperation at the same time
- Primes for inquiry investigations
- Develops Metacognition

7 Principles of Good Feedback

1) Helps clarify good performance
2) Facilitates self-assessment (reflection)
3) Delivers information to students about their learning
4) Encourages teacher and peer dialogue around learning
5) Encourages positive motivational beliefs
6) Provides opportunities to close the gap between current and desired performance
7) Provides information to teachers that helps shape instruction

(Nicol & Macfarlane-Dick, 2006)

Next Generation Science Standards



Disciplinary Core Ideas

Physical Sciences
PS 1: Matter and its interactions
PS 2: Motion and stability: Forces and interactions
PS 3: Energy
PS 4: Waves and their applications in technologies for information transfer

Earth and Space Sciences
ESS 1: Earth's place in the universe
ESS 2: Earth's systems
ESS 3: Earth and human activity

Life Sciences
LS 1: From molecules to organisms: Structures and processes
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LS 3: Heredity: Inheritance and variation of traits
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Engineering, Technology, and the Applications of Science
ETS 1: Engineering design
ETS 2: Links among engineering, technology, science, and society

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Assess More than Content

- Science and Engineering Practices
- Habits and Dispositions
- As students are attempting to figure out the QQ, they are often meeting many of the SEPs
- You will also meet some cross-curricular goals
  - Crosscutting Concepts
  - Mathematics

Essential Features of Classroom Inquiry and Their Variations

FEATURE	Less .... Learner Self-Direction .... More More .... Direction from Teacher or Material .... Less			
1. Learner engages in scientifically oriented questions	A. Learner engages in question provided by teacher, materials, or other source	B. Learner sharpens or clarifies question provided by teacher, materials, or other source	C. Learner selects among questions, poses new questions	D. Learner poses a question
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Source: National Research Council. 2000. Inquiry and the National Science Education Standards: A Guide for Teaching and Learning. Washington, DC: National Academy Press, P. 29

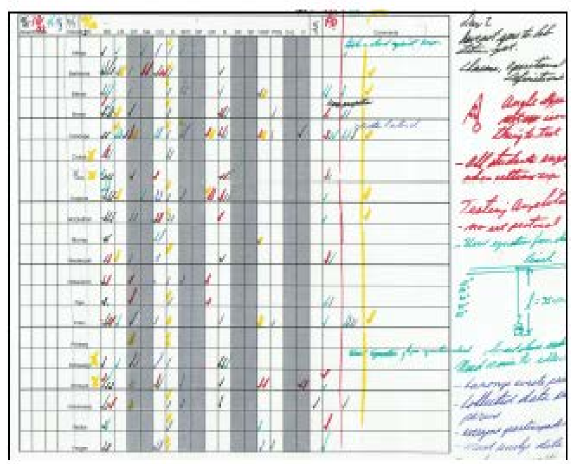
Homework Discussion Last Week

- Assess
  - Procedural
  - Conceptual
  - Meta
  - Flipped

Learning Cycle and SEPs

NGSS Science Practice	Learning Cycle stage			
	ENGAGE	EXPLORE	EXPLAIN	APPLY
(SP 1) Asking questions	√			√
(SP 2) Developing and using models			√	√
(SP 3) Planning and carrying out investigations		√		
(SP 4) Analyzing and interpreting data		√	√	
(SP 5) Using mathematics and computational thinking		√		
(SP 6) Constructing explanations			√	√
(SP 7) Engaging in argument from evidence			√	√
(SP 8) Obtaining, evaluating, and communicating information		√	√	√

Fig. 6.2. Opportunities for students to engage in the Next Generation Science Standards practices (Achieve, Inc., 2013) throughout the stages of the Learning Cycle



Informal Formative Assessment

- Maladaptive students may resist playing the education game
- Modeling is a key aspect of science
- Students exposing their thoughts allows for assessment
- Student talk is valuable

Assessment for Learning

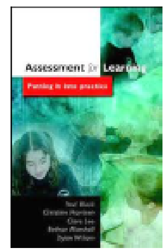
- Assess First - Let it Guide Instruction
- Assessing Last - Too Late!
- Misconceptions will remain unless uncovered
  - Students often play the game of school
    - They avoid the cognitive work
    - Teachers must engineer lessons that help to expose student thinking
    - Teachers must have PCK

5 Practices for Orchestrating Productive Task-Based Discussions

- **Anticipating** – how students are likely to respond to a task
- **Monitoring** –what students actually do as they work on the tasks in pairs or small groups
- **Selecting** – particular students to present their work during the whole-class discussion
- **Sequencing** – the student work or products that will be displayed in a specific order
- **Connecting** different students' responses and connecting the responses to key scientific ideas

Assessment

- Summative testing is for ranking - not learning
- Formative Assessment is for learning
  - FA can double the learning!
  - Use halfway testing
  - Determine what the performance is first and design lessons to align to those outcomes



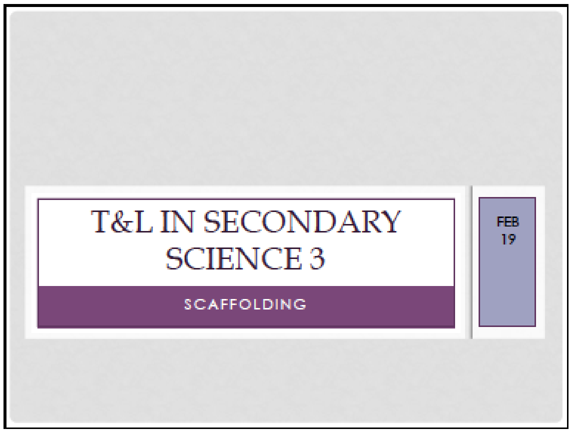
SLR	Standard Laboratory Routine	Students gather materials, report to lab table, use tools given to them, follow directions
DR	Data Recorder	Recording data (observation)
SA	Student Analyzer	Student detects patterns in data
SPS	Student Puzzle Solver	Students attempt to solve a puzzle given to them by teacher. Ex. Can you make a 1-second pendulum
SPD	Student Protocol Designer	Students attempt to operationalize a procedure
SI	Student Inquisitor	Students attempt something without explicit instruction, such as manipulating a variable. Making observations obvious, such as that the pendulum swings the to the same height each time. Asking open questions, such as what is on the middle of the that hair
ED	Experimental Designer	Attempts to persuade nature to reveal her secrets by manipulating the material agents
CP	Claim Poster	Posts a claim; Ex. I think that the pressure will increase with temperature
SPC	Student Presentation Constructors	Students determine how to present their claims, ideas, and/or data
SP	Student Presenters	Students present their work to the class or the teacher
QR	Question Responder	Students answers a non-IRE questions posed by the teacher or student, requiring complex answer (not simple yes or no)
BS	Brain Stormer	How can we build a 1-second pendulum
NGP	Nitty-Gritty Problem	Students encounter an inherent problem (not posed by the teacher, but happens as a consequence of engagement) that needs solved
SkI	Skeptical Inquisitor	Skeptically questions claims, critically questions methods
CQ	Confirmatory Questioner	Asks confirmatory questions or for confirmation about results, pushes on the student (or teacher) for more
ER	Error Reducer	Concern for minimizing errors
AoW	Accountability of Work	Has responsibility for ensuring that the work is done correctly. May have to argue to convince group of utility
OoW	Offerer of Work	Group or individual offers their work, even though they do not get points
LR	Leadership Role	Student asks if the entire class agrees with a statement, leads in forming a consensus

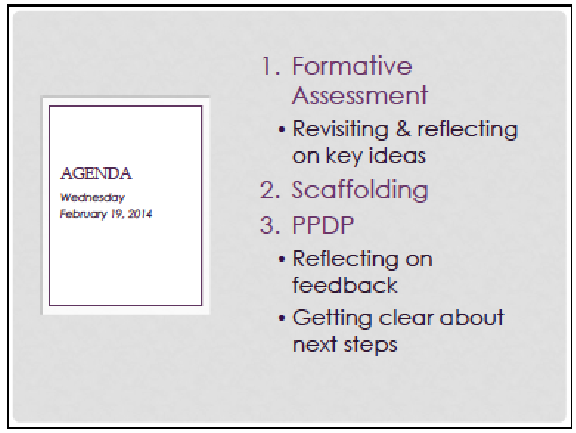
Class 7

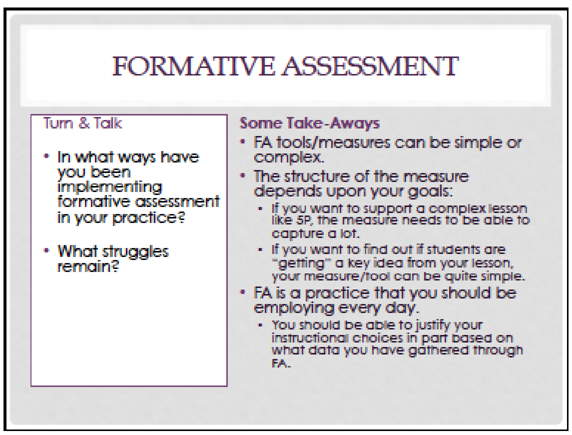
Scaffolding

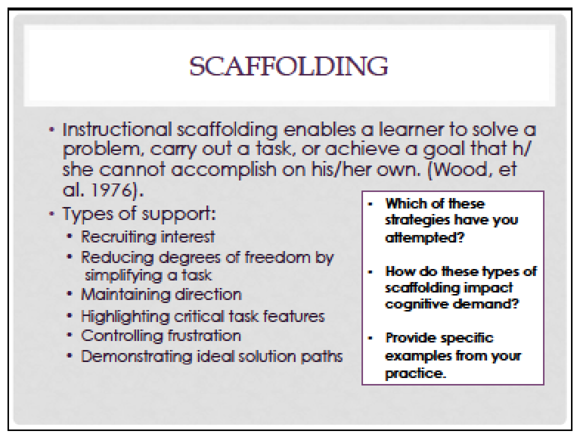
In preparation for Class 7, the PSTs read "Tools for Scaffolding Students in a Complex Learning Environment: What Have We Gained? What Have We Missed?" by Puntambekar and Hübscher (2005). Using this reading as a guide, the PSTs examined their own practice and identified the various types of scaffolds they have tried in their own teaching citing specific examples from their own practice. Further discussion involved the discussion of the ways in which these types of scaffolds impacted the cognitive demand of the task. The goal was to highlight for the PSTs that often many scaffold lower the cognitive demand instead of maintain the desired demand for students throughout the task. During the remainder of the class, the PSTs worked on their unit plans. What follows are the slides used to guide instruction.

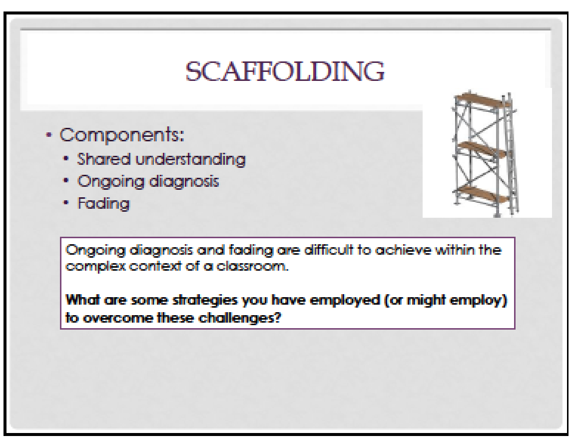
Class 7 Slides

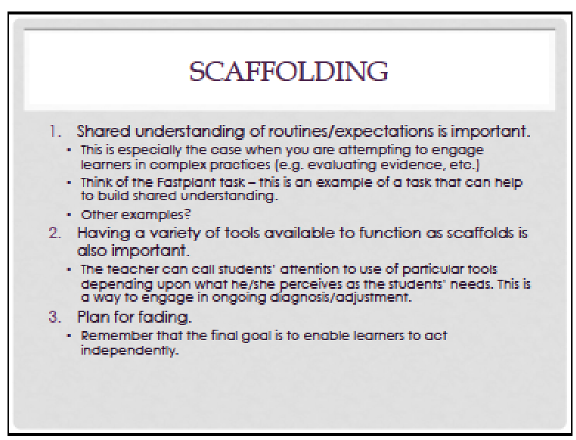










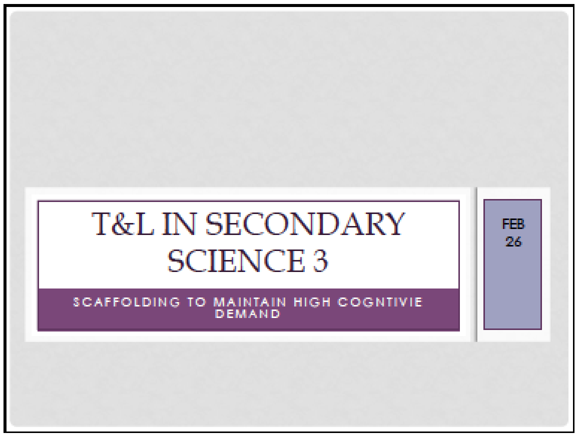


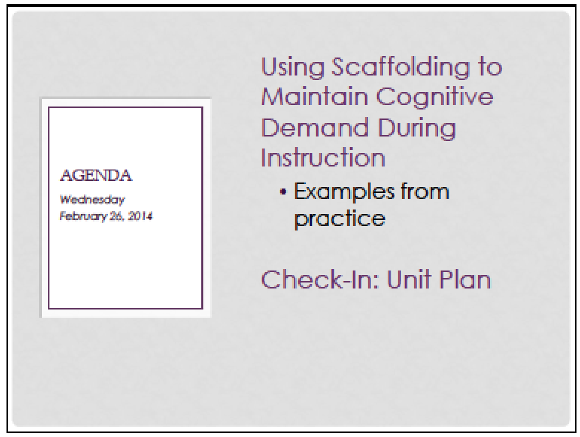
Class 8

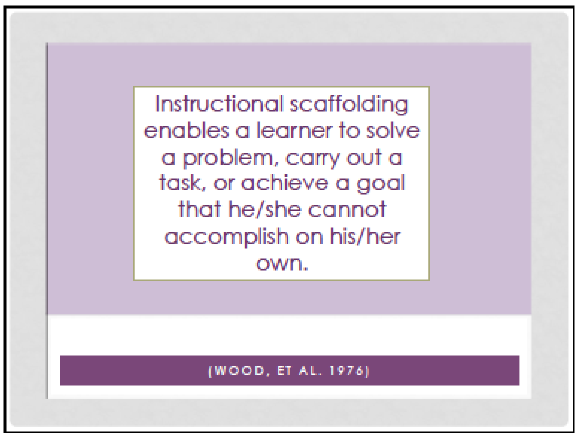
Maintaining Cognitive Demand

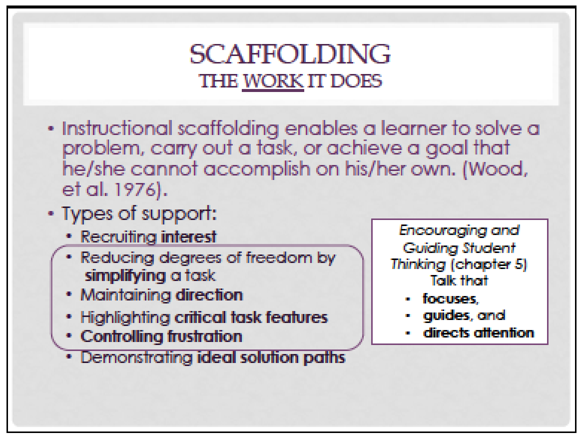
The final class on which this study focuses, Class 8, aligns directly with Class 7. The instructors told the PSTs to bring materials from a high demand task they have taught. These materials included copies of the task, marking tools, and any other representational tools used. The PSTs then discussed how they maintained the cognitive demand during this task as well as ways in which they might alter their approach. Finally, each group of PSTs selected a representative task to present to the class to further a discussion and provide additional examples of scaffolding to maintain cognitive demand. The PSTs discussed the various affordances and drawbacks of designed scaffolds and tasks. During the second half of the class, the PSTs worked on their unit plans. What follows are the slides used to guide instruction and the presentations made by each content group.

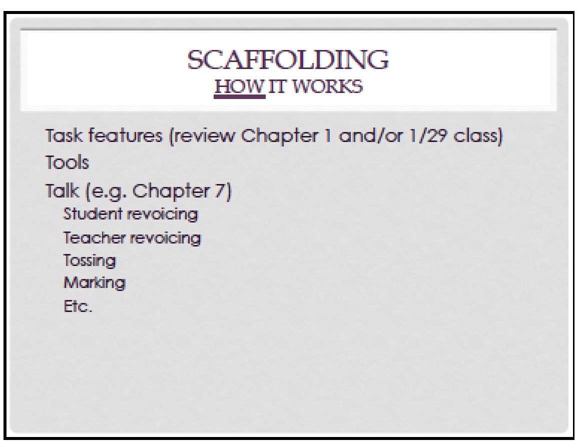
Class 8 Slides

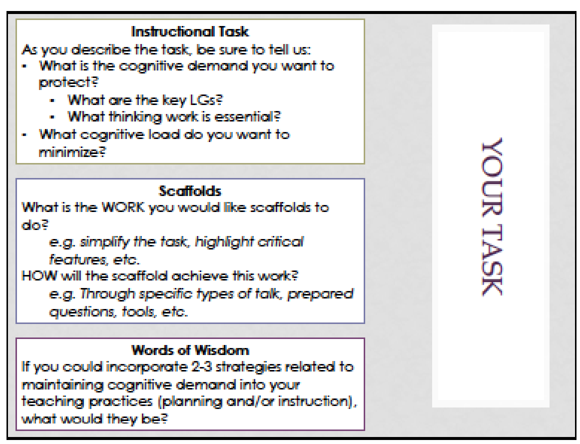


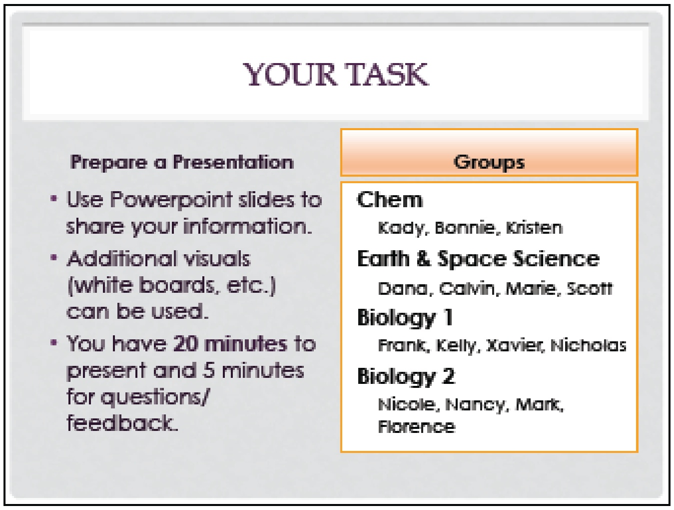




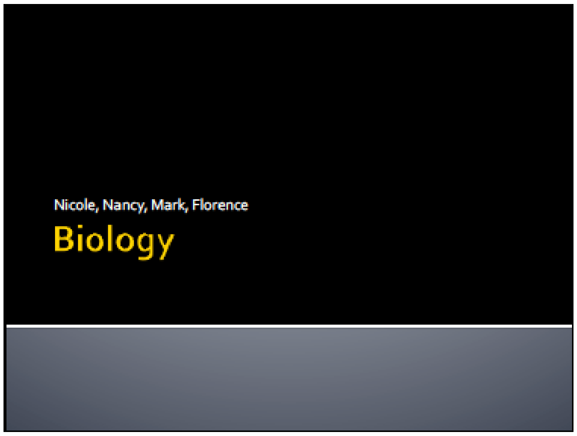


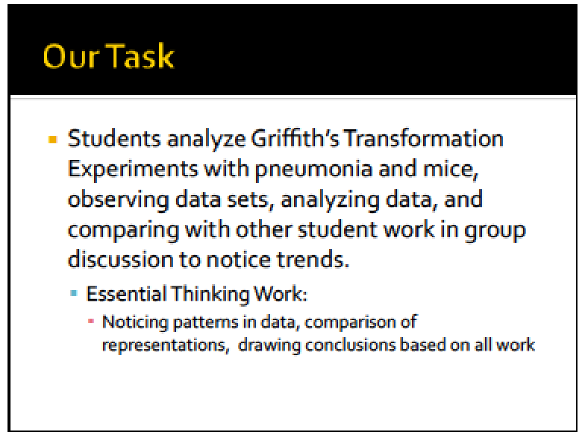


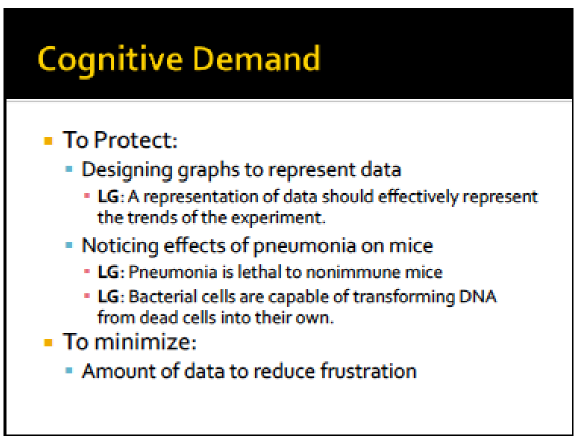


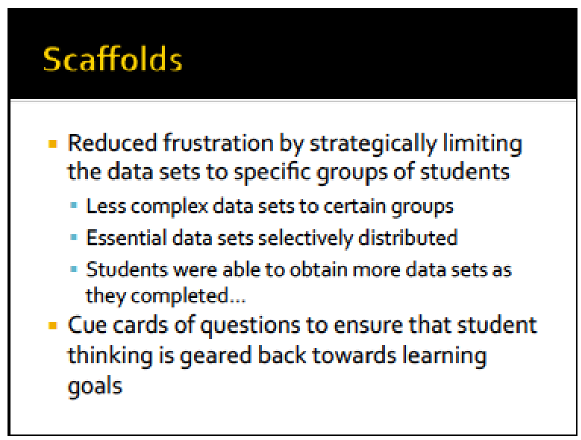

YOUR TASK
Prepare a Presentation
• Use Powerpoint slides to share your information.
• Additional visuals (white boards, etc.) can be used.
• You have 20 minutes to present and 5 minutes for questions/ feedback.
Groups
Chem
Kady, Bonnie, Kristen
Earth & Space Science
Dana, Calvin, Marie, Scott
Biology 1
Frank, Kelly, Xavier, Nicholas
Biology 2
Nicole, Nancy, Mark, Florence

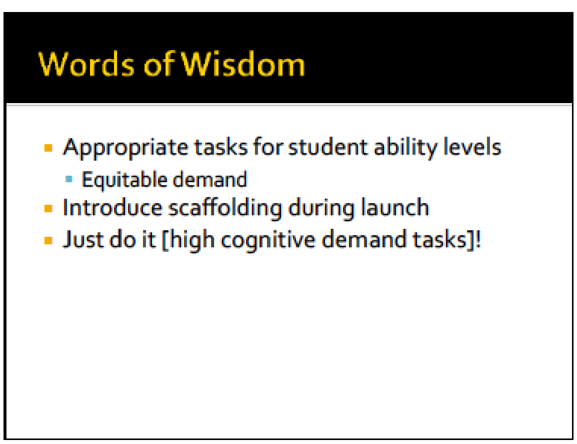
Biology Scaffolding Example



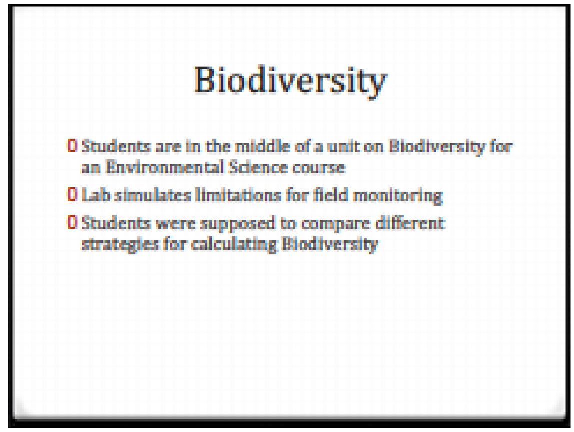


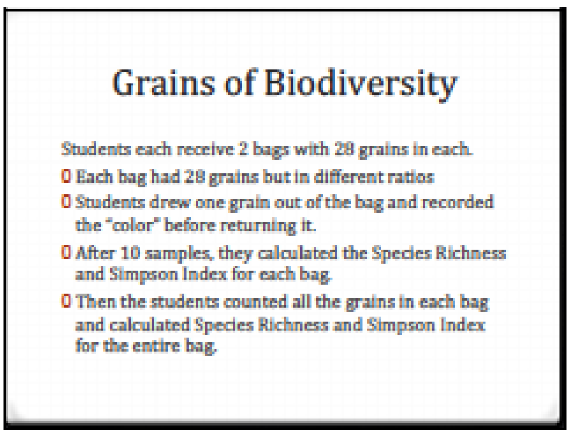


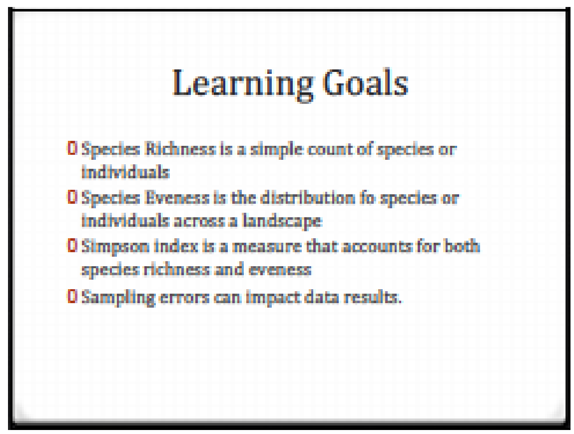


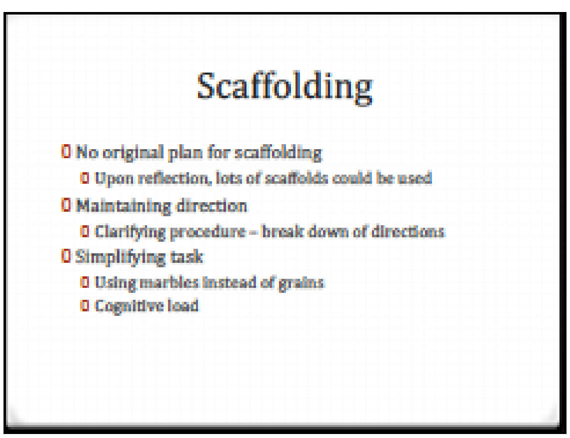


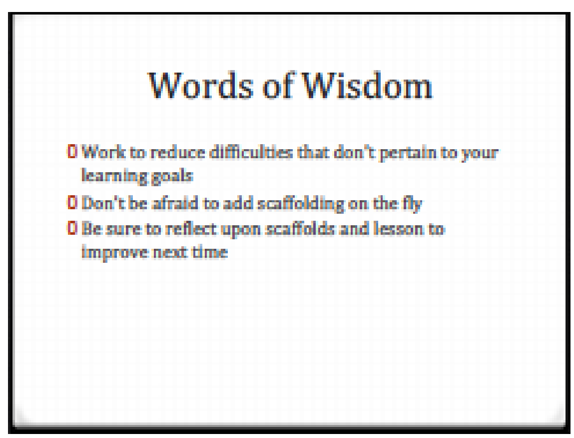
Biology Scaffolding Example #2



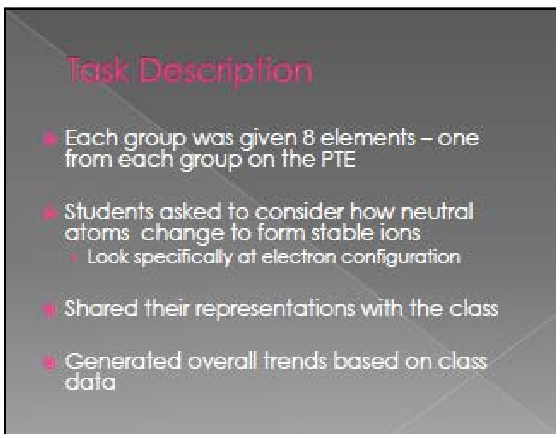


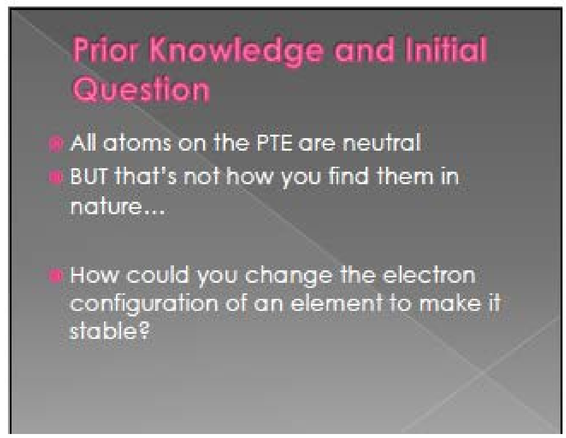


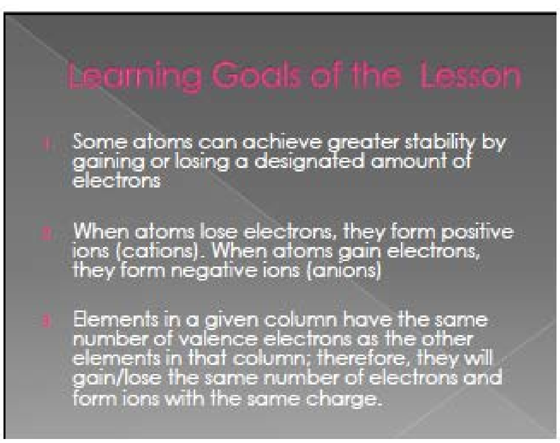


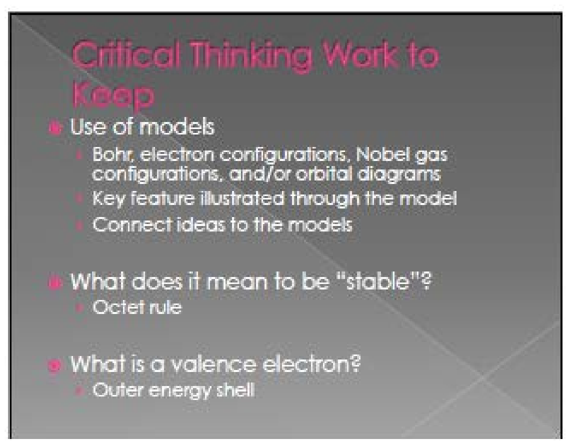


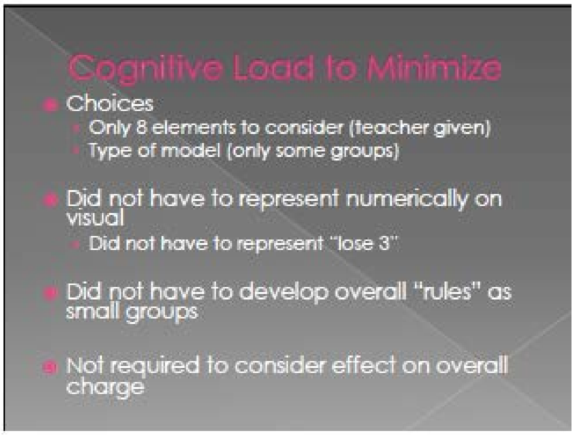
Chemistry Scaffolding Example



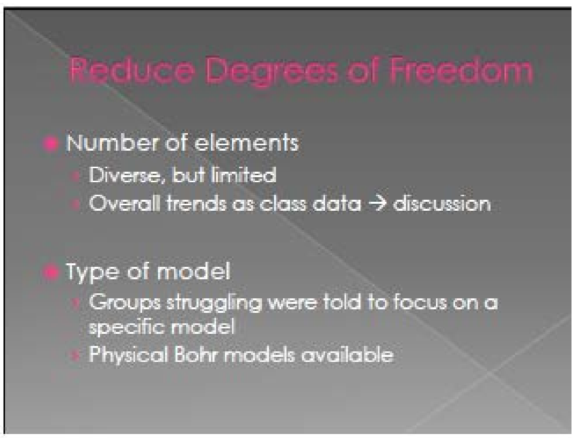


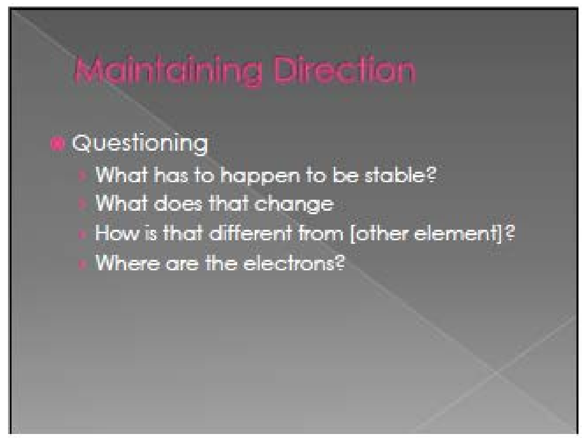


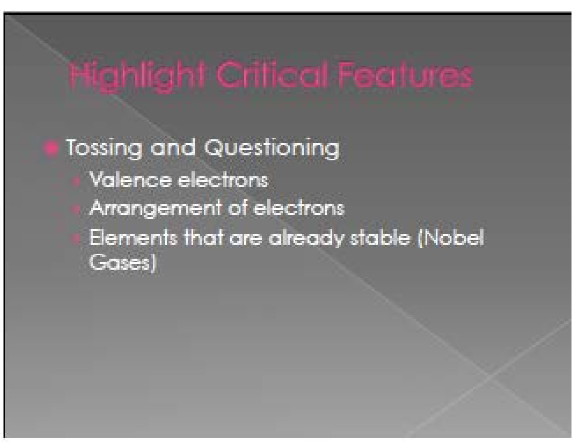


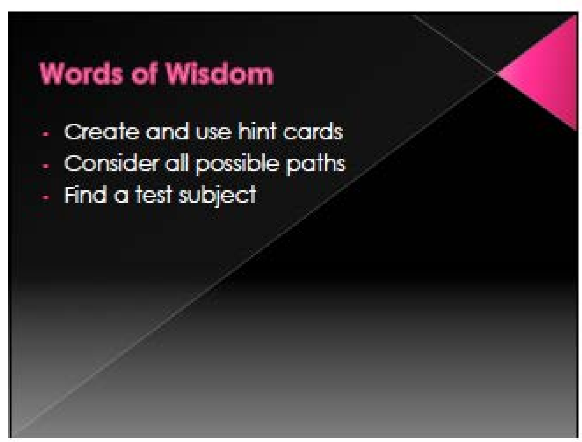

Cognitive Load to Minimize
Choices
Only 8 elements to consider (teacher given)
Type of model (only some groups)
Did not have to represent numerically on visual
Did not have to represent "lose 3"
Did not have to develop overall "rules" as small groups
Not required to consider effect on overall charge


Scaffolding the Task
The work they do, and how they work

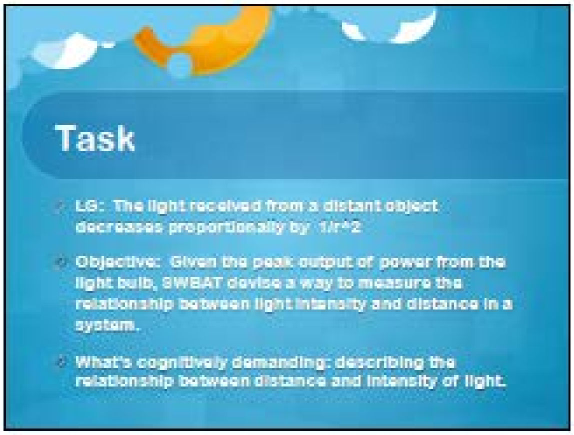

Reduce Degrees of Freedom
Number of elements
Diverse, but limited
Overall trends as class data → discussion
Type of model
Groups struggling were told to focus on a specific model
Physical Bohr models available

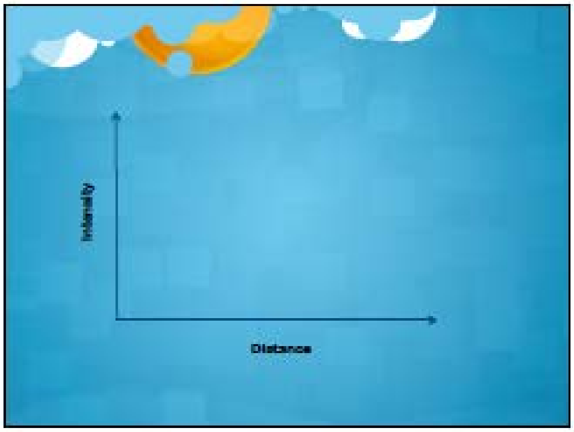

Maintaining Direction
Questioning
What has to happen to be stable?
What does that change
How is that different from [other element]?
Where are the electrons?

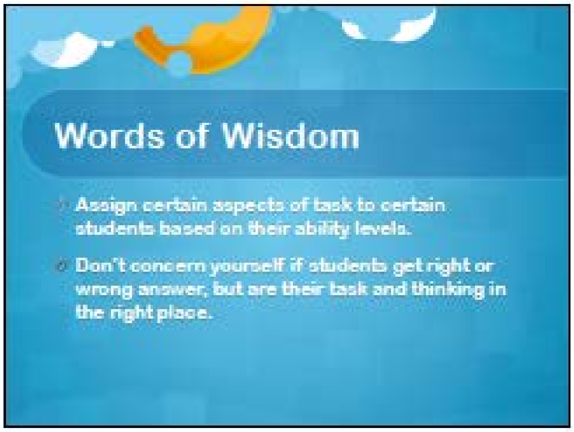

Highlight Critical Features
Tossing and Questioning
Valence electrons
Arrangement of electrons
Elements that are already stable (Nobel Gases)


Words of Wisdom
Create and use hint cards
Consider all possible paths
Find a test subject

Physics/Earth Science Example







APPENDIX B

PST TASK ANALYSIS FORM

Teacher:
Grade:
Course/Subject:
Period:
Date Lesson Taught:

PART A
Description of the Lesson

PART B
TYPE OF TASK AND POTENTIAL LEVEL OF DEMAND

CURRICULUM MATERIALS

1. Identify the Type of Science Task of this activity as it appears in the curriculum materials.
   a. Experimentation
   b. Data Representation, Analysis, & Interpretation
   c. Explanation
   d. Other
   e. Memorization

   Provide detail and examples to justify your explanation.

2. Using the STAT analysis tool, identify the level of cognitive demand in the **curriculum materials.**

Type of Task	Demand of Task (High/Low)	
Experimentation		
Data Representation, Analysis, & Interpretation		
Explanation		

Provide detail and examples to justify your answer regarding this task as it appears in the curriculum materials.

PST TASK ANALYSIS FORM (Completed)

PST TASK ANALYSIS FORM

Teacher: Ms. Nicole Timko
Grade: 9
Course/Subject: Biology
Period: 7
Date Lesson Taught: Oct. 25, 2013

PART A
Description of the Lesson

Cell Membrane Model – students complete models of the cell membrane. Big Idea – all living things are composed of cells.

PART B
TYPE OF TASK AND POTENTIAL LEVEL OF DEMAND

CURRICULUM MATERIALS

1. Identify the Type of Science Task of this activity as it appears in the curriculum materials.
   a. Experimentation
   b. Data Representation, Analysis, & Interpretation
   c. Explanation
   d. Other
   e. Memorization

   Provide detail and examples to justify your explanation.

***This task is an explanation task because students are explaining the structure of a cell. It is at the lowest level an explanation task. Students are explaining what they have learned regarding the structures of the cell and how it related to their own models and representations.**

2. Using the STAT analysis tool, identify the level of cognitive demand in the **curriculum materials.**

Type of Task	**Demand of Task (High/Low)**	
Experimentation		
Data Representation, Analysis, & Interpretation		
Explanation	Low Level Explanation Task – students are explaining already learned ideas about the cell and cell model.	

Provide detail and examples to justify your answer regarding this task as it appears in the curriculum materials.

See above for description

APPENDIX C

THE SCIENCE TASK ANALYSIS TABLE[10]

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

	Low		High	
	Tasks	***Lesson Plan***	***Tasks***	***Lesson Plan***
Experimentation	Students— • follow a **highly specified** procedure. • Do not make choices about what data to collect or how to collect it. • Are not engaged in being critical about the data collection procedure.	The teacher— • provides no evidence of planning to support students' understanding that data collection is occurring in the service of answering a question.	Students — • must **make decisions** about **what** data to collect and/or **how** to collect it. • **compare/contrast or critique** experimental protocols, considering issues such as reliability and "fit" between data gathered and the underlying question driving the experiment.	The teacher— • provides evidence of planning that ensures students are supported in understanding how their data collection must help them achieve the goal of answering a particular question.
Data Representation, Analysis & Interpretation	Students— • **follow specific instructions** about how to transform *(e.g. calculate the mean temperature)* and/or represent data *(e.g. draw a bar graph)*. • **answer specific questions** about the data *(e.g. In which city is the average monthly temperature highest?)*.	The teacher — • provides evidence of plans to accept only very specific representation types or strategies.(i.e. multiple solutions or strategies are not possible). • provides no evidence of planning to press for students to justify their answers using the data representations.	Students— • **seek to describe** general (e.g. the *s*-shaped growth curve of Fastplants) and specific (e.g. trematode infection is 4-5 times higher in Charles, Emerald, and Baker ponds than in other ponds) **patterns** that are evident in the data. • **select what** data to represent and/or **how** to represent it. • **compare/contrast** various representations, considering issues such as the ease with which various patterns or relationships can be visualized.	The teacher — • provides evidence of planning to provide opportunities for students to share and discuss a variety of data representations. • provides evidence of planning to require students to provide a rationale for the choices they have made related to transforming or representing data. • provides evidence of planning to require students to identify specific data or elements of data representations that provide evidence for the patterns/trends they've identified.
Explanation	Students— • **provide explanations without justification** or specific connection to data. • **repeat factual knowledge** previously learned.	The teacher— • provides evidence of planning to request discrete answers to questions without justification *(e.g. What causes a solar eclipse? [answer] The Moon blocking the Sun.)*	Students — • **provide explanations with justification**. • are engaged in **developing new explanatory knowledge**. • **are critical** of the explanations offered by others, requesting clarification and supporting evidence when appropriate. • **draw upon a variety of representational tools** (e.g. diagrams, tables, simulations, etc.) to communicate with peers.	The teacher— • provides evidence of planning to press students to provide explanations and to justify their assertions. • provides evidence of planning for opportunities for students to share and critique one another's explanations. • provides evidence of planning to encourage students to use a variety of tools to communicate (e.g., questions, reminders).

APPENDIX D

TASK AND LESSON PLAN CODING RUBRICS

D.1 ELEMENTS OF A HIGH-LEVEL TASK SCORING RUBRIC (HLTR)

Elements of a High-Level Task	No Evidence/Low Score = 0	Medium Score = 1	High Score = 2
Defined Lesson Goal/Objective in Lesson Plan	No Goal exists or Lists Performance Goal(s) only	Lists Performance Goal(s) **and** General Learning Goal(s)	Lists Performance Goal(s) **and** Specific Learning Goal(s) or only Specific Learning Goal(s)
Demand of Task	No task provided or task provided is insufficient to assess	Experimentation, Data Analysis/Interpretation, or Explanation task at **Low** level **or** any task at low level	Experimentation, Data Analysis/Interpretation, or Explanation task at **High** level
Support of student engagement *NGSS* Science and Engineering Practices	Evidence of support of student engagement in SEPs does not exist	N/A	Evidence of support of student engagement in SEPs
Task as designed supports student engagement in productive whole class discussion	Evidence of task supporting whole class discussion does not exist	Task allows students to provide explanations and ideas without justification or evidence	Task allows students to share and discuss their thinking using artifacts created as a result of the task
Students create artifacts as a result of the task	Evidence of students creating artifact as a result of the task does not exist	Students can create only one artifact as a result of the task	Students can create multiple artifacts as a result of the task

D.2 ELEMENTS OF A LESSON PLAN THAT SUPPORTS DISCUSSION SCORING RUBRIC (LPDR)

Elements of a Lesson Plan that Supports Discussion	No Evidence Score = 0	Low Score = 1	Medium Score = 2	High Score =3
Anticipates Students' Correct Thinking	Evidence of anticipating students' correct thinking does not exist	Vaguely describes correct thinking students may use when working on the task OR describes what students might do and/or notice during the task	Specifically describes at least one correct strategy/idea students may use when working on the task. But, the strategies/ideas do describe the various ideas/features/representations students produce as a result of the task	Specifically describes correct ideas/thinking students may use when working on the task AND there is an attempt to identify the various possible strategies or representations students may produce
Anticipates Students' Incorrect or Incomplete Thinking	Evidence of anticipating students' incorrect or incomplete thinking do not exist	Vaguely describes incorrect thinking students may use when working on the task or vaguely describes incomplete ideas students may have about the task OR describes what students might NOT do and/or NOT notice during the task	Specifically describes at least one incorrect way students may think about the task or specific question students might ask or difficulty students may have as they work on the task. However, the challenges and misconceptions do not represent an attempt to describe the many challenges or misconceptions that students may have	Specifically describes incorrect ways in which students may think about the task or specific questions students may ask or difficulties students may have as they work on the task AND there is an attempt to identifying the many challenges or misconceptions students may encounter with the given task
Plans for Monitoring Student Work on the Task	Evidence of plans for monitoring do not exist	Includes plans to "circulate around the room" or observe students as they work does not provide a monitoring tool	Includes a blank monitoring tool without anticipated ideas/student responses	Includes a monitoring tool with anticipated ideas/student responses or approaches to the task

Plans Questions to Elicit, Challenge, or Extend Students' Thinking	Evidence of specific example questions do not exist	Provides a specific example question to ask students, but the circumstances in which the question will be asked is not detailed, not appropriate, or not designed to advance scientific thinking	Provides several example questions to ask students, and includes the appropriate circumstances in which the question will be asked	N/A
Plans for a Storyline for How the Discussion Unfolds	Evidence of a storyline or specific plans for how the discussion unfolds does not exist	Provides an outline of the ideas/concepts and the order in which they will emerge	Provides a vague script for how the discussion unfolds, however ideas/scientific concepts are missing	Provides a detailed script including questions and/or answers teacher and students will ask AND script follows logical order of scientific ideas
Plans to make connections between students' ideas and to disciplinary ideas	Evidence of a connections between students' ideas and to disciplinary ideas or specific plans for how the discussion unfolds does not exist	Provides an outline of strategies/idea, but no clear connection between conceptual ideas, representations, or students' ideas etc.	Provides plans to address how key ideas are represented differently in various representations. No clear connection made between conceptual ideas and student strategies.	Provides a detailed script or plans to support students to form connections between the shared strategies and between the shared strategies and representations and the underlying conceptual ideas, e.g., discussion of: the pros and cons of various strategies/representations, how a key idea is represented differently in the various representations and between the shared strategies and representations and the underlying conceptual ideas, the pros and cons of various strategies/representations

Purposefully Selects and Sequences the Ideas that Will Emerge During the Discussion	Evidence of selecting and sequencing ideas that will emerge does not exist	Indicates student ideas/approaches will be selected during enactment, but does not detail sequence in lesson plan	Provides purposeful selecting and sequencing of specific ideas and/or student representations/approaches that will emerge during the discussion, however ideas do not build on each other in a meaningful way	Provides one or more purposeful selecting and sequencing of specific ideas and/or student representations/approaches that will emerge during the discussion and ideas build on each other in a meaningful way
Plans Marking Strategies to Highlight Important Ideas	Evidence of marking strategies do not exist	Vaguely describes the important ideas that will be marked during the discussion <u>or</u> does not provide the many important ideas	Provides the many specific student ideas, scientific ideas, etc. that will be highlighted during discussion, but does not provide marking tool/table/representation that will be created	Provides the many specific student ideas, scientific ideas, etc. that will be highlighted during discussion by creating a marking tool/table/representation of ideas <u>AND</u> noting those ideas during storyline

D.3 COMPLETED ELEMENTS OF A HIGH-LEVEL TASK AND ELEMENTS OF A LESSON PLAN THAT SUPPORTS DISCUSSION SCORING RUBRICS

Participant Name: Kelly Hendrick

Coder Name: Danielle Ross

Lesson: DNA Structure and the Cell Cycle

Date of Lesson Plan: 10/22/13 Instructional Performance 1

High Level Task Rubric Score	**10**
Lesson Plan Supporting Discussion Rubric Score	**21**
Total Score	**31**

Elements of a HIGH LEVEL Task Scoring Rubric
Maximum Possible Score (HLTR) = 10

Elements of a High-Level Task	No Evidence/Low Score = 0	Medium Score = 1	High Score = 2	Score Assigned (0, 1, 2)	Provide Evidence of Rationale for Assigned Score
Defined Lesson Goal/Objective in Lesson Plan	No Goal exists or Lists Performance Goal(s) only	Lists Performance Goal(s) **and** General Learning Goal(s)	Lists Performance Goal(s) **and** Specific Learning Goal(s) or only Specific Learning Goal(s)	2	**Performance Goals and Specific Learning Goals are provided. They are very detailed – LG " the cell cycle includes…"**
Demand of Task	No task provided or task provided is insufficient to assess	Experimentation, Data Analysis/Interpretation, or Explanation task at **Low** level **or** any task at low level	Experimentation, Data Analysis/Interpretation, or Explanation task at **High** level	2	**Students observe data and analyze the phase of mitosis the cell is in most of the time. There is a clear question –" Where does the cell spend most of its time?" That the students are answering.**
Support of student engagement *NGSS* Science and Engineering Practices	Evidence of support of student engagement in SEPs does not exist	N/A	Evidence of support of student engagement in SEPs	2	**Analyzing data and constructing explanations.**
Task as designed supports student engagement in productive whole class discussion	Evidence of task supporting whole class discussion does not exist	Task allows students to provide explanations and ideas without justification or evidence	Task allows students to share and discuss their thinking using artifacts created as a result of the task	2	**This task could lead to a productive discussion, There is clear planning for what the teacher will say and what the students will say.**
Students create artifacts as a result of the task	Evidence of students creating artifact as a result of the task does not exist	Students can create only one artifact as a result of the task	Students can create multiple artifacts as a result of the task	2	**Students generate a representation as a result of the task depending on their choice – bar, line graph, etc.**

Elements of a Lesson Plan that Supports Discussion Scoring Rubric
Maximum Score Possible (LPDR) = 23

Elements of Lesson Plan Supporting Discussion	No Evidence Score = 0	Low Score = 1	Medium Score = 2	High Score =3	Score Assigned (0, 1, 2, 3)	Provide Evidence of Rationale for Assigned Score
Anticipates Students' Correct Thinking	Evidence of anticipating students' correct thinking does not exist	Vaguely describes correct thinking students may use when working on the task **OR** describes what students might do and/or notice during the task	Specifically describes at least one correct strategy/idea students may use when working on the task. But, the strategies/ideas do describe the various ideas/features/representations students produce as a result of the task	Specifically describes correct ideas/thinking students may use when working on the task **AND** there is an attempt to identify the various possible strategies or representations students may produce	**3**	**Anticipates students correct thinking regarding the pie chart. Pg. 5**
Anticipates Students' Incorrect or Incomplete Thinking	Evidence of anticipating students' incorrect or incomplete thinking do not exist	Vaguely describes incorrect thinking students may use when working on the task or vaguely describes incomplete ideas students may have about the task **OR** describes what students might NOT do and/or	Specifically describes at least one incorrect way students may think about the task or specific question students might ask or difficulty students may have as they work on the task. However, the challenges and misconceptions do not represent an attempt to describe the many	Specifically describes incorrect ways in which students may think about the task or specific questions students may ask or difficulties students may have as they work on the task **AND** there is an attempt to identifying the many challenges or misconceptions students may encounter with the given task	**3**	**Clearly explains the possible representations and what each says about students' understanding. "I anticipate that several groups will make a bar graph with each phase given being a different bar. This approach does work and shows the data, but it perhaps might not be the best**

		NOT notice during the task	challenges or misconceptions that students may have			**answer to the question. Ask the students why they think this design best shows the answer to the question?"**
Plans for Monitoring Student Work on the Task	Evidence of plans for monitoring do not exist	Includes plans to "circulate around the room" or observe students as they work does not provide a monitoring tool	Includes a blank monitoring tool without anticipated ideas/student responses	Includes a monitoring tool with anticipated ideas/student responses or approaches to the task	**3**	**There is a monitoring tool with the specific student anticipated approaches in the tool.**
Plans Questions to Elicit, Challenge, or Extend Students' Thinking	Evidence of specific example questions do not exist	Provides a specific example question to ask students, but the circumstances in which the question will be asked is not detailed, not appropriate, or not designed to advance scientific thinking	Provides several example questions to ask students, and includes the appropriate circumstances in which the question will be asked	N/A	**2**	**There are clear questions to elicit, extend, or challenge students' thinking and she also describes the circumstances in which these questions will be asked (see anticipating above for an example).**
Plans for a Storyline for How the Discussion	Evidence of a storyline or specific plans for how the	Provides an outline of the ideas/concepts and the order in	Provides a vague script for how the discussion unfolds, however	Provides a detailed script including questions and/or answers teacher and students will ask	**3**	**There is clear evidence of a storyline for the discussion and it has**

Unfolds	discussion unfolds does not exist	which they will emerge	ideas/scientific concepts are missing	<u>**AND**</u> script follows logical order of scientific ideas		**a logical progression of ideas.**
Plans to make connections between students' ideas and to disciplinary ideas	Evidence of a connections between students' ideas and to disciplinary ideas or specific plans for how the discussion unfolds does not exist	Provides an outline of strategies/idea, but no clear connection between conceptual ideas, representations, or students' ideas etc.	Provides plans to address how key ideas are represented differently in various representations. No clear connection made between conceptual ideas and student strategies.	Provides a detailed script or description to support students to form connections between the shared strategies and between the shared strategies and representations and the underlying conceptual ideas, e.g., discussion of: the pros and cons of various strategies/representations, how a key idea is represented differently in the various representations and between the shared strategies and representations and the underlying conceptual ideas, the pros and cons of various strategies /representations	**3**	**Clear connections planned between the ideas and the disciplinary ideas by asking what is the best representation, etc.**
Purposefully Selects and Sequences the Ideas that Will Emerge During the Discussion	Evidence of selecting and sequencing ideas that will emerge does not exist	Indicates student ideas/approaches will be selected during enactment, but does not detail sequence in lesson plan	Provides purposeful selecting and sequencing of specific ideas and/or student representations/approaches that will emerge during the discussion,	Provides one or more purposeful selecting and sequencing of specific ideas and/or student representations/approaches that will emerge during the discussion and ideas build on each other in a meaningful way	**3**	**There is a clear order for the discussion starting with line graphs and ending with pie charts. This seems to be a clear logical progression of ideas.**

			however ideas do not build on each other in a meaningful way			
Plans Marking Strategies to Highlight Important Ideas	Evidence of marking strategies do not exist	Vaguely describes the important ideas that will be marked during the discussion **<u>or</u>** does not provide the many important ideas	Provides the many specific student ideas, scientific ideas, etc. that will be highlighted during discussion, but does not provide marking tool/table/representation that will be created	Provides the many specific student ideas, scientific ideas, etc. that will be highlighted during discussion by creating a marking tool/table/representation of ideas **<u>AND</u>** noting those ideas during storyline	**1**	**Evidence of a clear marking strategy is not provided. She does vaguely state that she will write down what certain groups and students say, but doesn't clearly indicate how or what.**

APPENDIX E

INTERVIEW PROTOCOLS

E.1 INTERVIEW PROTOCOL FOR INTERVIEW 1[11]

Time when Interview was started: ___________

PART 1 – What should be in a lesson plan?

- **For the first part of the interview, please describe the resources you used when planning your first lesson plan.**
- **Ok, please tell me about the things you believe you should think about or consider when planning a science lesson.**
  - Can you say more about (item that is unclear or brief)?
  - What do you mean by (term they used)?

PART 2 – The PSTs' lesson planning practices during the first semester of the teacher preparation program.

- **Ok, now I would like to ask you some questions related to your lesson planning in general.**
- **I'd like you to talk about the things that influence your planning. So I'll start by asking, how do you decide what to include/not include in a lesson plan?**
  - **What role does your textbook or curriculum play in your planning?** *(sub-prompts, if needed, may include: "How do you use your textbook or curriculum when you plan?", "Does the textbook or curriculum influence your planning in any way?, if so, in what ways?")*
  - **What other resources do you use when planning lessons?** *(prompts, if needed,*

[11] Adapted from Hughes, E.K. (2006). *Lesson planning as a vehicle for developing pre-service secondary teachers' capacity to focus on students' mathematical thinking.* (Unpublished doctoral dissertation). University of Pittsburgh, Pittsburgh, PA.

may include: "Besides the curriculum materials, do you seek out or use other resources when planning? Do these resources influence your planning in any way, if so how?")

  - **What role does your mentor teacher play in your planning?** *(sub-prompts, if needed, may include: "Do you discuss your lesson plans with your mentor teacher?", "Have you planned lessons together?", "What kinds of things have you discussed with your mentor teacher, with respect to lesson planning?")*
  - **What role does your university supervisor play in your planning?** *(sub-prompts, if needed, may include: "Do you discuss your lesson plans with your university supervisor?", "Have you planned lessons together?", "What kinds of things have you discussed with your university supervisor, with respect to lesson planning?)* **In what ways are the lesson plans you provide for your university supervisor similar and different from those you usually produce?**
  - **What other things influence your planning?** *Move on only after teachers have offered as many factors as they can.(these could include such things as: time constraints (either in the time they have to devote to planning or in the time they have to teach something), things they are learning/doing in their teacher education program, their beliefs about what it means to learn and do mathematics and about students, resources available, PSSA, parents, students, etc.).*
  - **Do you believe your planning has changed in any ways, over the course of this semester?** *If yes, then* **Can you describe the ways in which your planning has changed?**
  - **Are there any other ways in which you believe your planning has changed?**
  - **Is there anything else you would like to say about your lesson planning?**

PART 3 – Talking about instructional performances the teacher has written:

(Prior to the interview, teachers were asked to bring a the instructional performances they completed during the semester. For each IP, you will proceed through this section of questions.)

- **For this part of the interview, I'd like to discuss the lesson plans that you were asked to bring with you today. First I'd like to ask a few questions about the lesson and then I would like for you to talk in more detail about the lesson plan you've written.**
  - **What class/course is this lesson plans for? How many sections of the course do you teach? Which period(s)?** *(be sure to get the Subject of the course (e.g., Biology, Life Science, Conceptual Physics, etc.) & have them explain any descriptors, such as PPS, AP, Honors, etc.)*
  - **How long have you been teaching this course and section?**
  - **How long have you been making lesson plans for this course and section?** *(be sure to distinguish between teaching and planning)*
  - **Earlier, you identified some things that influence your planning. I'd like to ask about the role they played in planning this specific lesson. For example,…***Referring to things the teacher identified in Part 2 of the interview that influence their planning, ask if these were factors present in planning this lesson by using the following prompts as appropriate:*

- **In what ways did you use your textbook in planning this lesson?**
- **Did you plan this lesson with your mentor teacher?**
- **Did you plan this lesson with your university supervisor?**
- **In what ways did you use the "Learning Cycle" in planning this lesson?**
- **In what ways did you use the "Five Practices" in planning this lesson?**
- **Now I'd like you to walk me through this lesson plan, providing as much detail as possible about your thinking when you planned it?**
- *Probes: You should probe on anything related to the four key elements of planning a high-level task and supporting a discussion*

- Use the general probes below to offer teachers an opportunity to provide more specificity if they are thinking about one or more of these elements, but do not specifically prompt them on any of the elements listed above.
  - Can you say more about (lesson element that is unclear)?
  - What do you mean by (term they used)?
  - Can you say more about why you decided to (decision that is interesting)?

** If aspects of the written lesson plan are not brought up by the PST, (e.g., they have a goal written on their lesson plan, but have not yet talked about the goal of the lesson) then ask about them…"I noticed you have (x) in your lesson plan here, can you tell me about that?

- **Is there anything (else –** *if appropriate)* **that you thought about in planning the lesson that is not included in your written lesson plan?**
- **In looking at the list you made earlier of the things you think you should think about when planning a lesson, I'd like you to talk about whether or not you think this lesson plan included all of the aspects you identified as important. Are there any aspects that are on the list that are missing from this lesson plan?**

** Provide a copy of the course timeline for the PST to examine.

- **After examining this course timeline, could you please identify and explain the classes and/or topics that you feel had the greatest influence on your planning.**
- *Give the PST a few minutes to examine the timeline. Ask PST to circle topics that had the greatest influence on his/her planning.*
- **Ok, great. I noticed you circled…. Could you please tell me how you feel this course influenced your planning?** *Continue this line of questioning until you have addressed all the circled items.*

** If the PST does not identify any specific topics above. You may specifically probe using these questions. (The "Learning Cycle" and the "Five Practices" were introduced in your coursework this semester.)

- **What role, if any, has the "Learning Cycle" and/or "Five Practices" played in your planning?**
- **Is there anything else you would like to say about your planning for this lesson or lesson planning in general?**
  Ok, great. Thank you very much for participating in this interview.

  Time interview ended: ___________

E.2 INTERVIEW PROTOCOL FOR INTERVIEW 2[12]

Time when Interview was started: ___________

PART 2 – The PSTs' lesson planning practices during the second semester of the teacher preparation program.

- **Ok, now I would like to ask you some questions related to your lesson planning in general.**
- **I'd like you to talk about the things that influence your planning. So I'll start by asking, how do you decide what to include/not include in a lesson plan?**
  - **What role does your textbook or curriculum play in your planning?** *(sub-prompts, if needed, may include: "How do you use your textbook or curriculum when you plan?", "Does the textbook or curriculum influence your planning in any way?, if so, in what ways?")*
  - **What other resources do you use when planning lessons?** *(prompts, if needed, may include: "Besides the curriculum materials, do you seek out or use other resources when planning? Do these resources influence your planning in any way, if so how?")*
  - **What role does your mentor teacher play in your planning?** *(sub-prompts, if needed, may include: "Do you discuss your lesson plans with your mentor teacher?", "Have you planned lessons together?", "What kinds of things have you discussed with your mentor teacher, with respect to lesson planning?")*
  - **What role does your university supervisor play in your planning?** *(sub-prompts, if needed, may include: "Do you discuss your lesson plans with your university supervisor?", "Have you planned lessons together?", "What kinds of things have you discussed with your university supervisor, with respect to lesson planning?)* **In what ways are the lesson plans you provide for your university supervisor similar and different from those you usually produce?**
  - **What other things influence your planning?** *Move on only after teachers have offered as many factors as they can.(these could include such things as: time constraints (either in the time they have to devote to planning or in the time they have to teach something), things they are learning/doing in their teacher education program, their beliefs about what it means to learn and do mathematics and about students, resources available, PSSA, parents, students, etc.).*
  - **Do you believe your planning has changed in any ways, over the course of**

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[12] Adapted from Hughes, E.K. (2006). *Lesson planning as a vehicle for developing pre-service secondary teachers' capacity to focus on students' mathematical thinking.* (Unpublished doctoral dissertation). University of Pittsburgh, Pittsburgh, PA.

this semester? *If yes, then* **Can you describe the ways in which your planning has changed?**

- **Are there any other ways in which you believe your planning has changed?**
- **Is there anything else you would like to say about your lesson planning?**

PART 2 – Talking about instructional performances the teacher has written:

(Prior to the interview, teachers were asked to bring a the instructional performances they completed during the semester. For each IP, you will proceed through this section of questions.)

- **For this part of the interview, I'd like to discuss the lesson plans that you were asked to bring with you today. First I'd like to ask a few questions about the lesson and then I would like for you to talk in more detail about the lesson plan you've written.**
  - **What class/course is this lesson plans for? How many sections of the course do you teach? Which period(s)?** *(be sure to get the Subject of the course (e.g., Biology, Life Science, Conceptual Physics, etc.) & have them explain any descriptors, such as PPS, AP, Honors, etc.)*
  - **How long have you been teaching this course and section?**
  - **How long have you been making lesson plans for this course and section?** *(be sure to distinguish between teaching and planning)*
  - **Earlier, you identified some things that influence your planning. I'd like to ask about the role they played in planning this specific lesson. For example,…***Referring to things the teacher identified in Part 1 of the interview that influence their planning, ask if these were factors present in planning this lesson by using the following prompts as appropriate:*
    - **In what ways did you use your textbook in planning this lesson?**
    - **Did you plan this lesson with your mentor teacher?**
    - **Did you plan this lesson with your university supervisor?**
    - **In what ways did you use the "Learning Cycle" in planning this lesson?**
    - **In what ways did you use the "Five Practices" in planning this lesson?**
    - **Now I'd like you to walk me through this lesson plan, providing as much detail as possible about your thinking when you planned it?**
    - *Probes: You should probe on anything related to the four key elements of planning a high-level task and supporting a discussion*

    - Use the general probes below to offer teachers an opportunity to provide more specificity if they are thinking about one or more of these elements, but do not specifically prompt them on any of the elements listed above.
      - Can you say more about (lesson element that is unclear)?
      - What do you mean by (term they used)?
      - Can you say more about why you decided to (decision that is interesting)?

** If aspects of the written lesson plan are not brought up by the PST, (e.g., they have a goal written on their lesson plan, but have not yet talked about the goal of the lesson) then ask about them…"I noticed you have (x) in your lesson plan here, can you tell me about that?

- **Is there anything (else –** *if appropriate)* **that you thought about in planning the lesson that is not included in your written lesson plan?**
- **In looking at the list you made earlier of the things you think you should think about when planning a lesson, I'd like you to talk about whether or not you think this lesson plan included all of the aspects you identified as important. Are there any aspects that are on the list that are missing from this lesson plan?**

** Provide a copy of the course timeline for the PST to examine.

- **After examining this course timeline, could you please identify and explain the classes and/or topics that you feel had the greatest influence on your planning.**
- *Give the PST a few minutes to examine the timeline. Ask PST to circle topics that had the greatest influence on his/her planning.*
- **Ok, great. I noticed you circled…. Could you please tell me how you feel this course influenced your planning?** *Continue this line of questioning until you have addressed all the circled items.*

** If the PST does not identify any specific topics above. You may specifically probe using these questions. (The "Learning Cycle" and the "Five Practices" were introduced in your coursework this semester.)

- **What role, if any, has the "Learning Cycle" and/or "Five Practices" played in your planning?**
- **Is there anything else you would like to say about your planning for this lesson or lesson planning in general?**

PART 3 **–** Talking about planning and implementing discussion in general:

- **Did you teach any other discussion lessons besides the ones we discussed during the year?**
    - **How did those lessons compare to these Instructional Performances?**
- **Describe anything that hindered your ability to plan and teach discussion lessons like these during the year.**

Anything else you would like to add or questions you would like to ask?

Ok, great. Thank you very much for participating in this interview.

Time interview ended: **___________**

E.3 INTERVIEW CODING DEFINITION RULES

Code	Definition	*Example Interview Excerpts*
Mentor Support	Describes how mentor supported PST's planning and/or task selection/design	
Planning	Mentor supported in planning of lesson in a variety of ways	*So the task that I had them do for that was a – was a two-dimensional collision simulation. Um, it was a PhET simulation and, um, my mentor was more involved with that one – at least – at least with setting up the ov-, helping me set up the overall structure and, um, seeing some of the things that we wanted to emerge from that.*
Logistics	Mentor supported with behavioral, classroom management, or logistical planning	*She was the one that said we couldn't have 4 different groups all scattered about the room. She had suggested maybe having smaller groups, and having the other students on working on something, when someone came up.*
Task Design	Mentor supported in design or selection of task for the lesson	*So a lot of them are just tasks that my mentor teacher has used before. We sit down a day or few before we use them. She says these were the parts of the tasks that I did like last year. Then we just talk about, we alter them together.*
None	No evidence of mentor support	*With my mentor teacher usually for Integrated Science, she kind of stays hands off of that one. That she is like, that's yours now.*
School/Team Support	Other teachers or their grade level/curriculum team at school provide planning support for PST	*But also we have PLCs. So I collaborate a lot with the other teachers. Everyone that I teach with is kind of a 1st year, or 2nd teacher, whether that's because of a career change or what.*
Anticipate	Mentor supported PST in anticipating students' PK and experiences, what they will say/do, what they will notice, or think	*So she helped me anticipate kind of what students would say. I would say, "Okay, well, I think I'm going to teach it this way." She's like, "Well, but what if they say this?"*
Selecting & Sequencing	Mentor support PST in selecting and/or sequencing student work/ideas in planning for the discussion	*We talked together about selecting and sequencing. That helped immensely because it was the first time I'd done all 5 practices. She didn't help a lot, but she knew more about the students than I did. It was more like, "Are sure you want them to talk about that, because I think they might have better kind of prior knowledge," and things like that." Maybe something that I hadn't noticed before, in being more of a passive observer.*

Supplies	Mentor supports PST in gathering or identifying necessary supplies and materials for the lesson	*In the actual planning, not like a huge part. He gave me all the materials. So I should say he played a part and that he let me do it myself, kind of.*
Instruction	Mentor gives PST feedback or support regarding instruction post-lesson	*So, he doesn't give me a whole lot of feedback on my plans, mostly on just my implementation.*
Supervisor Support	Describes how supervisor supported PST's planning and or task selection/design	
Logistics	Supervisor supported with behavioral, classroom management, or logistical planning	*So say, for instance, I could have set everybody up to do this at a time with something projected on the Smart Board, but I didn't plan for that. That would be a type of feedback she would give me.*
Planning	Supervisor supported in planning of lesson in a variety of ways	*So he was kind of able to help me see where students would think, or um, help them, like, design a task that would really get to the ideas of types of reactions, without just telling the student, "This is what it is, this is what it looks like." But letting them determine what it looks like on their own, so that they could put it in their own words.*
Task Design	Supervisor supported in design or selection of task for the lesson	*We were talking about we spent a lot of time looking at the 4 different scenarios, curves, swings and over under hills. We center on those because those are the classic basic examples like, you'll always have a problem when you are going down a hill or over a hill, but you need to know how to go through a curve, or just in a circle.*
None	No evidence of supervisor support	*My supervisor didn't give me any feedback because that was my fault, because I didn't put up my lesson 48hours in advance, let alone 24 hours in advance. So, I didn't get any feedback from her in advance on this one.*
Instruction	Supervisor gives PST feedback or support regarding instruction post-lesson	*For example, one thing that he's done that's been very helpful is making me think about, what did I do right in this lesson. And if I did the same thing would it go right, if I taught in this different classroom.*
First Lesson Resources	Resources PST used to design task and plan first lesson	
Personal Texts	PST describes use of personal textbooks or texts in planning and designing task and/or lesson	*I had also used some resources from college. So, for my undergrad I used a textbook that I had, that talked about product squares and about meiosis.*
Personal Knowledge and Experiences	PST describes using personal experiences or knowledge in planning and designing task and/or lesson	*I used for my resources, mostly going back through what I remember doing; I worked as a TA in the labs for genetics in college. We did worksheets about pedigree analysis.*

School Curriculum	PST describes use of school curriculum or district materials in planning and designing task and/or lesson	*I think the first resource I went to was a Conceptual Physics book that was given to me actually the summer before I worked with my mentor teacher.*
Web-Based	PST describes use of internet or web-based services in planning and designing task and/or lesson	*A lot of it was me searching online. I think I went to Teachers pay Teachers, and more kind of browsed through tasks that existed.*
Standards	PST describes use of standards (PA standards, NGSS, NSDL, etc.) in planning and designing task and/or lesson	*Standards wise I went through PDE websites. I don't recall at this time, how I did big ideas of learning goals or objectives, or if I even included them.*
Resources	Resources PST used to design task and plan lesson	
School Curriculum	PST describes use of school curriculum or district materials in planning and designing task and/or lesson	*So, the school textbook plays a lot into helping me develop my learning goals. So, that's really where I usually go for my learning goals. Those are also based off my standards. I get the standards usually from my curriculum.*
Web-Based	PST describes use of internet or web-based services in planning and designing task and/or lesson	*So the task that I had them do for that was a – was a two-dimensional collision simulation. Um, it was a PhET simulation.*
Personal Texts	PST describes use of personal textbooks or texts in planning and designing task and/or lesson	*So I use all of my books. I've just acquired some of my books from college, Introductory Physics.*
Peer Lesson Plans	PST describes use of peers' materials or lesson plans in planning and designing task and/or lesson	*I do talk to the other kids in class, about how they have done things, like especially since Kelly has already done like everything already, because she has block scheduling, and everything.*
Personal Knowledge & Experiences	PST describes use of personal knowledge, learning, or own experiences in science in planning and designing task and/or lesson	*So I mean this – this was something we talked about in my physics class. So I knew that it was – and it landed with me so I thought maybe it would land with these kids, too.*
Standards	PST describes use of standards (PA standards, NGSS, NSDL, etc.) in planning and designing task and/or lesson	*Now I use the SAS website for the eligible content and standards. They also have the voluntarily model curriculum which I will just go to, to look for the resources that they suggest. I have recently started using the NSDL.*

Mentor Created Materials	PST describes use of materials created by his/her mentor in planning and designing task and/or lesson	*The textbook is pretty much, not used at all. My mentor has created this really cool tool. She has this, at the beginning of the year she sends all this stuff down to, like there is like a printer in the school. This huge industrial printer. She has these books binded, that the kids then have all the materials that we need for the class throughout the entire year in there.*
Family/Friends	PST describes use of family or friends in planning and designing task and/or lesson	*I ask my girlfriend stuff all the time, so I was like, "Why do you think? I remember this was the first time that I did it. I asked her "Why are plants green?" She was just like, "I don't know." Same thing as like my kids would say. So I started trying to get her to think about it.*
University Instructors	PST describes use university instructor support in planning and designing task and/or lesson	*We also used, one of our professors, gave us some suggestions on how we might do that, because I had a very hard time deciding what those patterns were, that I really wanted the students to see.*
Five Practices	PST discusses use of the Five Practices Instructional Model in planning for task-based discussion	
Anticipating	PST describes how students are likely to respond during task	
Think About	PST describes thinking about anticipating, but does not explicitly include his/her thinking in the LP	*I will say that I often forget to include my anticipation for sooner response like I'm thinking it. I want to come up with the questions without thinking like, what they might be answering it. But I will admit in my writing, what I am thinking is never always on the paper, but sometimes I think that it's there.*
Logistics	Describes anticipating classroom/behavior management or other logistical issues	*So setting forth the expectations and kind of describing to them what it should look like and telling them they should be responding to each other and that's okay.*
Students Do	Describes anticipating what students will do/see/notice during the lesson	*I anticipate what I think students will do, and then they do 8 million other things that I didn't anticipate.*
Students Think	Describes anticipating what students will think during the task/approaches to the task/etc. (as defined by Cartier et al., 2013)	*As far as anticipating, I think I have my expected table that I thought they would draw which I , again, changed a couple of hours before. So, I included the different demos, and then what I wanted them to write on the micro the nano. And then what I thought they might draw for the symbolic.*

Identifies None	No planning of anticipating or identification of anticipating in PST lesson plan	*I don't have a whole lot of that in here. I have like right here; I guess that's more about my thinking process going on here. Maybe I really don't know. I guess that I have a lot more things about what I was going to be thinking about.*
Monitoring	Plans to keep track of what students actually do as they work on the task in pairs or small groups and plans questions to elicit student thinking during this work	
Monitoring Tool	PST discusses use of a monitoring tool, or aid, in planning lesson	*I think I would say that, every monitoring tool that I have made, like none of them have been perfect. I think obviously that's something that comes with time, but not trying just putting it out there.*
Functional	PST creates monitoring tool that is functional for them, but not a tool that is useful in terms of LGs or features of student thinking as described by Cartier et al. (2013)	*So, what prompted me was we totally had it, we needed to have it. So, if you actually look my monitoring tool, it is just a layout of the classroom with student numbers, and names on it.*
Features	PST creates a monitoring tool that focuses on LGs or student ideas/approaches to a task... Focuses on features PST wants students to notice... "a 5P monitoring tool"	*A monitoring tool, and I knew the types of things I wanted to see and I knew the types of things that I did not want to see. So those were the ideas that I knew.*
Plans Questions	PST discusses his/her planning of questions to elicit student thinking during small group work	*So, I have guiding questions for each dataset that I was going to ask the students. Making sure that I got them to really focus on the pattern that I wanted them to see.*
No Tool	PST discusses his/her planning of questions to elicit student thinking during small group work	*For this one, I believe, let me check real quick. I did not have a monitoring tool for this lesson.*
Selecting	PST discusses selecting groups/students to present during the discussion	
Think About	PST describes thinking about selecting, but does not explicitly include his/her thinking in the LP	*I don't like going blind into things. So I know that I would have thought through it, but maybe not to the point of being able to articulate well into the paper.*
During Lesson	PST selects during the lesson and does not specifically plan it	*But what I was trying to do was just in the moment like select and sequence things and that can kind of get, you know, within a, basically a five minute window to make a final decision.*

Identify Groups/Sts	PST describes explicitly identifying or choosing groups or students in his/her plan	*Like which groups I wanted to talk. Then they had numbered orders, and then I put little questions to help me remember what I wanted. If nobody else asked this question, then I would say blah, to get out of that group what I wanted them to say so as far as the sequencing.*
Sequencing	PST discusses sequencing groups/students during the discussion	
Think About	PST describes thinking about anticipating, but does not explicitly include his/her thinking in the LP	*I don't think so, I think I put, I will choose them randomly. So, I didn't feel like I needed to sequence them in any kind of specific order.*
During Lesson	PST sequences during lesson, but no attempt made in planning	*I don't think so, I think I put; I will choose them randomly. So, I didn't feel like I needed to sequence them in any kind of specific order.*
Identify Groups/Sts	PST describes explicitly sequencing groups or students in his/her plan	*Because it is an important part of getting the conversation to go where you want to go, without realizing it is where you've been wanting to go. That's how I kind of use sequencing. So in order for the kids to think that they are in control, I have to have some idea of where I am going to go with it.*
Connecting	PST describes connecting students' ideas with one another and connecting their responses to the disciplinary ideas	
Storyline	PST plans a detailed storyline and/or script to plan for the discussion	*I tried to do something like, I know that you're supposed to do it whenever you're telling a story. Like, you plan the beginning, you plan the end, and then you have certain set points along the way that you want to hit, and you're not sure how you're going to get there, but you know that eventually you want to get to Point A, Point B, and Point C and, like, the end.*
Outline	PST creates an outline of ideas/questions during the discussion	*Um, but the stuff in the middle, I find that I do better if I don't script it. Like, I have an idea of who's going where and what they need to say, and that's usually, like, this, like my scaffolding questions, I know who's gonna talk and if these don't come up I'm gonna ask these things. Yeah I still have questions and everything like that; it's just less… "say this, say this" kind of thing.*
Questions	PST only discusses a list of questions to ask during the discussion, but it is not explicit in his/her planning	*I had a series of 5 different questions that I would ask for them. Then under each of those I had what idea may emerge and then the misconception.*
Think About	PST admits thinking about connecting of some sort, but it isn't in the LP	*So, according to my lesson plan, I didn't. But thinking about the weekend and like when I had the time, to kind of set up for it. Basically I knew I wanted the students to do a lot of the talking to try to come up with this idea.*

Plans Questions	PST plans a list of questions to ask during the discussion	*But for the most of part it was me wanting to make sure that I had really covered the entire scope of what the discussion was supposed to be about. Instead of just letting it, okay so we are talk about this, but how we talk it and that, it doesn't really matter. So I really wanted to make sure that we are talking about it in a coherent matter so that it wasn't just a chaotic discussion. And they were actually able to get those connections out of what they were supposed to be reading.*
Plans for Marking/ Charting	PST clearly plans for ideas to mark and/or chart during the lesson	*I think for this one we made a group or as a class we made a big one. But on the PowerPoint, we did kind of a class one of these with what we thought was as a class the most correct representations for the micro, the nano and the symbolic for each one.*
Acknowledge difference	PST acknowledges or eludes to the fact that the 5P is a different type of discussion than other discussions or student talk	*I don't know that I ever did a full – full five practices. A lot of times I would do, um – or it wasn't structured quite as formally, where the – if the students might generate artifacts in small groups, and then if ha – instead of having, like, the class discussion around one or two, like selecting and sequencing individually, I would put them all up on the board, um, and we would kind of work as a class to develop a single mode.*
No difference	PST does not clearly acknowledge there is a difference between the 5P discussions and other discussions	
Other Instructional Frameworks	PST used another type of framework, like the learning cycle, 5E, bloom's taxonomy, etc.	
Learning Cycle	PST explains that he/she used the learning cycle during her planning of this lesson	*Good question. I think a little bit because I did have like and engage, and then explore. And then explain would be our discussion that we had about it. So, I would say, yeah. We did focus on the learning cycle on what did there, I would say.*
Engage	PST acknowledges that this lesson is an "engage type" lesson	*The second one was definitely I think an engage. Because once we got past this lesson we didn't talk about who discovered DNA so much, but we talked about the structure and that's what launches into the structure of DNA in transcription and translation.*
Not Used	PST states the LC is not used during planning	*I would say not quite, no. I don't think I used really the learning cycle for this lesson.*
Coursework vs. Daily	PST describes how his/her coursework planning differs from daily planning	

Same	PST indicates planning for coursework and daily planning is the same in terms of effort and detail	*They're the same. I think maybe I'm one of the few that in talking my progress. Maybe I'm one of the few that does it, but I tend to put the same amount into every lesson plan that I do when my supervisor comes. They're maybe slightly more detailed. But on the whole, they're pretty much the same. I tend to spend a lot of time writing lesson plans.*
Less Detailed	PST indicates less detail in coursework lesson plans	*N/A*
More Detailed	PST indicates more detail provided in coursework lesson plans	*Maybe whenever I have a like whenever I'm actually turning something in, or whenever I have an observation coming up, I will put in a little bit, like I will try to make my thinking a little bit more transparent. Because you know like, "Well I thought about that while I was writing it." They are not going to know that I was thinking about that.*
Reflection influence on Future LPs	PST indicates influence of teaching the lesson and reflecting on the lesson on future IPs or LPs	*So, yeah, um, the big takeaway to me with the discussions is just describing what the discussion is supposed to look like.*
Logistics	PSTs focuses on logistical changing in planning, e.g., grouping, classroom management, behavioral management	*Absolutely. My first one I had them like in my lesson plans it says that I was I going to get them in to a circle, but then I did not do that, because 4th period, I had some misbehaviors in that class. So I opted just to keep them facing forward. It was very difficult, I felt like I had to the majority of the talking.* *Then in the second one, even though there had been like a little conflict right before the discussion started, I had them in them in a U. They could all see each other, they all had their planes and the data if they took any, showed and displayed for the other students*
Think About 5P	PST describes thinking about how to incorporate or revise discussion using the 5 Practices	*My planning changed a little bit in that I did decide how I was going to sequence students. I thought a little bit more about which students I wanted to talk about which datasets.*
Include in Planning	PST clearly indicates he/she included revisions to 5 Practices in planning	*Yes, anything that I think worked. So like all the anticipation that I realized totally paid off because I was able to like sequence them pretty well. First time I was like, definitely I will do that again.*
Did not include in planning	PST indicates he/she didn't include evidence of 5 Practices in planning	*A 5 practice model where they would maybe do something and then try to discover these principles on their own to give us, to give me this actual, like, this new knowledge that they've come to. I really haven't done that.*
Anticipating	PST includes how students are likely to respond during task	*I think that I try and do a lot of anticipating. I mean I try and really – not ha – I mean I put that sort of extra column in there for student work as – as a way to really explicitly make myself anticipate what students are doing.*

Monitoring	PST discusses use of a monitoring tool, or aid, or lack of influencing planning lessons or planning questions to elicit students thinking	*Um, but reflecting on it now, it's something that maybe I would have done to capture more student thinking rather than, um, their collection of data. So, because the discussion itself kind of fell to pieces in the end, because I think I really didn't know who had certain ideas, and there really was no sequence there in the end, because I didn't know who I wanted to have talk first, and where I wanted that to go.*
Selecting	PST discusses selecting groups/students to present during the discussion	*As far as practical things go, I think you have to be really careful. I think you need to give yourself a night to look at - to look at what they created.*
Sequencing	PST discusses sequencing groups/students during the discussion	*I have more examples of how exactly I was going to question students, and the ways in which I was going to sequence which students were going to talk first. So, scaffolding the discussion in a more advanced way*
Connecting	PST describes connecting students' ideas with one another and connecting their responses to the disciplinary ideas	*I have more examples of how exactly I was going to question students, and the ways in which I was going to sequence which students were going to talk first. So, scaffolding the discussion in a more advanced way.*
Remove Parts	PST states that he/she has started to remove parts of their lesson plan they used to include b/c of more experience, time constraints, etc.	*Actually I think – I think I started taking some things out – from last semester. I dunno, and I have apparently – I've been told – a tendency to write really, really long lesson [laughs] plans.*
More Student Talk	PST states that he/she incorporate mores student talk in lessons	*So yeah, I use elements of it all the time. So just the idea – the ideas in the discussion – I forget which chapter it is, but just having a discussion and – and what the teacher's role should be in a student centered discussion, that sort of thing is something that I use.*
Activity Structures	PST states that he/she uses various activity structures used in teaching	*Discussion based off of, like, mitosis and meiosis. But I… do use discussion a lot more now – not in the whole, you know, necessarily based on activity but, um, the think, pair, share activity structure.*
Success Builds Confidence	PST explains that his/her/students success in one 5 practices lesson builds confidence to plan more lessons like this	*Um, from the beginning, this, like, I – I guess I got lucky with that very first one. Like, I had really intense planning, 'cause I knew my mentor wasn't gonna be there, it was gonna be really stressful, and I, like, planned the whole thing - and – and it worked. So then every time I have to do one of these lessons I just kind of… plan the same way, because it worked. It was one of those "if it ain't broke, don't fix it", you know?*

Important Coursework Sessions	PST indicates important coursework sessions in Teacher Preparation Program that influenced and supported planning of 5P discussions - *PST must circle and discuss session as important in order for it to be coded*	
T&L 1	Classes during Teaching and Learning 1/JumpStart – First two weeks of the fall semester.	
Fastplants	Class 1 & 2 - Sessions engaging in Science As Learners - A model of engaged learning - the Fastplants measurement lesson	*Okay, yeah, I'm trying to think. So definitely, when we started talking about the model of engaged science learning, California is on the Direct Interaction Instruction, so the DII model. So pretty much everything I'd ever grown up with was just lectures. High school, we do lectures, college, we do lectures.*
LP Intro	Class 5 - Introduction to Lesson Planning session	*Yeah, and then let's see. The introduction to lesson planning. So that was a really enlightening day just like, what are we supposed to include in the lesson plan? I had my thoughts, and I compared them against, I looked up other high school science lesson plans to try, and figure out what it would be.*
NGSS	Sessions topics including the *Next Generation Science Standards*	*So for the next generation science standards and we talked about the science and engineering practices. To me this was really what the heart of what, especially in my school that science education really needs to be about. Is it needs to be about these practices, and in the principles that underlie science as a discipline, as opposed to the specific content ideas.*
T&L 2	Classes during Teaching and Learning 2 – remainder of fall semester	
LGs & Objectives	Class 1 - Sessions focusing on creating learning goals and objectives/performance goals	*So, then once we got to discipline block 2, learning goals and objectives are really important. Because especially after the very, very first lesson plan we did, I learned the importance of selecting learning goals first before you look for a task. Because that's really what you want to students to know.*
Task Selection	Class 1 -Sessions focusing on selecting and designing high demand tasks	*Then after that is when you get to the task selection. It is okay to find a task and change it. It is okay to only use part and mix and match, but the task needs to match to the learning goals, and not the other way around.*
Anatomy of a Lesson	Class 1 - Sessions about components of a Lesson - Launch, Activity/Body, Close	*Anatomy of a lesson, I think that was helpful.*

Launch	Class 1 - Microteaching episode	*When I was in high school or even in college, in the lab warm up questions, so the whole thought to me was like really bizarre just in general. Like why don't we come in and just start the lesson? I was really mystified probably a couple of weeks as to why we needed a warm up, or anything. But learning how to engage students in the topic of the day I thought that was really neat. It's still something that sometimes I struggle with like I don't even remember now, oh electron configuration. They were having a tough time. They were like, "How does this connect to our life?"*
Five Practices	Class 3 & 4 - Sessions where students participate in role plays of the Five Practices model	*So, I think that microteaching part was really the most influential for me to actually see how it would play out.*
S, S, & C	Class 4 - Selecting, Sequencing, & Connecting	*So, like that didn't click for me for much longer time, but the selecting and sequencing, all time I would be walking around the classroom and I would realize, there is 3, 4 students that aren't getting it. So I want to hear from them before I hear from the ones that do get it. It started to make a lot more sense to me like; I'm not going to go to these same people all the time. If I want to make it easy on myself that's what I would do, but that's not really helping the rest of them. So, I started selecting and sequencing a lot more based upon that. Then that made more sense to me with the whole 5 practices thing is, that it is just something that even if you are not going to use it, as being like a select in that sequence that you originally thought.*
A & M	Class 3 - Anticipating and Monitoring	*When we discuss the parts of 5 practices with anticipating, monitoring, selecting, sequencing, and connecting, like that whole mini lesson that we taught or enacted, and acted as the student storing, really helped. Because if I had read the book and just tried to do that without messing up in front of the class, and really messing up because we definitely changed our entire approaches in the 30 minutes that other groups went, before we went. So doing that with the class and with guidance even though the guidance didn't come until the end. You know just seeing it happen, because I was completely unfamiliar with this type of lesson planning, and implementing this type of lesson. Also coming from a background where from K to 12 it was entirely lecture teacher fronted. You know with a few exception like my freshman biology teacher, which why I'm in this program to begin with.*

Co-Planning	Sessions where students co-planned and provided feedback to each other on their planning	*So, co-planning was very helpful. Seeing who I was paired with. We have talked since and we have very similar classrooms. I don't know if it was set up that way whatever we were planning, or like paired together, but it worked very well. Seeing like what her kids want to do. What my kids I was planning on doing what I hope for them to do and comparing the types of tasks that we have. Because I realized that my tests were very simple compared to what she was giving her students and then I could push mine more.*
Technological Resources	Sessions focusing on planning and using technology in science lessons	*Resources, effective use of technical logical resources. That is helpful because I think like everything that I find in our curriculum is not good, or not great we'll say. So a lot of the tasks that I find, I find inspiration for on the internet, whether it's like teaching blogs, or I did this, or it's different types of activities. Those are usually what I use for my tasks.*
Assessment	Sessions on writing assessment questions	*Then last thing that I think helped was when we talked about writing assessment items. I think that it is important in doing these because I mean for the large portions of students they are going to have to take a test. So the information can be through the discussion, still needs to be able to be assessed, but assessed in way that like is fair to your classroom, and what you are doing.*
Lesson Arcs	Sessions on Lesson Arcs in planning	*Lesson arc is important to figure out where I'm coming from and where I want to go from here. Because if you just try and stick a discussion somewhere in the middle without really having anywhere to take it to, then it doesn't really serve any purpose. Because you talk about this, but why should I care about that tomorrow kind of thing. So, lesson arcs helps me kind understand of how all lessons kind of work together and how you can make those connections clear to students.*
Literacy	Supporting literacy sessions	*Because I wanted to do reading-based discussions, it was really important for me to have these techniques, and these ways of supporting their learning and supporting their literacy. So that it makes it accessible, and can help them improve it without scaring them off and just making them give up, because they don't understand or they don't have the tools. Or I didn't provide them with the tools they needed to be able to understand the text, and get the information out of it.*
Learning Cycle	Sessions on planning and implementing learning cycle lessons	*The learning cycle, I mean I think that that's a really valuable thing to learn, because it is not always able to be done one day.*

T&L 3	Classes during Teaching and Learning 3 (Spring Semester)	*And whenever [the instructor] started talking , he didn't talk about the five practices. These alarm bells off –were going off in my head and I was like, "What are we learning today?" And then about a minute later whenever he started talking about like, "Oh, I've got this problem," I was like, "Oh, my goodness. He's doing a five practice [laughter]." And from there I was like, "Okay. Just like play along, but just absorb everything you can." And from that moment like I was – like every transition he made, and every like different movement, and like what he was thinking or where he was in the classroom, I just tried to pay attention to 'cause I really wanted to see what this actually looked like –for someone to be doing that.*
Learning Cycle & Five Practices	Class 2 - Sessions focusing on engaging as students in the Learning Cycle and 5 Practices lessons	*I remember the instructor telling us that if you could design, like, a lab activity, and make the kids think that it's real, you know, that they're a lot more engaged with it, that they're a lot more willing to participate and help out and try to do stuff like that.*
Formative Assessment	Class 3 & 6 - Sessions on formative assessment during lessons	*I felt like those were really helpful because, I mean, I knew what formative assessment was, and I knew how to make a monitoring tool, but I didn't know how to use it in a way that would make it work for me. So I felt like it had to be this thing that I had to have, but I didn't really see a whole lot of value in it.*
High-Demand Tasks	Class 4 - Sessions on planning and designing high-demand tasks	*I actually really like that one too, because that made me think a lot about the stuff like, are you giving work just to make it harder, or are you trying to take away some of these things?*
Scaffolding	Class 7 - Sessions on scaffolding lessons and tasks	*The scaffolding and I think the maintaining high cognitive demand kind of go hand in hand with each other of what do you give students to help them along without – making the task now simple again. But I think a lot of times when we think, "Oh we're scaffolding," we're really not; we're just making the whole thing easier for them to actually do.*
Maintaining Cognitive Demand	Class 8 - Sessions on maintaining cognitive demand	*And then I also circled scaffolding. So, I thought the scaffolding lesson was very helpful because often, I'm trying to find a balance between lowering the cognitive load without lowering the cognitive demand.*
IP Task	PST describes how he/she created or designed IP task(s) (see Brown, 2009	
Offload	PST used task as is regardless of source	*It was pretty much as is, except for instead of having 5 students throwing balls around the room, I just had 2.*

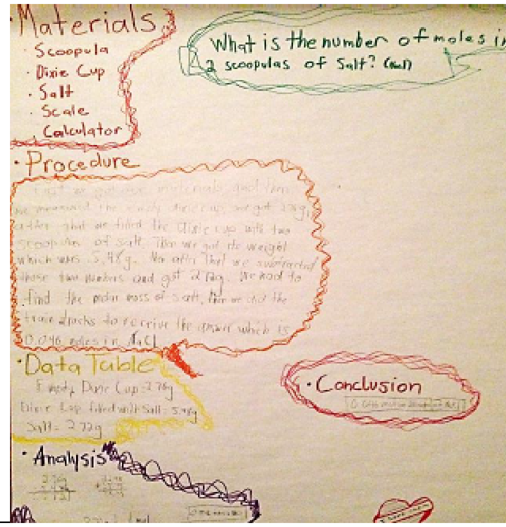
Adapt	PST revises and adapts task in an effort to meet needs of lesson and students	*My, um… the curriculum has this mole lab, right? that's in there that they… give us. Um, with no directions. And it wasn't formatted really well… um, and it was just like, "Do the mole lab." Okay. Um, so I had that mole lab, and from… that – I mean, I had all these lists of, like, how many whatevers – how many molecules in a sugar cube, how many this or this? So I changed some of them to be more practical, um, 'cause I wasn't gonna go find, like, a liver or something.*
Improvise	PST created new task for the lesson	*So, the first one that I ever taught was this one about mitosis. The idea for the task really kind of just came out of nowhere. I just had this kind of crazy idea.*
PST Learning	PST identifies what he/she has learned over the course of the year	*Well, honestly I think that [laughs] for the most part it really helped me learn about my kids.*
Challenges	PST identifies challenges to teaching this type of lesson (5P)	*I think a lot of it was a difficulty of it not being a routine that was established until later in the year.*
Time Constraints	PST describes time being a constraint of planning and teaching a Five Practices discussion	
Personal	PST describes limited personal time to plan	*So first off, not having enough time to plan them, because it does take a lot of effort to be able to anticipate and build some questions that are really going to guide students to where you want them to be, but also within the curriculum.*
Curriculum	PST describes not enough time in curriculum to have discussions	*I would just say that, uh, I had to be conscious though of how much time I was spending doing it. You know, like I wouldn't want to spend a third day doing it, because you know, if it was the one day of the normal lesson*
School Norms	PST describes norms and routines of the school hindered students' ability or willingness to openly participate in the discussions productively	*So my students aren't used to having academic discussion in class, and respectfully responding to one another, and even just being quiet while somebody else is talking. So that took us a long—still is taking us a long time to get there.*
Mentor Flexibility	PST describes mentor's willingness or flexibility, or lack thereof, to allow more discussions in her/his classroom	*Which when I was talking to my mentor teacher about it, he was like, "You need to stop doing that [laughter] 'cause like those discussions are kind of long. You're not getting through enough material."*

APPENDIX F

EXAMPLE INSTRUCTIONAL PERFORMANCE 4 MONITORING TOOLS

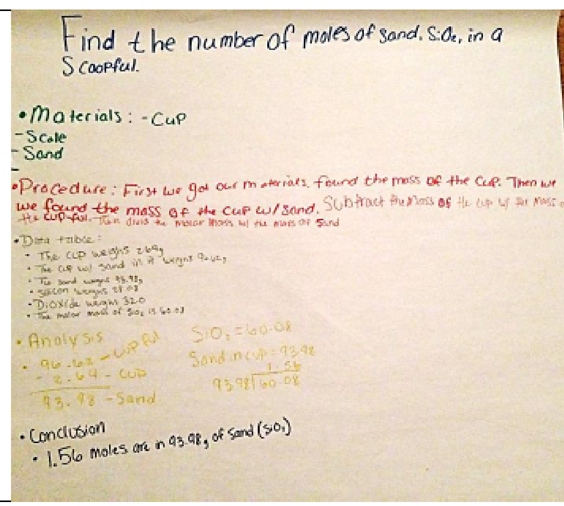
F.1 KRISTEN INGALL’S MONITORING TOOL FOR INSTRUCTIONAL PERFORMANCE 4

Mole Lab Monitoring Tool – Period 1

Group	Organizing Trend(s)	Organizational Model
1	_X_ Correct sections on poster ___ Correct number of significant figures used throughout _X_ All relevant data is included _X_ Reasonable answer to question _X_ Clear procedure	

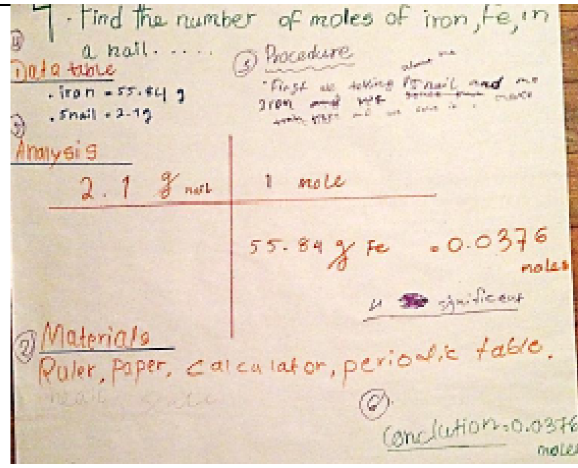
Scaffolding Questions:

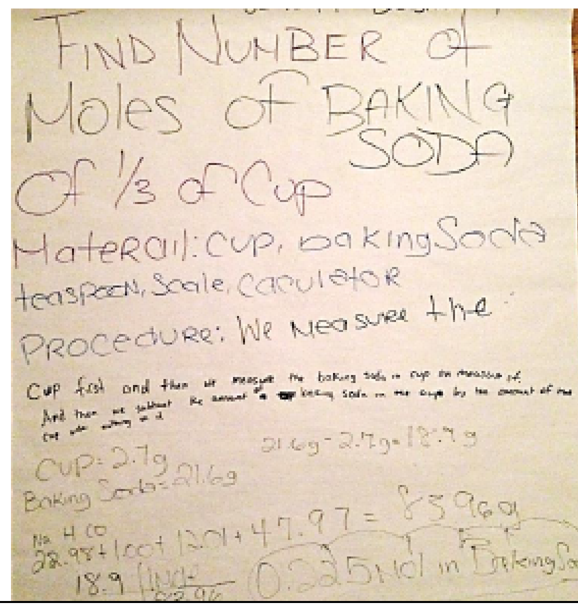
- How did you calculate the mass of the salt?
- Do you think there is a different way that you could have labeled the calculations in "Analysis"?
- Were they level scoopfuls or heaping? How could you make your descriptions clearer so that your experiment is repeatable?

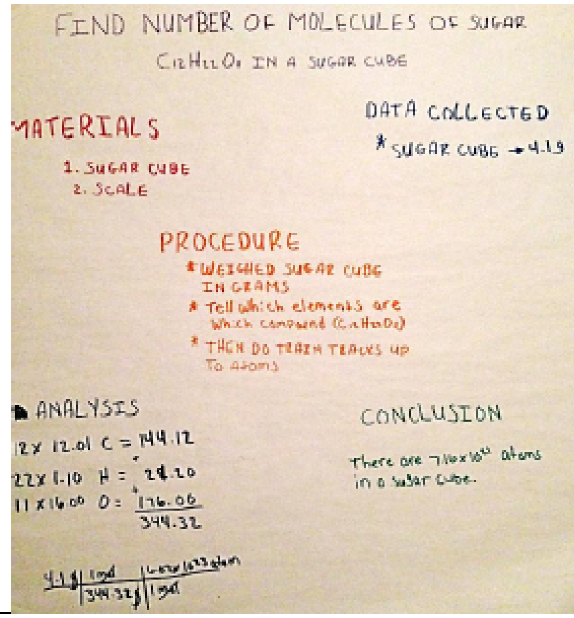
Group	Organizing Trend(s)	Organizational Model
2	_X_ Correct sections on poster ___ Correct number of significant figures used throughout _X_ All relevant data is included _X_ Reasonable answer to question _X_ Clear procedure	

Scaffolding Questions:

- How did you measure a scoopful?
- What does the atomic mass on the periodic table represent?
- How did you decide what conversion factor to use in your calculations? SiO_2 isn't on the periodic table!

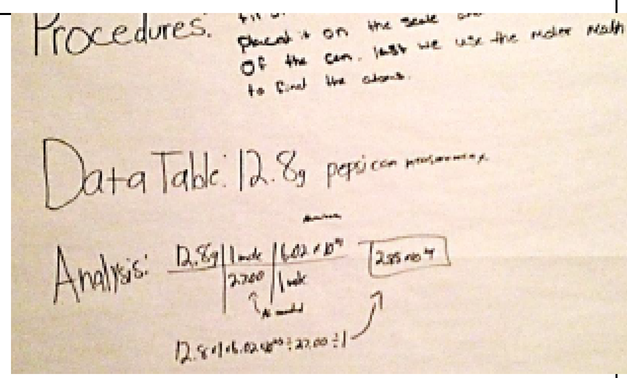
<table>
<tr>
<td>3</td>
<td>_X_ Correct sections on poster
___ Correct number of significant figures used throughout
_X_ All relevant data is included
_X_ Reasonable answer to question
_X_ Clear procedure</td>
<td>
</td>
</tr>
<tr>
<td colspan="3">Scaffolding Questions:
• Does your research question reflect the data you collected?
• Can you think of anything that was missing from the materials section?</td>
</tr>
<tr>
<td>4</td>
<td>_*_ Correct sections on poster
___ Correct number of significant figures used throughout
_X_ All relevant data is included
_X_ Reasonable answer to question
_X_ Clear procedure

*not all sections were labeled</td>
<td>
</td>
</tr>
<tr>
<td colspan="3">Scaffolding Questions:
• Do you think there is a way to write the procedure so that it is easier to follow?
• Is 1/3 of a cup the same measurement for all size cups?</td>
</tr>
</table>

5	_X_ Correct sections on poster ___ Correct number of significant figures used throughout _X_ All relevant data is included _X_ Reasonable answer to question _X_ Clear procedure	

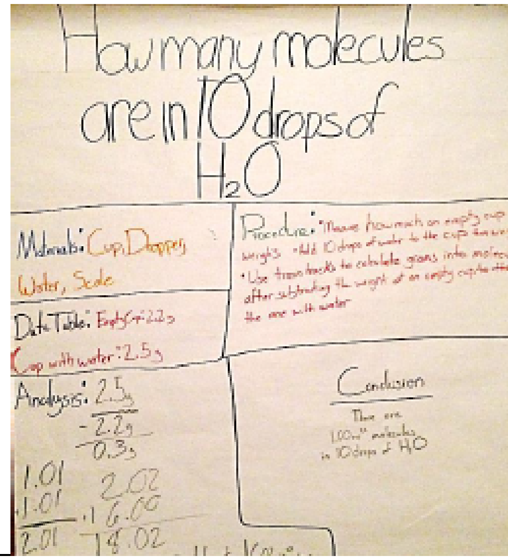
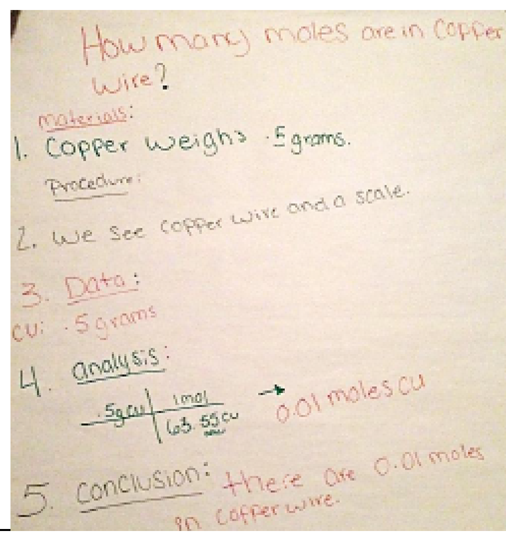
Scaffolding Questions:

- What does the atomic mass on the periodic table represent?
- How did you decide what conversion factor to use in your calculations? $C_{12}H_{22}O_{11}$ isn't on the periodic table!
- How would your answer be different if you were asked to find the number of molecules in two sugar cubes?

6	___ Correct sections on poster _X_ Correct number of significant figures used throughout _X_ All relevant data is included _X_ Reasonable answer to question _X_ Clear procedure	

Scaffolding Questions:

- Can you think of a way to make the procedure easier to follow?
- Do you think that a calculator should be considered a material?

7	_X_ Correct sections on poster ___ Correct number of significant figures used throughout _X_ All relevant data is included _X_ Reasonable answer to question _X_ Clear procedure	
Scaffolding Questions: • Why did you decide to weigh the empty cup first? • Why couldn't we just take the mass of the cup with water in it?		
8	_X_ Correct sections on poster _X_ Correct number of significant figures used throughout ___ All relevant data is included _X_ Reasonable answer to question _X_ Clear procedure	
Scaffolding Questions: • How much copper wire did you use in your experiment? • Do you think someone else could follow your procedure and come to the same answer? • What additional information might someone need? • Did you use any other materials to find your answer?		

F.2 BONNIE KYLE'S MONITORING TOOL FOR INSTRUCTIONAL PERFORMANCE 4

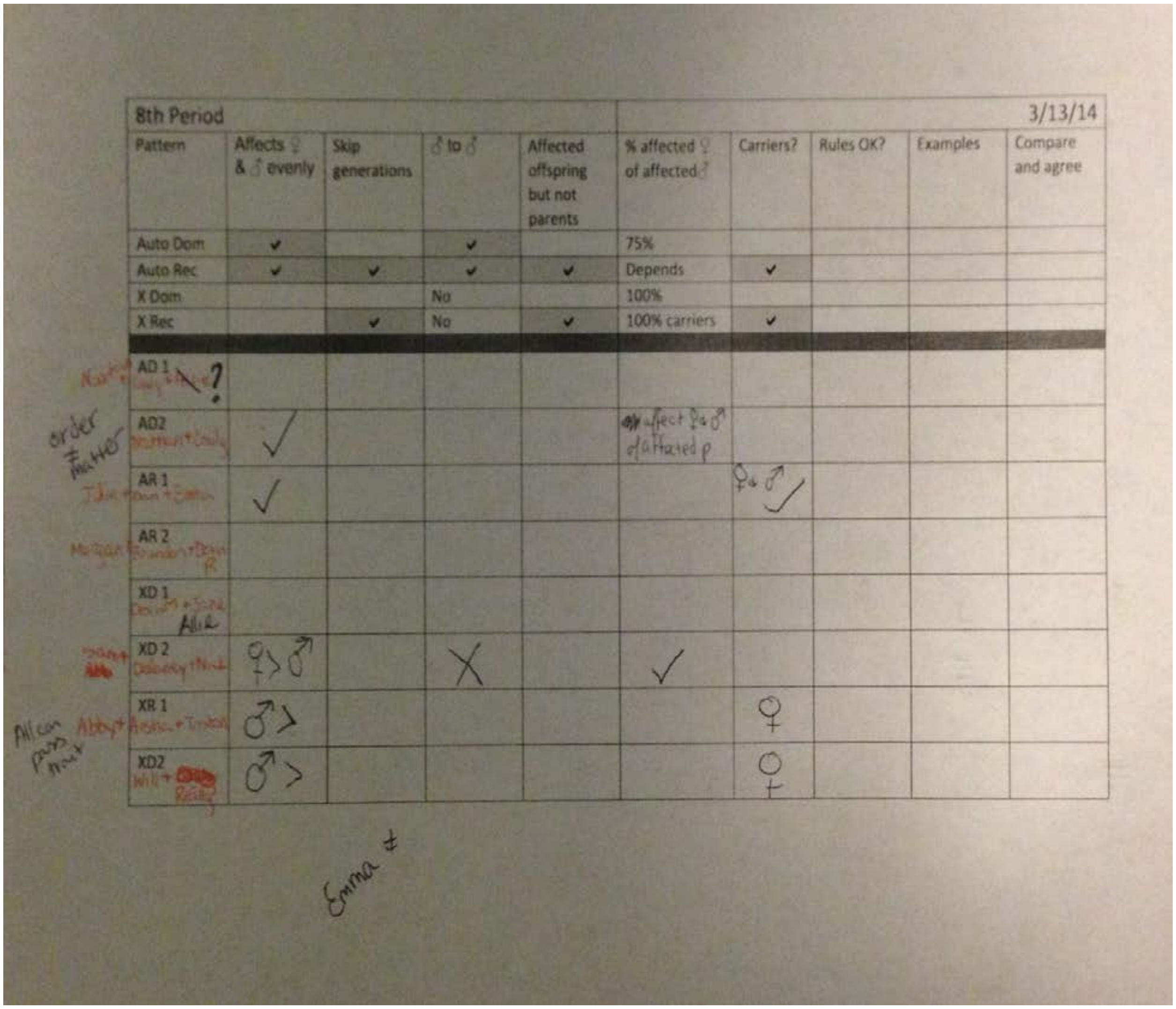
Group 1:	Group 2:
Sets: 2 (S), 3 (SR) and 4 (DR)	**Sets: 1 (D), 3, (SR), and 4 (DR)**
Patterns:	**Patterns:**
Bonds change	**Bonds change**
Number of atoms	**Number of atoms**
Types of atoms	**Types of atoms**
Naming:	**Naming:**
Word in other contexts	**Word in other contexts**
Correct	**Correct**
Incorrect	**Incorrect**
SEP:	**SEP:**

Group 3:	**Group 4:**
Sets: 1 (D), 2 (S), 5 (C)	**Sets: 2 (S), 3 (SR), 5 (C)**
Patterns:	**Patterns:**
Bonds change	**Bonds change**
Number of atoms	**Number of atoms**
Types of atoms	**Types of atoms**
Naming:	**Naming:**
Word in other contexts	**Word in other contexts**
Correct	**Correct**
Incorrect	**Incorrect**
SEP:	**SEP:**

F.3 NANCY HALL'S MONITORING TOOL FOR INSTRUCTIONAL PERFORMANCE 4

	Genotype vs. Phenotype	Explanation	Misconceptions	Notes
Group 1	___ genotype linked to chromosomes/DNA ___ phenotype linked to appearance	___using Punnett square/3:1 ratio? ___ using verbal explanation ___using other device to explain ___ incorporating parental input (1 copy each) ___correct explanation?	__ Different traits are caused by cross- or self-pollination __ Ratios askew __ other	
Group 2	___ genotype linked to chromosomes/DNA ___ phenotype linked to appearance	___ using Punnett square/3:1 ratio? ___ using verbal explanation ___using other device to explain ___ incorporating parental input (1 copy each) ___correct explanation?	__ Different traits are caused by cross- or self-pollination __ Ratios askew __ other	
Group 3	___ genotype linked to chromosomes/DNA ___ phenotype linked to appearance	___ using Punnett square/3:1 ratio? ___ using verbal explanation ___using other device to explain ___ incorporating parental input (1 copy each) ___correct explanation?	__ Different traits are caused by cross- or self-pollination __ Ratios askew __ other	
Group 4	___ genotype linked to chromosomes/DNA ___ phenotype linked to appearance	___ using Punnett square/3:1 ratio? ___ using verbal explanation ___using other device to explain ___ incorporating parental input (1 copy each) ___correct explanation?	__ Different traits are caused by cross- or self-pollination __ Ratios askew __ other	
Group 5	___ genotype linked to chromosomes/DNA ___ phenotype linked to appearance	___ using Punnett square/3:1 ratio? ___ using verbal explanation ___using other device to explain ___ incorporating parental input (1 copy each) ___correct explanation?	__ Different traits are caused by cross- or self-pollination __ Ratios askew __ other	
Group 6	___ genotype linked to chromosomes/DNA ___ phenotype linked to appearance	___ using Punnett square/3:1 ratio? ___ using verbal explanation ___using other device to explain ___ incorporating parental input (1 copy each) ___correct explanation?	__ Different traits are caused by cross- or self-pollination __ Ratios askew __ other	

F.4 FLORENCE EDWARD'S MONITORING TOOL INCLUDED IN HER INSTURCTIONAL PERFORMANCE 4 ARTIFACT PACKET



8th Period									3/13/14
Pattern	Affects ♀ & ♂ evenly	Skip generations	♂ to ♂	Affected offspring but not parents	% affected ♀ of affected ♂	Carriers?	Rules OK?	Examples	Compare and agree
Auto Dom	✔		✔		75%				
Auto Rec	✔	✔	✔	✔	Depends	✔			
X Dom			No		100%				
X Rec		✔	No	✔	100% carriers	✔			
AD 1 ?									
AD2	✓				affect ♀&♂ of affected p				
AR 1	✓					♀&♂ ✓			
AR 2									
XD 1									
XD 2	♀>♂		X		✓				
XR 1	♂>					♀			
XD2	♂>					♀			

F.5 XAVIER IDOL'S MONITORING TOOL FOR INSTRUCTIONAL PERFORMANCE 4

5/21

Student Name	Partic.	Working	Questions	Responding	??	LG1	LG2	LG3	LG4	HW	Disrupt	Comments
		X	||		||					O		
										A		
	X	X	|||	|	|					✓		
	X	X	|	||	|					1/2		
	X	X	|		|					1/2		
	X	X			|					✓		
		X	||	||	|					1/2		
		X	|		|					✓		
	X	X	|||	|	|					✓		
										A		
	X	X	|		|					✓		
	X	X	||	|	|					✓		
	X	X	|		|					1/2		
	X	X								O		
	X	X	|		||					O		
		X			||					1/2		
	X	X								✓		
	X	X	||		||					1/2		
	X	X	||	|||						O		
	X	X	|	||						✓		

APPENDIX G

NANCY HALL'S SELECTING AND SEQUENCING FOR INSTRUCTIONAL PERFORMANCE 4

Group 1 Presentation	I selected this group's presentation first because it covers some of the basics of the task that I asked for but it shows a misconception. Particularly, it shows an incorrect ratio of offspring in the F2 generation (66.6 % of offspring have yellow peas). I expect that this will be called out by other students fairly quickly. They have the correct proportions verbally written; 1 green pea for every 3 yellow peas, so I will try to get them to see the difference. Charting on the board may also help to show this relationship.
Group 3 Presentation	This presentation shows a fairly complete summary of all the data that we have seen so far, including Mendel's peas (though there is an absence of the ratio) and the sex chromosome Punnett square. It is unclear if there is a misconception embedded in this presentation about blending; I notice that the color of the "genotype" green peas is a little lighter than the phenotype green peas and I wonder if this is because these students have a notion of these genetic factors blending in offspring.
Group 2 Presentation	This presentation incorporates the Punnett square, but uses it in a way that reflects only the phenotype (yellow vs. green) instead of the genotype (which would require incorporating the notion of chromosomes and inheriting one chromosome of each pair from either parent). This presentation has the raw material in it to really connect genotype to phenotype: it shows that "yellow" and "green" are being inherited in a Punnett square-like fashion (which is something that I have not shown students). These students give the parental genotypes to be "Yellow Yellow" and "Yellow Green" though they should both be "Yellow Green." Keeping Group 3 and Group 2 presentations up together at the same time and talking about them both might help students to make these connections as we discuss.
Synthesizing Group 3 and Group 2 Presentations by stacking the deck	Keep both group 3 and group 2 presentations on the board, put up a new poster in between them. "I think that there are some really important ideas in these presentations, and they go together really well. I want us to all focus as a class to try and merge what is going on in these two presentations. I want you all to grab a piece of lined paper so that we can try and get down the essence of what is going on between these two posters." How many copies of each chromosome do you get from each parent?

APPENDIX H

XAVIER IDOL'S INSTRUCTIONAL PERFORMANCE 4 TASK

Name ____________________ Number ____

Period ____

The Mice of Panther Hollow

Background Information

Panther Hollow is a recreational park/trail/wooded area right in the heart of Pittsburgh's Oakland neighborhood. In recent years, a foreign mouse population has moved in and started to push out the native mice and small rodent populations. This is of course a bad situation because it will disrupt the fragile ecosystem that has been established in the habitat. These mice are much larger than the native species and more aggressive. There are many ecologists out there that argue that introducing more local predators will help to control this new mouse population, or even destroy it. Others say that there are probably better methods to keep the population from rising like a large range of traps, poisons, and population separation. What we currently know about this new species of mouse is the majority of them are dominantly a cream color a small percentage of these mice are brown.

Right now, it seems like the powers that be are leaning towards introducing large numbers of a natural predator that already exists in the area. In particular, they are looking at the Red Tailed Hawk or Eastern Milk Snake. We know that hawks hunt their prey by sight, snakes usually use heat sensors or sense of smell/taste. Which of these two predators would you suggest? Does it matter?

We are going to run a simulation where you and your partner will each be one of these two types of predators.

Objective

To determine which type of predator will best rid the area of mice and see if there are any noticeable patterns in the data collected.

Hypothesis

(This MUST be a statement describing what you think and WHY.)

Safety

Do not eat mice in excess! Do not throw mice or anything else.

(This MUST be a statement describing what you think and WHY.)

Safety

Do not eat mice in excess! Do not throw mice or anything else.

Materials

- Brown/black/green construction paper
- White chocolate morsels (White mice)
- Milk chocolate morsels (Brown mice)

Procedure

<u>Part 1</u>

1. Obtain a sample group of "mice" – 12 white and 4 brown, and two sheets of construction paper (the colors will be assigned to you)
2. Randomly assort the 16 mice on the two sheets of construction paper, the "map"
3. Between yourself in your partner decide who wants to be a snake and who wants to be an owl (the hawk will go first)
4. The hawk will turn away from the map for 5 seconds, then quickly look back at the map and grab the first mouse they see
   a. It is very important to NOT look at the map for very long; it should really be the FIRST mouse that they notice
5. Repeat step 4 an additional five times
6. Repopulate the map by adding additional mice that are the same color as the ones that are still alive
   a. E.g. if you have 6 white and 6 remaining brown mice, add an additional 6 white and 6 brown mice
7. Record the results in the chart in Appendix A
   a. The number of mice of each color should be recorded AFTER repopulation
8. Repeat steps 4-7 an additional three times so that the data table is complete
9. Each time you repopulate, take an additional two mice away
   a. You took six mice in generation 1, take eight from generation 2, take 10 from generation 3, etc.

<u>Part 2</u>

10. It is the snake's turn now – repopulate the map with just 12 white and 4 brown mice
11. The snake needs to keep their eyes closed the entire time and randomly grab seven mice from the board
12. Repopulate exactly as was done in Part 1
13. Record data in Appendix B
14. Repeat steps 11-13 three more times so that the data table is complete

Analysis

1. Were either the hawks or the snakes more successful?

2. What general ideas can you draw from your simulation?

3. Was your hypothesis supported or refuted? Why do you say so?

4. Are there any trends that you noticed in your data?

5. Why do you think that is?

6. Why do you think it is not a good idea to use poisons or traps?

7. What would you tell the Panther Hollow Park Commission? What conclusion have you reached?

Appendix A

	Brown Mice	White Mice	Mice Eaten
Generation 1			
Generation 2			
Generation 3			
Generation 4			
Generation 5			

Figure 1: (Describe what this chart shows)

Appendix B

	Brown Mice	White Mice
Generation 1		
Generation 2		
Generation 3		
Generation 4		
Generation 5		

Figure 1: (Describe what this chart shows)

APPENDIX I

EXAMPLE INSTRUCTIONAL PERFORMANCE 4 LESSON PLANS

I.1 KRISTEN INGALL: INSTRUCTIONAL PERFORMANCE 4 LESSON PLAN

Mole Lab – Creating Artifacts

Grade Level: 10	**Time Length:** 43 minutes	**Date:** 3/13/14

Big Idea:
"How much" of a chemical can be measured by the mass of the particles, numbers of particles, or numbers of groups or particles (moles).

Learning Goals:

- To convert between two different units of measurement, a conversion factor is needed. When working with moles, this conversion factor is 1 mole = 6.022×10^{23} atoms/molecules.
- The molar mass of a compound is calculated by totaling the number of grams of each element contained in one mole of the compound.

Objectives:

- Given a sample of an element or compound, students will be able to collect the necessary data and calculate the number of moles contained in that sample with 70% accuracy.
- Given the number of moles of an element or compound, students will be able to calculate the number of atoms contained in that sample with 85% accuracy.
- Using their knowledge of gathering data, students will be able to determine the order steps in a procedure to calculate the number of moles, atoms, or molecules in a designated sample with 80% accuracy.

Standards:

- CHEM.A.1.1.3: Utilize significant figures to communicate the uncertainty in a quantitative observation.
- CHEM.A.1.1.4: Relate the physical properties of matter to its atomic or molecular structure.
- CHEM.B.1.1.1: Apply the mole concept to representative particles (e.g., counting, determining mass of atoms, ions, molecules, and/or formula units).

Materials Needed

For each student:

- Mole Lab Handout

For the lab counter:

- Sugar cubes
- Table salt ($NaCl$)
- Empty soda cans
- Iron nails
- Scoopulas
- Copper wire
- Baking soda ($NaHCO_3$)
- Sand (SiO_2)
- Vinegar ($C_2H_4O_2$)
- Pipettes

For each group:

- Balance
- Poster
- Calculator
- Markers

For the teacher:

- Lesson plan
- Powerpoint

Safety Concerns:

- Identify students that have not completed their laboratory safety quiz, have not returned their signed safety contract, and are not dressed appropriately and inform them that they will be completing an alternate assignment.
- Ensure that each student has a laboratory apron and safety goggles and remind them to tie back their hair and wear their PPE (personal protective equipment) at all times.
- Tell students to treat all chemicals as highly toxic and use caution when handling them. If they do touch a chemical, walk immediately to the sink and begin washing your hands with cold water. Have one of your lab partners alert the teacher to the situation.
- Remind students that there is no eating or drinking in the laboratory and that they should refrain from putting their hands in their mouth to avoid ingesting dangerous chemicals. They should wash their hands thoroughly when leaving the lab, even if they don't think that they touched any chemicals.
- Remind students to move slowly and carefully in the lab to ensure there are no accidents.

Set Up:

- A copy of the lesson plan is printed and on my desk.
- The smartboard is showing the Warm-Up.
- Copies of Mole Lab Handout are printed and ready to hand out.
- The lab is set up according to the materials above. There will be seven stations with balances.

Accommodations/Modifications:

- The student who has a learning disability has been placed in a group with a strong leader who will help him to understand today's laboratory activity and complete the lab handout. In addition, this student has preferential seating.
- The student with autism works quickly, but is allowed any additional time he needs to complete the activity. He does not require preferential seating.

Lesson Opening:

Warm-Up (3 min): Pre-assessment of student knowledge

How many moles are in 324.19g of $NaNO_3$?

Class Discussion (4 min):
Students should use what they learned during the previous lesson to complete these questions. I am looking for students to use the correct units in their answers. I will again stress that if they do not include the units or they include the incorrect units, the answer is incorrect. In addition,

they will need to be able to calculate the molar mass of the compound to use in this calculation. During the discussion, I will also remind students about the importance of significant figures as well as its impact on the accuracy of our answers. This question is used to prepare students for the laboratory activity today as they will need to know how to do these calculations to successfully complete the lab.
The answer to the warm-up question is 3.8142 moles.

"Great job class! You remembered how the periodic table helps us determine the mass of one mole of either an element or a compound. You will need to use this skill to complete today's laboratory activity about moles. On Tuesday, we completed an activity that helped us determine how to find the number of atoms or moles in a sample. Today we will be using what we learned during that activity to write our own labs!"

Support of Lesson Activities:

Launch (6 min)

I will tell students:

- Over the past week and a half, we have been learning how to do mole conversions by using our mole roadmap. Yesterday, we practiced gathering first-hand data to calculate how many moles and atoms are in a piece of aluminum.
- Today you will be given a similar task – you will be finding the amount of moles or atoms in a given substance.
- But wait, there's a catch... I am not giving you any instructions on HOW to do this! You will need to rely on what you (or your partner) know about how grams, atoms, and moles are related.
- During the lab, I want one person to be recording EVERY step you do! This is going to be labeled as your procedure. You can write this down on a separate piece of lined paper or on the back of your lab handout.
- I also need you to write down the materials you use. Don't forget to include things like the balance or a scoopula!
- You should also have a data table of some kind that displays the data you collect.
- Each group also needs to have an analysis section where you show all of your calculations.
- Finally, you need to have a conclusion where you share your final answer.
- By the end of the period, you need to have a poster completed that has all of these sections displayed on it!

Any Questions?

- I will leave these instructions up on the PowerPoint during the laboratory today in case your group forgets one of these sections.
- All of the materials are on the back lab bench, so you will need to collect anything that

you need to conduct your laboratory. There is already a balance and a calculator at each lab station.

- The posters and markers are in the classroom.
- Remember to ask your lab partner your question before you ask me!
- You will be working in pairs to complete this laboratory activity.
- Please let me know what your group chooses to investigate!
- Before we begin, let's go over some safety reminders! (Read these from the top of page 2).

Any Questions????

- We are starting at (time) so you have until (time) to finish the activity and the required sections.
- Ready…. Go!

Activity Time (23 min)

- As students work in the lab, I will be circulating so that I will be available to answer any questions that they may have regarding the activity and ensure that everyone is working ***SAFELY***.
- An example of anticipated student thinking is included at the end of this lesson plan.
- Throughout the activity, there will be several questions that I will want to ask groups to start them thinking about and/or discussing the phenomenon they are seeing.
    - **What does the atomic mass on the periodic table represent?** *I expect students to tell me that the atomic mass indicates the mass of one atom of the element (in amu) and/or one mole of the element (in grams). It is important for students to understand the difference between these two quantities as students are often confused by the difference between atoms and moles.*
    - **What do you need to find in order to calculate the number of moles of a substance?** *I expect students to tell me that they need to have either the mass of the substance or the number of atoms in order to calculate the number of moles. I will push them to think about what is practical in this situation (i.e. can they count the number of atoms?). They should realize that they need to first find the mass of their sample before they can do any calculations about how many moles or atoms they have. If they are having trouble coming up with an answer to my question, I will encourage them to consult their mole conversion roadmap.*
    - **How did you decide what conversion factor you needed to use when converting into atoms?** *I expect students to tell me that they knew that one mole equals 6.022×10^{23} atoms (this is the conversion factor) from class over the past couple of days. They should then tell me that they multiplied the number of moles of their substance by 6.022×10^{23} to calculate the number of atoms. They should also show all of their work and use the "train-track" method. Another good check for understanding here is to make sure they multiplied by 6.022×10^{23} instead of dividing. Students tend to initially be very confused when working with these*

types of calculations.

If students finish this activity early, I will ensure that they have all of the required sections on their poster. If their poster is complete, I will allow students to work on the homework packet for this week during the time remaining.

Class Discussion (0 minutes):

None today! The discussion will take place tomorrow as a 5 Practices Discussion.

Lesson Close *(3 min)*:

Ask students to leave their posters on their tables as leave; I will collect them after the period is over. They should also clean up their lab stations and ensure that everything is put back where they found it.

Remind students that they should be working on their homework for this week. It is due on TOMORROW!

No exit slip today! Creating the posters will likely take the entire period.

Assessment:

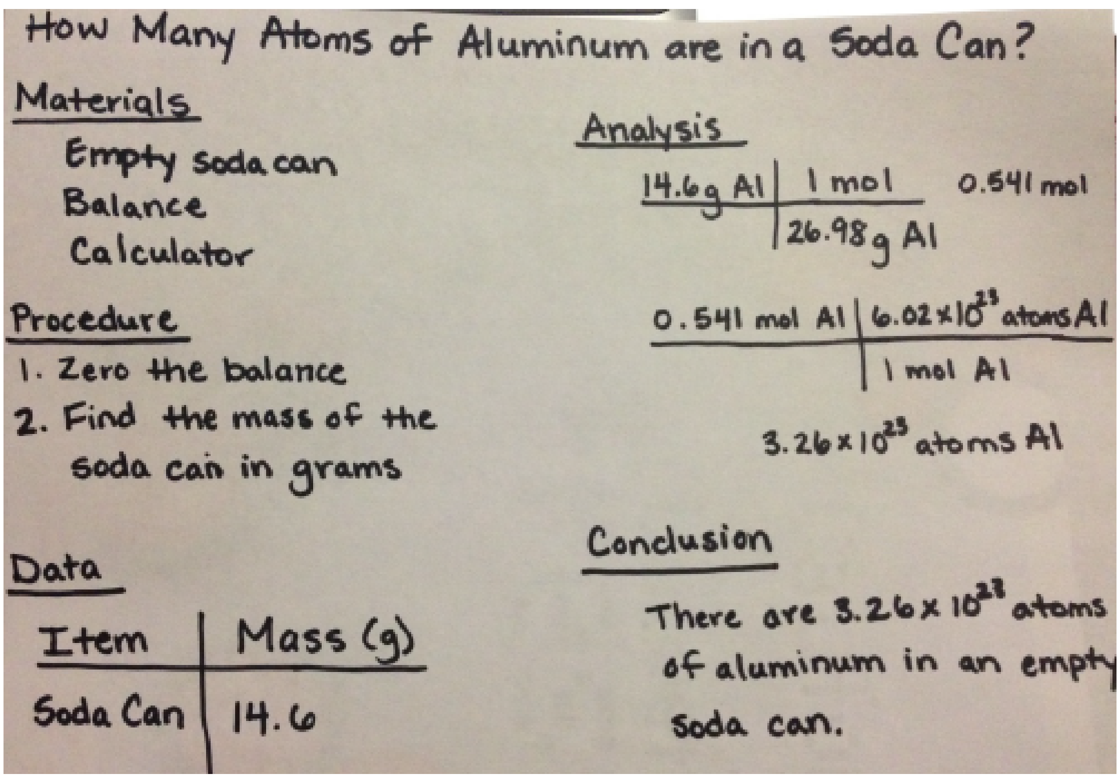
Objective	When Assessed	How Assessed
Given a sample of an element or compound, students will be able to collect the necessary data and calculate the number of moles contained in that sample with 70% accuracy.	On the student poster and Mole Lab Handout	Students will collect data on the mass of their sample. They will then use this information to calculate the number of moles or atoms contained in that sample using either the atomic/molar mass as the conversion factor. It is required that they show all work and label their units. The answers should also include the correct number of significant digits.
Given the number of moles of an element or compound, students will be able to calculate the number of atoms contained in that sample with 85% accuracy.	On the student poster and Mole Lab Handout	Students should be able to calculate the number of atoms or molecules in a substance by using the "train-track" method (factor label). Students should use Avogadro's number as the conversion factor. It is required that they show all work and label their units. The answers should also include the correct number of significant digits.
Following the day's activity, students will be able to determine the correct order steps in a procedure to calculate	On the student poster and Mole Lab Handout	Students should say that they need to complete the following steps: 1. Determine the mass of the sample 2. Use the molar or atomic mass to calculate the number of moles

the number of moles, atoms, or molecules in a designated sample.		3. Use Avogadro's number to calculate the number of atoms or molecules Students should go into additional detail to describe the steps used to mass the sample (i.e. weighed the nail on a zeroed balance). Students may not use the term "Avogadro's number", but may use 6.022×10^{23} instead.

Resources:
I adapted this laboratory activity from the Pittsburgh Public Schools Chemistry Curriculum for Unit 5

Anticipated Student Thinking:

Example Poster:



Mole Lab – 5 Practices Discussion

Grade Level: 10	**Time Length:** 43 minutes	**Date:** 3/17/14

Big Idea:
"How much" of a chemical can be measured by the mass of the particles, numbers of particles, or numbers of groups or particles (moles).

Learning Goals:
- To convert between two different units of measurement, a conversion factor is needed. When working with moles, this conversion factor is 1 mole = 6.022×10^{23} atoms/molecules.
- The molar mass of a compound is calculated by totaling the number of grams of each element contained in one mole of the compound.
- Writing lab reports helps students to develop or sharpen skills associated with scientific inquiry, the scientific method, scientific thinking, and scientific communication, which are at the heart of the scientific process.

Objectives:
- Given a sample of an element or compound, students will be able to collect the necessary data and calculate the number of moles and/or atoms contained in that sample with 80% accuracy.
- Using their knowledge of gathering data, students will be able to determine the order of steps in a procedure to calculate the number of moles, atoms, or molecules in a designated sample with 80% accuracy.
- Following the class discussion, students will be able to write a lab report that contains correct information in all of the relevant sections (question, materials, procedure, data, analysis, and conclusion) with 70% accuracy.

Standards:
- CHEM.A.1.1.3: Utilize significant figures to communicate the uncertainty in a quantitative observation.
- CHEM.A.1.1.4: Relate the physical properties of matter to its atomic or molecular structure.
- CHEM.B.1.1.1: Apply the mole concept to representative particles (e.g., counting, determining mass of atoms, ions, molecules, and/or formula units).

Materials Needed
For each student:
- Mole Lab Handout

For the lab counter:
- Sugar cubes
- Table salt ($NaCl$)
- Copper wire
- Baking soda ($NaHCO_3$)

- Empty soda cans
- Iron nails
- Scoopulas
- Balance
- Sand (SiO_2)
- Vinegar ($C_2H_4O_2$)
- Pipettes
- Calculator

For each group:

- Poster
- Markers

For the teacher:

- Lesson plan
- Powerpoint

Safety Concerns:

- None! Students will finish constructing their posters and will be participating in a whole-class discussion.

Set Up:

- A copy of the lesson plan is printed and on my desk.
- The smartboard is showing the Warm-Up.
- Student posters and markers have been placed on each group's table.
- The materials listed above have been moved to the teacher's table. All students should be done with their measurements and these items are there only for discussion purposes.

Accommodations/Modifications:

- The student who has a learning disability was placed in a group with a strong leader who will assist him in composing his thoughts for the poster and participating in the discussion. In addition, this student has preferential seating.
- The student with autism works quickly and participates in discussion well, but is allowed any additional time he needs to complete the activity. He does not require preferential seating.

Lesson Opening:

Thought Question: Pre-assessment of student prior knowledge (1 min)

Think back to last semester when we discussed calculations and measurements with significant figures. Did you use significant figures in your calculations? If not, how would that change your answer?

Class Discussion (3 min)

Students should recall that significant figures are used to indicate how well we "know" an answer. Because many students used only a digital balance while gathering their data, they should not have any problems related to significant figures in their measurements. However, it is likely that many will have too many significant figures later in their calculations. The balances in this classroom only weigh out to a tenth of a gram, so students' answers on the posters should only have two or three significant figures. I am using this question as a thought question to have students remember that they should be taking significant figures into account when reporting their answers.

"Great job class! I know we have not talked about significant figures in a while, but they are always important when we do measurements and calculations. Think about it this way, you would be pretty upset if someone paid you 100 dollars instead of 143 dollars because they rounded to a different number of significant figures! If you are having a tough time remembering the rules for significant figures, look back in your notes. You will need to know these rules as we continue doing laboratory experiments."

Support of Lesson Activities:

Launch (3 min)

I will tell students:

- Last week, each group chose a question from the Mole Lab handout to answer.
- I didn't give you any instructions on how to arrive at your conclusion other than to answer the questions!
- However, I did ask you to have several specific sections on poster. These sections will be posted on the PowerPoint while we finish our posters if you have forgotten what they are.
- You have about ten minutes to wrap up your posters in your small groups before we come back together for a whole class discussion.

Any Questions?

- The posters and markers are already on your tables, so you should be ready to get to work!
- Remember to ask your lab partner any questions before you ask me!
- We are starting at (time) so you have until (time) to finish the activity and the required sections.
- Ready.... Go!

Poster Construction (7 min)

- During this time, I will be checking to see that all groups have each section represented on their poster in some way. These sections are question, materials, procedure, data, analysis, and conclusion.
- I will encourage groups who complete their posters early to consider how taking significant figures into account would affect their answer. They may want to revise their poster accordingly.
- After seven minutes, I will ask students to stop where they are so that we can begin the 5 Practices Discussion. Let these students know that they can finish their posters later if

they want to.

Transition Time (3 min)

- Ok, now that everyone has had a chance to wrap up their posters, we will be sharing your posters with the class!
- We are going to have a whole class discussion to come to a consensus on how we could gather data to determine the number of atoms or moles in a substance.
- In addition, we are going to be comparing our posters to determine what information is really important to have in a lab report.
- Ok class, this discussion is going to run similar to the discussions that we have when we answer our "Thought Questions" in the beginning of the period. One by one, groups will share certain parts of their poster and everyone else will have the chance to ask them questions and challenge their thinking.
- Before we get started, I want to remind everyone of ground rules before we get started. (They are on the next PowerPoint slide.):
    - Speakers:
        - Stand up when it is your turn to present and hold your poster up high so that everyone can see.
        - Remember to speak loudly!
        - Explain how you represented the neutral atoms and ions on your poster.
        - Also, explain how you decided what the charge would be on each of your ions as well as why they would gain or lose that amount of electrons.
        - When you are finished with your presentation, call on audience members to ask questions.
    - Audience:
        - Be respectful of your peers while they are presenting.
        - Listen to what the speakers are saying and take notes of any questions you might have. You will ask these questions at the end of their presentations.
        - Don't interrupt your classmates.
        - Make sure you are paying attention at all times; you never know when I might call on you!
        - As always, you receive bonus points for contributing to the discussion.

Any Questions???

- Alright let's get started! Michael's group, why don't you describe how your group went about answering your question? Don't forget to explain your thinking!

Discussion Time (21 min)

- During this discussion, I want to make sure that it remains student-driven and that I employ a great deal of "tossing" when questions are directed at me.
- Make sure to cold call students if needed so that everyone is involved.

- Use the monitoring tool to keep track of what groups bring up which ideas and what information still needs to be brought forward.
- Chart important ideas on the blackboard with sections for each of the sections that should be on each group's poster.
- Throughout the discussion, there will be key scaffolding questions that I will want to ask groups to address any misconceptions or prod their thinking deeper.
- Also, there will be several questions that I will want to ask groups to start them thinking about and/or discussing the phenomenon they are seeing.
    - What does the atomic mass on the periodic table represent? *I expect students to tell me that the atomic mass indicates the mass of one atom of the element (in amu) and/or one mole of the element (in grams). It is important for students to understand the difference between these two quantities as students are often confused by the difference between atoms and moles.*
    - What do you need to find in order to calculate the number of moles of a substance? *I expect students to tell me that they need to have either the mass of the substance or the number of atoms in order to calculate the number of moles. I will push them to think about what is practical in this situation (i.e. can they count the number of atoms?). They should realize that they need to first find the mass of their sample before they can do any calculations about how many moles or atoms they have. If they are having trouble coming up with an answer to my question, I will encourage them to consult their mole conversion roadmap.*
    - How did you decide what conversion factor you needed to use when converting into atoms? *I expect students to tell me that they knew that one mole equals 6.022×10^{23} atoms (this is the conversion factor) from class over the past couple of days. They should then tell me that they multiplied the number of moles of their substance by 6.022×10^{23} to calculate the number of atoms. They should also show all of their work and use the "train-track" method. Another good check for understanding here is to make sure they multiplied by 6.022×10^{23} instead of dividing. Students tend to initially be very confused when working with these types of calculations.*
- After all of the different solutions for this problem have been brought up and any misconceptions have been addressed, I will turn student's attention to the blackboard.
- I will have compiled information from all posters presented so that we can discuss the different sections of the lab report as well as what information should or should not go in each of these sections.
- Once the class has settled on a consensus for the information that should be contained in each section of their lab reports, we will use it to talk through how we would determine the number of molecules in 100 mL of isopropanol ($CH_3CH_2CH_2OH$).
- I will make sure to use appropriate revoicing language and include only those concepts explicitly stated by students.
- Once we have finished discussing the isopropanol investigation, students will record the information from the blackboard into their notebooks.
- As students are writing, let them know that we will be using these notes in the future to

conduct more scientific investigations and get more practice writing lab reports! We will be adding to this list as time goes on.

Expected List of Information to be Included in a Lab Report:

- Question
    - Why are you doing this experiment?
- Materials
    - What did you use?
- Procedure:
    - What did you do? BE SPECIFIC!
- Data Table
    - Show the data you collected
- Analysis
    - Calculations
- Conclusion
    - What is the answer to your question?

Lesson Close *(5 min)*:

Tell students that we had an awesome discussion today and that you are truly proud of how well they did. (I am thinking positively here!)

Reiterate that today we discussed how we would collect data to calculate the number of moles or atoms of a substance contained in a given sample. We also came to a consensus as to what information we should or should not include in a lab report so that we will be prepared to organize this information in the future!

Let them know that tomorrow we will begin talking about percent composition – the amount of one element contained in compound. In a week or so, we will be tying all of these ideas together with a percent composition experiment!

Ask students to leave their posters on the desk when they leave today.

Let students know that there is no homework tonight, but they will be receiving homework tomorrow on mole conversions and percent composition.

Exit Slip:
Use your calculator and show your work!
How many atoms are in 3.4 moles of carbon?

Assessment:

Objective	When Assessed	How Assessed
Given a sample of an element or compound, students will be able to collect the necessary data and calculate the number of moles and/or atoms contained in that sample with 80% accuracy.	On the student poster, Mole Lab Handout, and Exit Slip	Students will collect data on the mass of their sample. They will then use this information to calculate the number of moles or atoms contained in that sample using either the atomic/molar mass as the conversion factor. It is required that they show all work and label their units. The answer to the Exit Slip question is 2.05×10^{24} atoms.
Following the day's activity, students will be able to determine the correct order steps in a procedure to calculate the number of moles, atoms, or molecules in a designated sample.	On the student poster and Mole Lab Handout	Students should say that they need to complete the following steps: 4. Determine the mass of the sample 5. Use the molar or atomic mass to calculate the number of moles 6. Use Avogadro's number to calculate the number of atoms or molecules Students should go into additional detail to describe the steps used to mass the sample (i.e. weighed the nail on a zeroed balance). Students may not use the term "Avogadro's number", but may use 6.022×10^{23} instead.
Following the class discussion, students will be able to write a lab report that contains correct information in all of the relevant sections (question, materials, procedure, data, analysis, and conclusion) with 70% accuracy.	During the class discussion	During the class discussion and marking period, students will create a blackboard list of all relevant information that should be included in these sections. As a class, they should be able to use this list to verbally state the information that would be included in a lab report designed to investigate the number of molecules in 100mL of ethanol.

Resources:

I adapted this laboratory activity from the Urban Public Schools Chemistry Curriculum for Unit 5

I.2 SCOTT XANDER: INSTRUCTIONAL PERFORMANCE 4 LESSON PLAN

Momentum
March 12th, 2014
Five Practices – Two Dimensional Collisions

Big Idea

All motion can be explained using conservation of energy, conservation of momentum, and conservation of angular momentum.

Learning Goals

1. Momentum is a vector
2. Momentum is conserved even when colliding object move at an angle to one another.
3. To analyze momentum for angular directions we use vector techniques discussed in prior units.

Learning Objectives

- Students will be able to use ideas of conservation of momentum to solve problems involving collisions, explosion, etc.

Related Standards

- S11.A.1.1.1 :The position and velocity of an object or interacting objects can be represented and quantified in terms of its momentum, angular momentum, kinetic energy and potential energy.
- The total amount of momentum in a closed system is conserved

Materials Needed

For each student

- Simulation packet

For each group

- Computer
- Blank piece of paper for final problem

For teacher

- Make answer sheet.

Set Up

- Make entry slide

- Set out computers

Special Accommodations

Place weaker students in a pair with stronger students.

Warm Up (1 min)

- Project objective slide onto the board
  - AIM: How do we solve collision problems in two dimensions
    - Discuss Homework
    - Complete simulation activity
    - Work on two dimensional collision problem
    - Discuss problem and activity

Launch (5 min)

- Today we want to take ten minutes at the beginning of class to discuss any outstanding issues with last night's homework.
- Next we are going to complete an activity in which you will simulate various collisions using the computers from the cart.
  - This activity will involve two dimensional collisions
- Afterwards we will come back together to discuss some of the big ideas from the activity
  - Ideally after the discussion you will be able to solve two dimensional motion problems.
  - If there is time after the discussion, we will have some time to work on a few two dimensional collision problems

Work Time (30-35 min)

First ten minutes (Homework)

- Expect students will have biggest problem with 21 or 23a.
- Show them that this situation has some more moving parts, but the general schematic for solving the problem is still the same.
- We are going to again need these three big physics ideas to solve two-dimensional problems.

Introduce Activity

- In this activity you guys will be using computers to complete an investigation about two-dimensional collisions. (pass out packet)
- You will be working in groups of three. You will each need to complete one of the packets that I handed out. The directions should be pretty straightforward, but if you have any questions, ask Scoville or me.
- The main focus for this lesson is to understand how this idea of conservation of momentum applies to two-dimensional collisions.
- Groups

Group	Member 1	Member 2	Member 3
A	Kelly	Kevin	Howie
B	Mohammed	Nimo	Rachel
C	Zack	Amanda	Angela
D	Alexis	Mia	Tyler
E	Zoe	Crystal	Megan
F	Skyler	Ayanna	James
G	Dhundi	Miranda	Jeff
H	Carly	Makeda	Graham
I	Meredith	Aaron	Dre
J	Alivia	Summer	Alicia
K	Charity	Serenity	Mark

Next 20 minutes

- Students should engage with the simulation.
-
- Monitoring questions.
  - Is this introductory problem in one or two dimensions? How do you know?
  - Which do you think happens more frequently, one or two dimensional collisions?
  - What would happen if the objects stuck together instead of bounced apart?
  - What is the lpl figure showing you?
    - This is the magnitude of momentum
  - From the magnitudes of the momentum before and after, do you see that momentum is conserved?
    - Why could this be?

Second period

- Place students' problems on the ELMO.
- Ask students what they think about each solution.
- Give groups a chance to explain what they did.
- Show students how to solve the problem.
  - Have them watch me solve it then put in their notebooks

HW Problems

Summary (1 minutes)

- Tomorrow we will continue discussing how to solve two dimensional collision problems.

Momentum
March 13th, 2014
Five Practices Discussion – Two Dimensional Collisions

Big Idea

All motion can be explained using conservation of energy, conservation of momentum, and conservation of angular momentum.

Learning Goals

1. Momentum is a vector
2. Momentum is conserved even when colliding object move at an angle to one another.
3. To analyze momentum for angular directions we use vector techniques discussed in prior units.

Learning Objectives

- Students will be able to use ideas of conservation of momentum to solve problems involving collisions, explosion, etc.

Related Standards

- S11.A.1.1.1 :The position and velocity of an object or interacting objects can be represented and quantified in terms of its momentum, angular momentum, kinetic energy, and potential energy.
- The total amount of momentum in a closed system is conserved

Materials Needed

For each student

- Simulation packet

For each group

- Computer
- Blank piece of paper for final problem

For teacher

- Make answer sheet.

Set Up

- Make entry slide

- Make copies of simulation.
- Set out computers

Special Accommodations

- Place weaker students in a pair with stronger students.
- Ask students who are finished with the problem to begin thinking about how they will relay the information that they know to their classmates.

Warm Up (1 min)

- Project objective slide onto the board
    - AIM: How do we solve collision problems in two dimensions
        - Quick debrief about activity yesterday
        - Take ten minutes to complete what you did not complete yesterday
        - Discuss activity
        - Learn how to deal with two dimensional Collisions
        - HW: Collisions 2D

Launch (5 min)

- First off, I wanted to let you guys know that the test is no longer Friday. We are going to shoot for a Monday test
- Today we are going to finish the activity from yesterday involving the simulation. Take ten minutes at the beginning of this class to finish up the rest of the activity from yesterday. IF you have already finished the problem and feel confident in your solution, begin thinking about how you would explain your thought process to your classmates.
    - Does this solution path make sense for other situations or just this one?
- When ten minutes is up, we will come back together to discuss two-dimensional collisions. In this discussion we will try to synthesize a plan that will allow us to solve two all two dimensional conservation of momentum problems.

Work Time (50 min)

First ten minutes (Homework)

- Expect students will have biggest problem with 21 or 23a.
- Show them that this situation has some more moving parts, but the general schematic for solving the problem is still the same.
- We are going to again need these three big physics ideas to solve two-dimensional problems.
- Groups

Group	Member 1	Member 2	Member 3
A	Kelly	Kevin	Howie
B	Mohammed	Nimo	Rachel
C	Zack	Amanda	Angela

D	Alexis	Mia	Tyler
E	Zoe	Crystal	Megan
F	Skyler	Ayanna	James
G	Dhundi	Miranda	Jeff
H	Carly	Makeda	Graham
I	Meredith	Aaron	Dre
J	Alivia	Summer	Alicia
K	Charity	Serenity	Mark

- What is the |p| figure showing you?
  - This is the magnitude of momentum
- Why is |p| not the same as p_x or p_y
- How do you think the computer is calculating |p| based on p_x and p_y?
  - Does this remind you of anything that we've seen before?
- What do you notice about px and py before and after the collision
- Is |p| conserved for each object?
- Is |p| conserved for the system?
  - Does this violate conservation of momentum?

Discussion [30-40]

- Place students' problems on the ELMO.
- Pose situation of 1 kg ball being hit at a 45 degree angle with a speed of 50 m/s
  - Draw on the board. Label axes
  - What is the momentum of this ball right after it is hit?
  - What is the direction of the momentum?
    - Let's say up and to the left
  - How do we want to define our coordinate system?
    - Students will probably say make right positive or make direction of the ball positive.
    - Ask why they chose these.
  - Let's also call *right* the positive direction
  - If we choose the right to be the positive direction, how much momentum does this object have going to the right?
  - How much momentum does it have upward?
    - Can anyone think of a way to calculate these quantities?
    - Momentum just like forces, velocities, accelerations, etc. can be divided into components. If it is vector, it can go in any direction, so we have to have some way to break it down into parts that correspond to our axes.
- So now that we see momentum does not have to lie only on an axis, I want to think about the problem at the end of the handout I gave you yesterday.
- This problem is just one type of two dimensional collision problem. But it turns out that, just like one dimensional collision problems, two-dimensional problems only require three bits of physics knowledge pairs with some algebra skills.
- As we run through this problem, I will be putting some of your suggested answers up on the ELMO for your classmates to see.

- I want us to look critically at classmates' solutions. You should always be thinking….does this physical situation make sense? [in terms of both numbers and pictures]
    - I want you to see if you can think of ways to not only solve this problem, but also if you can abstract from what we see in this problem to find general solution paths for all two dimensional problems.
- What direction do you think the cars should move in after the collision?
    - North east.
    - It is good to get an intuitive understanding of what the *after* situation will probably look like.
    - Why do you guys think that the car will move to the northeast?
        - Should arrive at the one car has northward momentum. The other has eastward momentum. When they combine, their momentum combines.
    - Show other situations: southward and eastward moving cars. Predict outcomes
- We know they have some momentum in the north east direction?
    - How northeast is it?
    - When we saw a two dimensional collision in the simulation, was there momentum conservation?
        - How did you see that momentum was conserved.
        - Px, py, or |p|?
        - Only px and py
    - We know that the momentum in both the x and y directions must be conserved.
        - How do you think we figure out the total momentum of the car system after the collision?
        - Should arrive at "the px and py have to be the same so we combine them"
    - How do you think we combine them?
        - Vector addition
        - Head to tail
    - Is |p| for either of the objects conserved?
    - Is |p| for the system conserved?
- Come up with a schematic of how to solve these problems.
    - Write students steps on the board.
    - Make sure they explain all thinking. [mv because momentum equals mass times velocity]
    - Be careful with words. Momentum of the system vs. momentum of an object.
- Attempt to solve a two dimensional problem with westward and southward moving bodies.

Distribute HW and work on it if there is time left!

Summary (1 minutes)

- Tomorrow we will continue discussing how to solve two dimensional collision problems. As well as start our review for the test on Monday. Make sure that you complete the problems for homework tonight so that you can follow along and participate in the discussion tomorrow!

I.3 NICOLE TIMKO: INSTRUCTIONAL PERFORMANCE 4 LESSON PLAN

GETTING READY		
Unit: 4-Cell Growth and Division	**Period:** 7, 8, 9 **Date:** 2/6/14	**Time:** 42 minutes
Preparation: **Day of lesson:** • Make copies of lab packet	**Materials:** • Worksheet/Lab Packet per group • Whiteboards • Whiteboard markers • Erasers **Resources:** Lesson adapted from Julia Glick. Original materials can be requested. **Safety Concerns:** NONE	**Big Idea** The cell is the basic unit of life. The processes that occur at the cellular level provide the energy and basic structure organisms need to survive. DNA is the universal code for life; it enables organisms to transmit heredity information and along with the environment, determine an organisms characteristics. **Overarching Questions** • Why are cells so small? • How does a cell produce a new cell? • How is biological information passed from one generation to another?

Prior Knowledge:

1. All students are able to list the phases of mitosis in the correct sequential order.
2. Most students are able to list the key features of each phase.
3. Some students are able to identify images of mitosis and name the phase displayed

Misconceptions:

- Chromosomes do not occur in all types of cells.
- Chromosomes are divided up at each cell division, such that when a single body cell forms two body cells, the resulting cell contains fewer chromosomes than the original cell.
- Cells are smaller than chromosomes
- Not all types of cells contain DNA molecules

Vocabulary:

Tier 2:
Division
Replication

Tier 3:
Chromosome
Prophase
Anaphase
Metaphase
Interphase
Cytokinesis
Telophase
Chromatid
Centriole
Spindle Fiber
Chromosome
Metaphase Plate

Standards:

Keystone Standards:

Describe the three stages of the cell cycle: interphase, nuclear division, and cytokinesis. **BIOB.1.1**

Describe the events that occur during the cell cycle: interphase, nuclear division (i.e., mitosis, or meiosis), cytokinesis. **BIO. B.1.1.1**

A1.2.3.2.1: Estimate or calculate to make predictions based on a circle, line, bar graph, measures of central tendency, or other representations.

A1.2.1.1.1: Analyze a set of data for the existence of a pattern and represent the pattern algebraically and/or graphically.

Pennsylvania Academic Standards:

PA Academic Standards

3.1.B.A4 Summarize the stages of the **cell cycle**. Examine how interactions among the different molecules in the cell cause the distinct stages of the cell cycle, which can also be influenced by other signaling molecules.

NGSS Practices:

2. Planning and carrying out investigations.
3. Analyzing and interpreting data
4. Using mathematics and computational thinking
5. Constructing explanations (for science)
6. Engaging in argument from evidence
7. Obtaining, evaluating, and communicating information

Common Core:

CCSS# 2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Learning Goals:

- Interphase occurs before cell division. During interphase, the cell grows and prepares for cell division by replicating its DNA. Cells spend most of their time in this phase.
- Following interphase, the cell proceeds through the process of cell division: Prophase, Metaphase, Anaphase, Telophase, and Cytokinesis.
- The first phase of mitosis is prophase. In prophase, the genetic material inside of the nucleus condenses and the duplicated chromosomes become visible. Outside the nucleus, the spindle starts to form.
- The second phase of mitosis is metaphase. During metaphase, the centromeres of the duplicated chromosomes line up across the center of the cell. Spindle fibers connect the centromere of each chromosome to the two poles of the spindle.
- The third phase of mitosis is anaphase. During anaphase, the chromosomes separate and move along spindle fibers to opposite ends of the cell.
- The last phase of mitosis is telophase. During telophase, chromosomes gather at opposite ends of the poles and a nuclear envelope begins to reform around each cluster. The spindle begins to break apart. A cleavage furrow begins to form.

Getting Your Students Ready

Objective: *Today you will be able to...*	**Purpose**: *We are doing this...*
After viewing a slide of cells, students will be able to determine the phase of mitosis for each cell with 90% accuracy. After gathering data, students will be able to represent first hand data in an accurate graph. After representing the data, students will be able to draw conclusions about patterns demonstrated in the data to answer the question, "Where do cells spend most of their time?"	To determine where cells spend most of their time, in cell division or growth/preparation.

Building the Skill

Launch

ENGAGE	**Do Now** 2 min	Think: Where do you think cells spend most of their time growth (Interphase) or cell division (Prophase, Metaphase, Anaphase, Telophase, Cytokinesis)?
	Do Now Discussion 2 min	Pair: Turn to the partner next to you and discuss your answer (1 min) Share: Students share out and teacher charts on the SMART board (1 min) *Questions to guide student thinking:* -Why do you think cells spend most of their time in _________? -What evidence have we seen from our other activities that would suggest that cells spend most of their time doing _____? -What experiences have you had that make you think ________?

	Introduce Task 2 min	By the end of today, we are going to be able to answer the warm-up question: "Where do cells spend most of their time in growth or division?" We are going to do this by looking at pictures of microscope slides of real cells. As we know, we can't see cells without a microscope. Using your knowledge about mitosis, you will determine the phase of each cell on your slide.
	Review Phases of Mitosis 3 min	To review the phases of mitosis, I want you to match up your note cards. I will come around and check them.
	TASK	
EXPLORE	**Mitosis Phase Key** 8 min	Now that we have reviewed the phases, we are going to look at a few pictures of real cells under a microscope. We will work together to make a key that you can use to help you identify the cells during today's task. First, I want to identify the key features of each phase. If we were to see a cell in interphase, what would we expect to see? (Students respond) Okay, if that is what we expect to see, what picture above shows interphase? Great! Teacher continues to guide students through prophase, metaphase, anaphase, telophase and cytokinesis. *Anticipated problems: Picture F and Picture D* -Picture F is an example of a cell with two nuclei. This cell is in interphase. It is possible that the cell failed to complete cytokinesis and has now joined back together or two cells have formed together. -Picture D is an examples of prophase. The circle in this picture is the nuclei not the whole cell. In the nucleus, we can see that the DNA has been supercoiled into chromosomes. The chromosomes are now visible.
	Groups 2 min	We will now be moving into our groups to start identifying the cells. You and your table partner will have 8 minutes to identify each cell as one of the 6 phases: interphase, prophase, metaphase, anaphase, telophase, or cytokinesis. Use your key to help you!

	Students Gather Data 8 min	Students use their key to identify the phase of each cell. ***Guiding Questions to help students who are stuck:*** "Which picture on your key looks like the cell you are looking at?" "What is happening with the chromosomes in this cell? In what phase does this happen?" (Prompt students to use their mitosis worksheet to help them) "Where are the chromosomes in this picture?" *Teacher monitors using monitoring tool to determine which groups are determing which patterns and whether or not these patterns are correct.
	Introduce Data Representation 3 min	Now that you have gathered data, you need to represent your data in a graph so that other people can easily read your results. Each pair will get a whiteboard and marker to draw their graph. Try to make your graph as large and clear as possible because you will be presenting it to the class. What kind of graph might be use to represent this data and why?
	Students Make Bar Graph 10 min	Students make bar graphs to represent their data on large whiteboards. Teacher reminds students that they need to work collaboratively to make their graph, making sure that both students are contributing to the graph.
		BREAK BETWEEN PERIODS FOR 8/9 OR END OF LESSON FOR PERIOD 7
	Finish Graphs 2 min	Students finish their graphs if necessary.
	Finding Patterns/ Teacher Sequences 3 min	From you graph I want you and your partner to determine if cells spend most of their time growing or dividing. Let's remember that the growing phase is interphase and that the cell is in mitosis or division in PMATC. Take 1.5 minutes to answer the question, "Where do cells spend most of their time?" based on your data (graph).

		Teacher take pictures of student work and sequences student work based on the results of the monitoring tool which determined the patterns found and the claims made/evidence provided for each group.
EXPLAIN	**Introduce Discussion** 3 min	Now I will be calling up certain groups to present their findings. Unfortunately we will not have time for every group, but I expect everyone to participate. Remember that you can mark off the date for today's behavior bingo for "respectfully participating in class discussion". Remember to respectfully respond use the sentence, "I agree or disagree with ______ because…" When you present, please explain your graph to us and tell us where cells spend most of their time.
	Discussion Part I 10 min	Teacher asks specific groups to present their findings, as sequenced due to student thinking vai monitoring tool. *Teacher guides discussion with the following questions:* • When students say claim without evidence, teacher asks students to "show us where your graph explains your claim? Where do we see the evidence that cells spend most of their time in ______ phase?" • Toss to other students and ask if they agree or disagree with the student's pattern • Show us on the slide which cells you marked as dividing cells (or interphase cells) *Teacher has the picture of the slide that the group used up on the SMART board under the ELMO so that we can refer to it if necessary* *Anticipated Answers:* Dividing Pattern: Non-Dividing Pattern: Most all

	Discussion Part II 7 min	Why do you think we see two patterns emerge? Discuss with your partner (3 min) Students share out their responses and teacher charts on the SMART board. (3 min) ***Teacher guides students with questions during pair and share:*** What kind of cells do you think divide often? Why? How do you know that? What kind of cells do you think don't divide? Why? How do you know that? Which kind of cells do you think your group had? How do you know?
	CLOSURE	
	Explain 5 min	Teacher goes through each slide and explains the pattern represented in each picture and which type of cell it is. Teacher gives additional examples of types of cells. Image 1- Skeletal muscle cells Image 2- Onion cells Image 3- Root tip cells Image 4- Allium root tip cells Image 5- Image 6- Skin cells The majority of cells spend the most of their time in interphase. Cells that we see rapidly dividing occur in parts of organisms that are growing quickly such as the onion root tip and the
EVALULATE	**Exit Slip** 7 min	Students complete exit slip
Looking Forward 2 min		Tomorrow we will be talking about cancer. I know that this can be a sensitive topic. Many of us have known someone who has cancer, who has survived from cancer or has passed away from cancer. If you are concerned that talking about cancer might make you upset, please talk to me at the end of class today or the beginning of class tomorrow.
Clean-Up 2 min		Please help clean up by returning whiteboards, markers, and all materials.

Assessment	
Formative Assessments	Monitoring Tool Discussion Exit Slip

Differentiation	Contingency Plan
Some students will receive hint cards to help them with Discussion II. Some students will receive hint cards to help them make a bar graph. These cards will help them to determine the X and Y access.	If we are running out of time, we will save the whiteboards to continue the discussion the following day. If we have extra time, students will have some free time or be asked to study their mitosis cards.

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