Adapting to National Standards: The experience of one middle school science teacher's implementation of the Next Generation Science Standards (NGSS)

by

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DEDICATION

This dissertation is dedicated to three people:

My Dad, Uncle Mike Herrera, and Mrs. D

- Dad, I promised you that no matter what happened, I would finish this program. While I wish you were here physically to help me celebrate this moment, I know you are here in spirit and that you are happy that I am finally done. Thank you for pushing me to get it done.
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ABSTRACT

The Next Generation Science Standards (NGSS) advocate K-12 three dimensional (3D) learning, which necessitates a deeper understanding of science and engineering through the weaving of the three NGSS dimensions of practices, core ideas, and crosscutting concepts. Currently, little is known about the kinds of experiences science teachers have making sense of the NGSS as they plan and teach to support 3D learning. This two-phased, qualitative case-study investigated the experience of one middle school science teacher working to understand and to weave the three NGSS dimensions into an existing anti-drug health unit. Data analysis focused on interviews, classroom observations, and artifacts. Findings showed: (a) the teacher was uncertain about which NGSS practice/set of practices might best support 3D learning; (b) she used the NGSS practices in limited ways; (c) she was unclear about the significance of the NGSS crosscutting concepts; and (d) the weaving of the NGSS dimensions was a process that occurred in various ways (teacher-led, student-led, over multiple days). These findings suggest that science teachers will need multi-level support to utilize the NGSS dimensions. Developing teacher proficiency in 3D teaching is likely an alternating process. That is, as science teachers develop an understanding of the process of weaving and identifying instances of weaving they will likely gain proficiency in the three NGSS dimensions and their constituent parts and vice versa. To achieve this type of professional learning, teacher-to-teacher peer support within the context of the classroom might be beneficial for science teachers' undertaking of the NGSS. The study also found various ways in which the teacher used socio-scientific issues and the students' backgrounds and experiences to contextualize the science ideas as a way to support 3D learning.

The use of contextualization along with the NGSS within a health unit provides a unique opportunity to investigate how the NGSS applies to health, an area not explicitly addressed in the NGSS. Engaging students with elements of an applied science, like health, can serve as a vehicle that has relevance for students' lives in addition to being directly related to many ideas and phenomena highlighted in the NGSS.

CHAPTER I
INTRODUCTION

April 2013 marked the release of the Next Generation Science Standards (NGSS), science standards that are rich in science core ideas and science and engineering practices. Specifically, the NGSS focus on the *weaving* of three dimensions of science—*disciplinary core ideas* (hereafter referred to as NGSS core ideas), *science and engineering practices* (hereafter referred to as NGSS practices), and *crosscutting concepts*—as a way to develop students' ability to explain science phenomena and solve problems (NGSS Lead States, 2013). The NGSS replace the previous science standards called the National Science Education Standards (NSES). The NSES were released in 1996 and they have been used, for the last 15 years, by states to support the creation of their own science standards as well as student assessments. While the NSES have been widely used and accepted, there was concern that they no longer represented what is currently known about how people learn science (National Research Council, 2012).

Additionally, the NGSS strive to encourage a level of science education that can be benchmarked internationally and can prepare U.S. students for college and careers (NGSS Lead States, 2013). The creation of the NGSS document was supported by the Carnegie Corporation of New York; no federal funds were used to create the NGSS. Furthermore, it is important to note that the NGSS is a policy document, but it is not a mandated set of federal or national standards. This is important because it means that each state has the freedom to decide whether or not to adopt the NGSS as their state's science standards. California, the state in which this study was set, voted to fully adopt the NGSS on September 2, 2013 (California Department of

Education, 2015). As of this dissertation's writing (May 2016), the California State Board of Education has been working to complete the *Science Framework for California Schools: Kindergarten Through Grade Twelve* so that it aligns with the newly adopted NGSS. This framework is important because it helps guide all stakeholders in California with respect to how the NGSS should be implemented. The anticipated online release of the official *Science Framework for California Schools: Kindergarten Through Grade Twelve* is set for 2017. (California Department of Education, 2016).

The NGSS differ from the NSES in some fundamental ways. The NSES focused largely on inquiry and core ideas however, they were presented as separate standards (Reiser, 2013). In contrast to treating inquiry and core ideas separately, the NGSS aim to support and encourage students' ability to explain science phenomena and solve problems through this *weaving* of science and engineering practices, disciplinary core ideas (core ideas), and crosscutting concepts. This idea of promoting student learning of science through weaving these three dimensions of science is quite new in science education standards. Another important difference is the move away from the term "inquiry." Some in the science education community have argued that the NSES' use of the term "inquiry" was very broad and not very well defined for teachers or students (Anderson, 2002). While not discounting the term "inquiry," the NGSS have worked to improve and clarify what inquiry is by using the term *science and engineering practices*. In doing so, the NGSS have sought to do two things. First, the NGSS practices provide better elaboration and clarification on what it means to engage in inquiry in science and how that ultimately supports students' efforts to build scientific knowledge (Reiser, 2013). Second, incorporating engineering practices helps students develop and strengthen the ability to identify and solve problems by working to design solutions, as is the work of engineers (NGSS Lead

States, 2013). This weaving of the three NGSS dimensions and the incorporation of engineering practices is quite new to science standards in the United States.

Because many states, districts, schools, and science teachers are just beginning to grapple with the complexity of the NGSS and what it means to weave these three NGSS dimensions, little is known about the kinds of experiences teachers are having as they utilize these new standards in their own practice and within the real-world context of their classrooms. The depictions of NGSS in the classroom that do exist tend to focus on teaching lessons with the NGSS. The NGSS.NSTA.org offers a selection of webinars that have been created for teachers, by teachers that provides a view of what the NGSS look like in the classroom. The NSTA website also includes short stories submitted by teachers that convey their experiences of implementing the NGSS in their classrooms. These experiences are an important step towards helping the science education community grapple with utilizing the NGSS in the classroom; however, these anecdotes provide little detail and no extensive depiction of the teachers' struggles, or successes. In addition, these classroom stories and webinars provide little insight into the teachers' own *experiences* with the entire implementation process of planning and teaching with the NGSS. Knowing that the intent of the NGSS is for K-12 science students to explain scientific phenomena and solve problems using the three dimensions specified in the NGSS (disciplinary core ideas, scientific and engineering practices, and crosscutting concepts), detailed case studies about classroom enactments of the NGSS will provide valuable information to the science education community. Information gleaned from these studies could be used to design professional development experiences for in-service science teachers and/or pre-service science teacher education programs.

This dissertation is such a case study, an in-depth exploration that provides critical insight and reflections on one teacher's first experience using the NGSS in her classroom. Specifically, it is a case study of Mrs. D's—the focal teacher—experience interpreting, talking about, understanding, and ultimately utilizing the NGSS in her teaching practice. The study was designed to investigate one veteran science teacher's experience implementing (planning and teaching) various aspects of the NGSS related to middle school life science into an existing health unit on drugs and alcohol.[1] As I elaborate in the methods chapter, this was a veteran teacher who was highly qualified to teach science and health and extremely involved with her school community. Detailed insights into Mrs. D's experience implementing NGSS begin to provide some guidelines for providing support for all teachers to successfully implement these exciting, challenging, and important new standards.

Research Questions

This qualitative case study was guided by the central question: How does one 7th grade science teacher work to make sense of the Next Generation Science Standards' (NGSS) three dimensions of practice, disciplinary core ideas, and cross-cutting concepts (hereafter referred to as the *three NGSS dimensions*), and weave them into her existing anti-drug health curriculum so that the three dimensions work together in accordance with the vision of the NGSS? To fully explore this central question, I used the following sub-questions to further guide my research:

1. How does one middle school life science and health teacher interpret, talk about, understand, and ultimately utilize the three NGSS dimensions as she plans and teaches an existing anti-drug health unit?

[1] Although the NGSS were not specifically created with health in mind, some of the NGSS dimensions lend themselves well to health issues as will be explained in the methods chapter of this study.

2. How does she describe the three dimensions being woven together as she plans and teaches this health unit?

This qualitative case study occurred over the course of six months: December, 2013-May, 2014. The study utilized an ethnographic approach, based on Eisenhart's (1988) four ethnographic methods of data collection: participant observer, ethnographic interviewing, search for artifacts, and researcher introspective. The study was designed to investigate two phases of teacher implementation. Phase I examined Mrs. D's planning and Phase II examined how Mrs. D taught the unit. It was critical to design this study as a two-phased study to examine and document, in depth, Mrs. D implementing the new science standards. That is, Mrs. D was performing two tasks that needed to be documented; she was planning *and* teaching with the NGSS. The inclusion of her experiences planning (Phase I) and teaching (Phase II) provides a more complete and realistic story of how Mrs. D fully implemented the NGSS in her classroom.

As I will discuss in the next chapter, the inclusion of teachers' experiences both planning and teaching has not been routinely reported in science education research. Previous studies have focused on the teaching or classroom enactment piece of implementation from the perspective of self-reports from surveys and some interviews, but very few classroom observations. That is not to say that these studies are not valuable, simply that those studies have only looked at teaching and not how the teacher was also planning. I argue that in order to be able to properly support teachers in successfully utilizing the NGSS, it is imperative that both aspects of implementation be reported—teachers' experiences planning *and* teaching with the new reforms. Thus, this study aims to report both of these experiences of implementation.

We know from previous education research studies that implementing and teaching with new educational reforms can be challenging for teachers (Anderson and Helms, 2001; Klieger

and Yakobovitch, 2011; Schneider et al, 2005; & Spillane et al, 2002). Studies have found that teachers often resist change called for in new education reforms. There may be many different reasons why teachers find change difficult. Some teachers oppose standards or find them difficult to implement because they feel they do not have the core ideas knowledge necessary to teach the standards (Klieger and Yakobovitch, 2011). Other teachers feel their way of teaching has been successful in supporting student learning and no change is needed (Kleiger and Yakobovitch, 2012). Duit and Treagust (2012) found that teachers' lack of information on the current trends in teaching and learning often created obstacles to teachers' success in implementing new standards.

Whatever the reasons, it would be safe to say that similar challenges, ideas, and resistance to implementation of the NGSS will most likely occur as teachers grapple with the NGSS. Not only because the standards are new, but as previously mentioned, implementation is further complicated because the NGSS are asking teachers to weave science and engineering practices, core ideas, and crosscutting concepts, something that has not previously been done with science standards in the U.S. Some critics of the NGSS even note that the NGSS are going to be challenging because they are vague and difficult to read and understand (Bruno, 2013; and Asif, 2013). Discerning exactly what is vague and difficult to understand about these new standards and then figuring out how to make them clearer will become critical to teacher preparation and teacher professional development. It is critical that the science education community begin to understand this complicated work that is being asked of teachers so that various forms of assistance can be developed that promote the successful implementation of the NGSS by teachers.

One way to understand challenges that teachers might experience when implementing the NGSS is through detailing teachers' experiences as told by teachers themselves. Many studies have previously described teachers' self-reported attitudes and beliefs around standards implementation (Czerniak and Lumpe, 1996; Davis, 2003; Haney et al, 2002; Kleiger and Yakobovitch, 2011; Kleiger and Yakobovitch, 2012; Thomson and Gregory, 2013). One of the biggest messages from these studies is that in order to improve teaching there must a strong understanding about teachers' beliefs. Those beliefs include, but are not limited to, their beliefs about their teaching abilities and beliefs about their knowledge of the reforms. Knowledge of teachers' beliefs is critical because their beliefs are part of the equation that impacts teachers' abilities to teach with new education reform. Although these insights are critical to our understanding of how teachers implement new reforms, they are also limited to teacher beliefs as reported through surveys, and limited interviews and classroom observations. I argue that few have included in-depth examinations into and descriptions of teachers' actual experience implementing reforms. This study extends this previous research by providing such a perspective.

This in-depth case study that examined how Mrs. D experienced, talked about, utilized, and brought together various NGSS dimensions extends the science education research on teachers and reform implementation in two ways. First, within the science education research community, currently there are limited accounts of what teacher implementation of the NGSS—in a real-world classroom setting not utilizing a previously created NGSS-based curriculum—looks like. The National Science Teachers Association (NSTA) has created various free webinars for teachers by teachers that present K-5 teachers' experiences implementing various NGSS performance expectations in their classroom with a focus on supporting teachers' understanding

and implementing the new standards. Additionally, the website contains free webinars hosted by science education researchers that aim to support teachers in understanding the components of the three dimensions, the practices, the crosscutting concepts and various core ideas (NSTA, 2016). The book, *NGSS for All Students* (2015), presents 7 case studies that highlight research and standards based classroom strategies that teachers can use in the classroom to make the NGSS more accessible to a wide demographic of students. These resources are all essential and necessary support in order for teachers to successfully take on these new standards, but they do not necessarily focus such in-depth attention on the teachers' experiences, struggles, and successes utilizing the new standards as the current study aims to do. It becomes critical to examine, in depth, a teacher's experience so that it may further inform the science education community about the kinds of experiences other teachers might ultimately have with the NGSS.

Second, this study also extends the science education research on teachers and reform implementation by thinking about how science related fields, like health, might be one impactful way to engage students with the three NGSS dimensions. As noted previously, the NGSS aim to inspire student engagement with science around compelling phenomena through which they can gain science knowledge and skills to then explain those phenomena. Mrs. D chose to engage students with the three NGSS dimensions through the phenomenon of alcohol and drugs' effects on the brain (neurons) and the subsequent effects on physical and social activities. It was a health and science phenomenon that ran throughout the unit and formed the basis for all of the activities Mrs. D created. Mrs. D's use of health content to guide the creation and contextualization of this health and science unit was very important to Mrs. D. Especially important to Mrs. D was the students' ability to grasp and be able to explain to others the potentially negative effects drugs

have on the adolescent brain both from a scientific point of view as well as from a health and social point of view.

Why Health?

Middle school students should know about and be able explain the phenomenon of how alcohol and drugs' affect the brain. These are important issues because adolescent drug use is occurring and is a concern for the mental and physical health of developing adolescent brains. A 2012 National Institutes of Health (NIH) report on adolescent drug use shows that the use of marijuana and various other drugs among 8th graders has remained relatively unchanged over the 4 years spanning 2009-2012. However, when compared to drug use statistics from 2007, illicit drug use has actually been on the rise. Many point to marijuana's increasing popularity as one of the contributing factors for its increased use. As youth's perceptions of the dangers of marijuana have gone down, use has gone up (NIH, 1998; NIH, 2012; NIH, IOM, 2013). A National Research Council-Institutes of Medicine report (2013) describes how early drug use exposes adolescents to a myriad of future physical and mental health issues. Among racial/ethnic minority groups, drug use and its consequences are even more profound. According to a 1998 NIH report, *Drug Use Among Ethic/Racial Minorities*, "Because minorities, particularly African Americans and Hispanics, often are concentrated in central city areas [drug use is generally higher in urban areas compared to suburban and rural areas],[2] they may be more at risk for drug abuse" (p. 1) and, ultimately, more at risk for associated poor social and health outcomes. Adolescents, like the students attending Mrs. D's health and science classes, fit the adolescent descriptor perfectly. As I will describe further in the methods chapter, her urban students are

[2] The use of brackets [] throughout this dissertation signals, to the reader, that I have added some explanatory information to the quote that was not originally there and the added information is intended to add more context to the quote.

young, represent a range of SES and represent a range of minority communities. With this information in mind, it is imperative that we take a look at ways to support adolescents to become better educated about their health and therefore make better health decisions. Perhaps creating links between the NGSS and health, as Mrs. D attempted to do through the phenomenon of the effects of drugs and alcohol on the brain, are one way to support adolescents to become better informed citizens about their own health and safety.

Dissertation Outline

Following this introductory chapter, I present an overview of the literature related to teachers and education reform in Chapter 2. Included in the chapter is some discussion of the literature related to implementation of the NGSS and a brief discussion related to the literature on scientific literacy and student engagement in science. Chapter 3, research methods and design, presents the theoretical framework that drove this study. I include the research context, which consists of a detailed description of the focal participant, Mrs. D, as well as an explanation of my own role in the study. Finally, I describe the data set and the methods of analysis. Chapter 4 provides a brief overview of the overall findings of the dissertation. Chapter 5, the first of two findings chapters, presents the detailed findings and analysis related to Mrs. D's description of her experience utilizing the three dimensions. The chapter includes how she described her understanding of each of the three dimensions and descriptions of how those dimensions ultimately were observed in her teaching. Chapter 6, the second detailed findings and analysis chapter, examines how Mrs. D described the three dimensions being woven into her planning and teaching and how that weaving of the dimensions eventually presented itself in her teaching.

I conclude in Chapter 7, the discussion chapter, by considering the three main findings of this study and how these findings relate to and move our conversations forward with respect to

teachers' experiences taking on science education reform, specifically the NGSS. I also discuss implications for the important preparation of teachers needed to understand and utilize the various components of the NGSS. The implications call on science education researchers, professional development leaders, curriculum designers, and teacher educators to think about their work as they design supports for teachers that will support science teachers' success in utilizing the NGSS. Additionally, I consider implications for thinking about and utilizing the concept of contextualization as a way to engage students in their journey to become scientifically literate. Finally, I outline directions for future research.

CHAPTER II
A REVIEW OF THE LITERATURE

For this study, I draw on theory and research from various education fields to understand and report on one science teacher's experience around reform-based teaching utilizing the science standards known as the Next Generation Science Standards (NGSS Lead States, 2013). In this literature review, I provide a brief history of science standards, including the NGSS. Next, I provide a synthesis of the research that is relevant to issues relating to teacher implementation of reform, teacher beliefs related to reform, and issues specifically related to teachers utilizing the NGSS. I argue that research on teacher learning with regards to standards-based reform has taken a narrow approach, one that in many instances driven by surveys and self-reports. I also explore the ways in which the methods and findings of these studies have tended to overlook teachers' experiences working individually with the standards (i.e., using the standards to design their own curricula). In many cases teachers are given a ready-made, standards-based curriculum from which to work and are not necessarily encouraged to tap into their own expertise. I draw on the theories of situated learning and sensemaking to better understand the processes involved in teachers' experience planning and teaching with new science education reform (the NGSS).

Next, because this study was created and organized around a health issue, due to Mrs. D's own expertise in public health, I also begin to draw on literature that considers that there are important health issues that can be addressed in science education, and that those issues area often overlooked when considering teaching science ideas to students. I present literature that favors the use of issues related to health in science education. Phenomena from domains such as

health could serve as tools to support teachers' planning of lessons that strive to promote students' abilities to gain science knowledge. In addition, phenomena from domains such as health could potentially connect science to students' lives while at the same time promoting their development of scientific literacy as advocated in the NGSS documents. Finally, I articulate some of the contributions this study can make in the field of science education.

A Brief History of Science Standards

To understand and appreciate the latest effort to produce national science standards, it is important to take a brief look at the history of education standards. Historically, states have been the guardians of student education within their states. Each state deemed what core ideas were necessary to prepare their students for the future; this process included creating educational standards (Banard, 1851). As would be expected, there was quite a bit of variability among the states standards and that corresponded to varying expectations for teachers and students. Ultimately, all of this variation corresponded to varying levels of student achievement. In 1983, Ronald Reagan's National Commission on Excellence in Education released an historical report called *A Nation at Risk*. The report outlined the dire state of student achievement in the United States when compared to other countries (National Commission on Excellence, 1999). As a result of this report, a concerted effort was initiated to create more uniform, nation-wide education standards in the United States. In 1989, during another historical meeting between the then president George H.W. Bush and the nation's governors to specifically discuss education in America, the National Governors Association advocated for the creation of national education standards; it was the first time state governors had officially done so (Klein, 2014). Mathematics education was the first discipline to draft national standards and in doing so, essentially opened up the conversation for other groups to do the same (National Research Council, 1996).

The science education community was also active in this area with efforts to reform science education at the national level. In the science education community, one of the first attempts at national standards began in 1985 with the creation of Project 2061,[3] a part of the American Association for the Advancement of Science (AAAS). The goal of Project 2061 was for all Americans to be literate in science, math and technology by the year 2061. Consequently, Project 2061 worked to identify scientific ideas that were salient for students to know in order to be successful and literate in science, mathematics, and technology (AAAS, 2013). In 1989, the American Association for the Advancement of Science published *Science for All Americans*, which outlined what it meant to be a scientifically literate high school graduate in terms of what students should know and be able to do with respect to science. *Science for All Americans* envisioned people being able to make connections between "ideas in the natural and social sciences, mathematics, and technology" (AAAS, 1990 Introduction on AAAS Website). For example, the American Association for the Advancement of Science suggests that scientifically literate people should have an understanding of scientific ideas such as the scientific method as a method of inquiry and a sense of the kinds of skills, attitudes, and ways of thinking scientifically (AAAS, 1990). *Science for All Americans* was followed by *The Benchmarks for Science Literacy* in 1993. *Benchmarks* was a statement by Project 2061 about "what all students should know and be able to do in science, math and technology at the end of grades 2, 5, 8, and 12" (AAAS, 2013, Benchmarks for Science Literacy, para. 1) and provided educators with suggestions for sequencing various specific learning goals that they could use to create their science curriculum.

[3] This date was chosen because Haley's Comet last appeared in 1986 and will not reappear until 2061. Project 2061 gets its name from this, and has always said that it is within that time span that we should work to build a scientifically literate society.

However, the *Benchmarks* were not standards but rather recommendations—guidelines—about what and how to teach science (AAAS, 2013).

In 1991, there was a more concerted and organized effort by several science and education entities to begin working on national science standards that would be led by the National Research Council (NRC). In 1996, using the *Benchmarks* and *Science for All Americans* as supporting documents, and after much effort and input by many stakeholders, the National Science Education Standards (NSES) were released (NRC, 1996). Although called national standards, the document was a set of guidelines that could be used by the science education community, especially individual states, to create their own state standards.

The NSES have been well-regarded in science education. They were student-centered and focused on inquiry-based pedagogy as a way to engage students in science core ideas. However, as mentioned in the previous chapter, one of the critiques of the NSES was that they perpetuated a separation of science core ideas and practice. Current science education research indicates that for students to more authentically do science, practice and core ideas must be intertwined, something which the NGSS encourages (NGSS Lead States, 2013).

In 2012, with an intention to update earlier documents that were over 15 years old, as well as to draw more heavily on current education research related to how people learn, and specifically how they learn science, the National Research Council released *A Framework for K-12 Science Education* (hereafter referred to as the *Framework*). The *Framework* "outlined a broad set of expectations for students in science and engineering in grades K-12 which would be used to inform the development of new standards for K-12 science education, and revisions to curriculum, instruction, assessment, and professional development" (NRC, 2012, p.2). The

Framework document itself is not a set of standards. Rather, the *Framework* is a vision document and it has been used as the foundational document for the new science standards that are known as the Next Generation Science Standards (NGSS). Recall, the NGSS, similar to previous standards are not federally or nationally mandated standards, each state has the freedom to decide whether or not to adopt the standards. Likewise, these various standards are not curricula, but rather guidelines to be used by states, districts, and teachers to create their own curricula.

The Next Generation Science Standards

As discussed in the introduction, the NGSS were released in April 2013. The NGSS provide a unique approach that focuses on developing students' abilities to explain scientific phenomena and design solutions to problems. This unique approach promotes student development of these abilities to explain scientific phenomena and design solutions through their engagement with scientific practices that support students in concurrently developing knowledge using disciplinary core ideas and crosscutting concepts (Krajcik et al., 2014;NGSS Lead States, 2013; Reiser, 2013). Core ideas—or disciplinary core ideas (DCI's)—consist of specific scientific ideas related to topics like chemical reactions or natural selection. There are eight scientific practices that include, but are not limited to, developing and using models and analyzing and interpreting data. There are seven crosscutting concepts—or CCC's—including patterns and energy and matter. This unique process of weaving the three NGSS dimensions in learning science should help students build rich networks of scientific ideas. This is important for student learning because as Krajcik and colleagues (2014) state, "The more connections developed, the greater the ability of students to solve problems, make decisions, explain phenomena, and make sense of new information" (p. 158).

As of February 2016, 17 states and the District of Columbia have adopted the NGSS and are currently working to implement the new standards throughout their districts and schools (National Science Teachers Association, 2016). The adoption of NGSS by other states is currently being debated and voted on. For those states that have adopted the NGSS, districts, schools, and teachers are working to understand precisely how to embed the NGSS into their already existing curricula.

The NGSS are unique for several reasons, three of which I present here. First, the NGSS make a concerted effort to connect to *The Framework for K-12 Science Education* developed by the National Research Council. As mentioned previously, the *Framework* is not a set of standards but rather it is a vision document that provides a broad set of expectations around the science and engineering ideas that are important for students to learn in order to be college, career, and life ready upon graduation from high school. The *Framework* is unique because of its concerted effort to include engineering practices together with science, as well as its vision to bring together science core ideas, science and engineering practices, and crosscutting concepts. Ultimately, the aim of the *Framework* is to support all students having, upon graduation, "sufficient knowledge of science and engineering to engage in public discussions on [science-]related issues, be careful consumers of scientific and technical information…and enter the careers of their choice" (NRC, 2012, p. 1). The NRC vision of students developing the critical thinking skills to become proficient at explaining phenomena and designing solutions to problems through this weaving of the three dimensions, as well as supporting students' learning around issues related science and engineering was the foundational piece that supported the creation of the NGSS.

Second, the NGSS also makes a concerted effort to connect with the Common Core State Standards (CCSS and hereafter referred to as the Common Core) developed by the National Governor's Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO). The Common Core Standards are math and English language arts (ELA) standards that were released in 2009, four years prior to the NGSS. Similar to the NGSS, the Common Core Standards are considered policy but they are not national or federal standards; each state has the choice of whether to adopt them. As of 2016, 42 states and the District of Columbia have adopted the Common Core Standards (National Governors Association, Center for Best Practices, 2010).

What is unique about the Common Core Standards and the NGSS is that both documents have purposefully worked to make connections to one another. This is essential in order to show how interwoven English literacy, math literacy and science literacy really are to one another and not separate subjects to be learned in isolation. Previous English, math, and science standards have not been as intentional. Also, a critical and common aim that runs through both the NGSS and the Common Core Standards is that K-12 students develop critical thinking, problem-solving, and analytical skills and gain the knowledge that will help them prepare for college, career, and life (Lead States, 2013; National Governors Association, Center for Best Practices, 2010).

For this study, the focal middle school NGSS performance expectation, *MS-LS1-8 From Molecules to Organisms: Structure and Processes* states, "Students who demonstrate understanding can: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories" (Lead States, 2013, emphasis added). The underlined portion of the focal performance expectation has a

connection to the Common Core Standards which can be found on the Common Core State Initiatives website. On the website, under the *Grades 6-12 Literacy in History/Social Studies, Science & Technical Subjects*, under *Writing, Grades 6-8* there is a standard identified as CCSS.ELA-LITERACY.WHST.6-8.8 which connects to the focal performance expectation. The Common Core standard states:

> Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (National Governors Association, Center for Best Practices, 2010)

Together, the *Framework* and the Common Core Standards have provided a great deal of guidance in the creation of the NGSS.

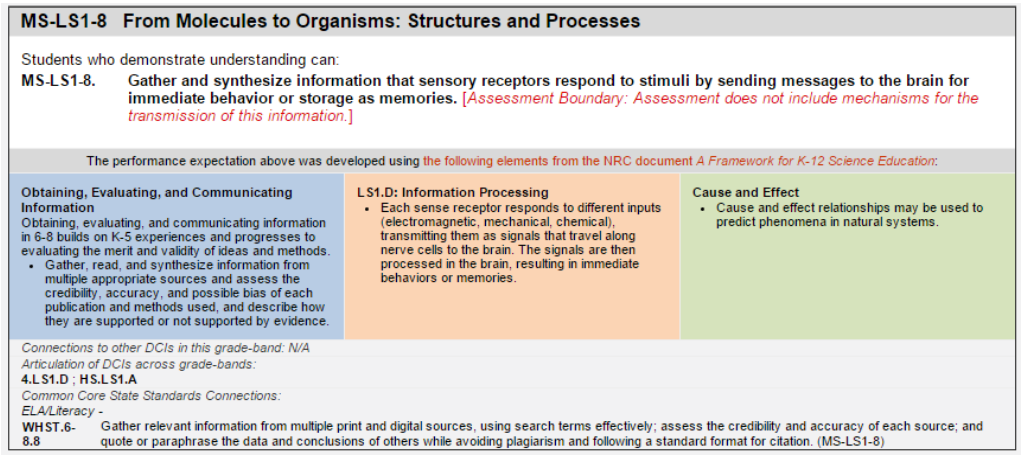
Third, the NGSS focus on this weaving of the three dimensions to students' development of three dimensional learning is unique to science standards. As previously noted, older science standards—such as the National Science Education Standards—tended to present core ideas and practice as two separate pieces of K-12 science education (NGSS Lead States, 2013). The NGSS are therefore unique in their vision that the three dimensions—science and engineering practices, core ideas, and crosscutting concepts—should be presented simultaneously in the science classroom. This weaving of the three NGSS dimensions is unique and important in order to more authentically represent the process of how scientists learn about the world. Ultimately, this weaving of the three NGSS dimensions aims to support the acquisition of scientific literacy by K-12 students and their development of critical thinking skills that allow/enable them to explain phenomena and design solutions to problems. This kind of learning is referred to as three dimensional or 3-D learning. To support 3-D learning, the science and engineering practices, the disciplinary core ideas, and the crosscutting concepts should be "interwoven in every aspect of

science education, most critically, curriculum, instruction, and assessment" (NRC, Developing Assessments, 2014, Summary p.1).

Consistent with the *Framework*, the NGSS are broken down by grade-level and domain. In the NGSS document, the standards are referred to as performance expectations (PE) which outline the various things students should know and be able to do at the end of each grade for each specified science domain (e.g. physical sciences and life sciences). This study focused on one life science middle school performance expectation as identified by Mrs. D because it was the most suitable performance expectation for her health unit goals. The performance expectation is identified as MS-LS1-8. Below, I outline the various parts that make up the performance expectation and it is also shown in Figure 2-1. The performance expectation, MS-LS1-8, is titled "From Molecules to Organisms: Structure and Processes." This performance expectation states, "Students who demonstrate understanding can: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories" (NGSS Lead States, 2013). In order to fully understand what this performance expectation means and how the three NGSS dimensions come together, readers must look at how the performance expectation is broken down into its parts, by referring to each of the dimensions that compose the performance expectation. For example, the middle school performance expectation mentioned above has the following three dimensions (also see Figure 2-1):

- The *science and engineering practice* - obtaining, evaluating, and communicating information (shaded blue in Figure 2-1),
- The *disciplinary core idea* (DCI) - information processing (shaded orange in
- Figure 2-1), and
- The *cross-cutting concept* (CCC) - cause and effect (shaded green in Figure 2-1) (NGSS Lead States, 2013).

Figure 2-1 NGSS Middle School Life Science Performance Expectation (PE)



MS-LS1-8 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-8. **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [*Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6-8 builds on K-5 experiences and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

LS1.D: Information Processing

- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural systems.

Connections to other DCIs in this grade-band: N/A

Articulation of DCIs across grade-bands:

4.LS1.D ; **HS.LS1.A**

Common Core State Standards Connections:

ELA/Literacy -

WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-LS1-8)

Image from the NGSS Lead States (2013) Website: http://www.nextgenscience.org/search-performance-expectations?tid_2%5B%5D=14&tid%5B%5D=33

When reading the performance expectation in its entirety, a reader should be able to identify the three dimensions. For the performance expectation above, the phrase “Gather and synthesize information” would refer to the NGSS practice outlined in blue in Figure 2-1 titled Obtaining, Evaluating, and Communicating Information. The phrase “the sensory receptors respond to stimuli by sending messages to the brain” would refer to the NGSS core idea outlined in orange under the title Information Processing in Figure 2-1. Finally, the phrase, “for immediate behavior or storage as memories” would refer to the NGSS crosscutting concept of Cause and Effect outlined in green in Figure 2-1. This is how the NGSS envision the three dimensions coming together to support students in gaining proficiency in the various performance expectations. As mentioned previously, the grade-level performance expectations are a set of standards that provide a layout of what students should be able to know and do at the end of each grade.

In addition to a brief description of the NGSS focal dimensions of science and engineering practice, disciplinary core ideas, and crosscutting concepts in Figure 2-1, there are three other important links in the performance expectation box that I discuss here. First, under the boxes containing the descriptions of the three NGSS dimensions, there is a title, *Connections to other DCI's in this grade-band*. In that section, the reader will find a list of any other core ideas, within the same grade, that relate to other core ideas within the same grade level. In Figure 2-1, there are no other core idea connections. Second, below the section that outlines the connections to other grade level core ideas, there is another section titled, *Articulation of DCI's across grade levels*. In this section the NGSS identify core ideas that helped form part of the foundational knowledge to support students in gaining proficiency in the current performance expectation. Usually, that means core ideas that were introduced in previous grades. Or, the section identifies core ideas that the current performance expectation will help to support, usually in subsequent grades. In Figure 2-1, HS-LS1-A is one of the core ideas identified under *Articulation of DCI's across grade levels*. The core idea relates to high school, life science, structure, and function. Therefore, the performance expectation MS-LS1-8 in Figure 2-1 should help provide some of the foundational knowledge and skills that students will need to gain proficiency in high school level core idea HS-LS1-A, life science structure and function.

The third important link that the NGSS identify in the performance expectation information box is to the Common Core State Standards and this is outlined at the very bottom of the performance expectation information box. As previously noted, the NGSS performance expectations for this study, MS-LS1-8, have a link to Common Core State Standards and is identified at the bottom of Figure 2-1 as *ELA/Literacy* –WHST.6-8.8, which states, "Gather relevant information from multiple print and digital sources; assess the credibility of each source;

and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources" (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). While this Common Core standard is not directly a part of the performance expectation MS-LS1-8, a reader can clearly see there is a link between the NGSS performance expectation and the Common Core. As I mentioned already, the NGSS link to the Common Core is unique because the NGSS standards provide both an outline of the science skills as well as the math and literacy skills necessary for students to become college ready and literate in the twenty-first century. Previous education standards have not made these connections as explicitly as the NGSS and Common Core have worked to do.

The science and engineering practice associated with this performance expectation—obtaining, evaluating and communicating scientific information—is highlighted as an important practice for students learning science in both *The Framework for K-12 Science Education* (NRC, 2012) and the NGSS (NGSS Lead States, 2013). Tenopir and King (2004) found that this practice is one of the most routinely utilized practices that scientists and engineers engage in with one another as well as the public (as cited in the NRC *Framework*, 2012, p. 74). According to Bricker and colleagues (in press), this practice of obtaining, evaluating, and communicating information "also involves important learning processes related to interpreting information, synthesizing personal understanding, and learning to make one's own thinking visible to others" (p. 4). The components of this practice are important parts of sense-making and all students should be supported, in their science classrooms, to gain the skills necessary to master and be able to utilize all of the facets of the practice in a way that will benefit students now and in the

future. Engaging students in authentic scientific communication would help support their ability to become scientifically literate as encouraged by the NGSS.

Teachers and Education Reform

Previously, I outlined the brief history of the NGSSS and the purpose and structure of the NGSS. I shift gears now to try to make the connection between education reforms, such as the NGSS, with what the research indicates about teachers' experiences with education reform. Here, I use the term "education reform" to refer to efforts, either locally or nationally, that aim to improve teaching and the educational outcomes of students. Various education researchers have reported that teachers, in general, find implementing new educational reforms and reform-based teaching challenging (Anderson and Helms, 2001; Haney, Lumpe, Czerniak, and Egan, 2002; Klieger and Yakobovitch, 2011; Schneider et al., 2005; Spillane, Reiser, and Reimer, 2002; Thomson and Gregory, 2013). Anderson and Helms (2001) stated, "Existing research shows that changes called for in the standards are difficult to put into practice, create dilemmas for teachers, require significant changes in teachers' values, beliefs…" (p.3). Although Anderson and Helms were referring to the old National Science Education Standards (NSES), the same challenges will most likely apply to the NGSS. To better understand the new science standards—NGSS—it will be necessary to review the literature, in general and across different education fields, about teachers and reform; what follows here is the overview of that literature.

Considerable research has been done to shed light on teacher self-reported attitudes and beliefs as a driving force behind how well reforms are, or are not implemented (Haney, Lumpe, Czerniak, and Egan, 2002; Czerniak and Lumpe, 1996; Kleiger and Yakobovitch, 2012; Davis, 2003). In one survey study by Klieger and Yakobovitch (2011), they found science teachers mostly viewed standards as a positive contribution to science education and their views of

implementing the standards varied depending on the science they were teaching and how long they had been teaching it. Those teachers with more science teaching experience seemed to implement the standards more fully than those with less science teaching experience. Their study was an important contribution to science education researchers' understanding of various teachers' attitudes about the effectiveness of science standards as well as teachers' views on how well they were able to implement the new standards. They also noted that future research should go beyond teachers' self-reports of standards' implementation; they seem to suggest future research could include research about how these self-reports then translate into actual classroom practice.

There is another set of literature that looks at teachers' perceptions related to the implementation of standards-based curriculum. Whereas the previous studies focused on their attitudes in general about implementing standards, the following literature focuses on studies where teachers were asked to implement curriculum that was standards-based. The findings from those studies, e.g., Davis (2003) and Kleiger and Yakobovitch (2012), suggested that teachers often felt frustrated that their own experience and knowledge was set aside at the expense of enacting the standards-based curriculum exactly as intended by the curriculum authors. Other studies related to standards-based curriculum have strictly measured adherence to a pre-designed, reform-based curriculum, e.g., Kempler and colleagues (2008) and Schneider and colleagues (2005). The majority of the teachers—in these studies of beliefs and standards-based curriculum implementation—found the work of implementing standards-based curriculum very challenging (Kempler et al., 2008; Kleiger and Yakobovitch, 2012 ; and Schneider et al., 2005). Consequently, many researchers have strongly suggested the need for more teacher input during the entire reform process—from the creation of the standards, to creation of the standards-based

curriculum, to teaching with the standards and standards-based curriculum—if reforms are to be successful (Battista, 1994; Bybee, 1993; Loucks-Horsley et al., 1998; & Smith and Southerland, 2007). These studies are an important contribution to our understanding of the kinds of challenges teachers encounter when implementing standards-based curriculum. However, I have not found in the literature any studies that looked at a teacher's experience utilizing the NGSS—in light of her own knowledge and experiences—without any reform-based curriculum. I argue that my research makes a contribution to the literature on teachers' use of standards-based reform (the NGSS), because Mrs. D is relying on her own experiences and knowledge to implement the standards without a standards-based curriculum and the science education field needs to better understand how teachers do this.

Studies on Teachers' Self-reports

Studying teacher self-reported perceptions, attitudes, and beliefs related to reform and reform-based curriculum is certainly an important aspect of teaching. Beliefs and attitudes are believed by some education researchers (Cohen & Ball, 1990; Czerniak &Lumpe, 1996; Haney, Lumpe, Czerniak, and Egan, 2002; & Thomson and Gregory, 2013) to affect how and what teachers implement in their classrooms. Yet, studying beliefs, attitudes, and the like, is by no means the only way to measure reform implementation in the classroom and may have limitations. Self-report is limited to how teachers see themselves, not necessarily how or what is actually implemented in the classroom. As studies have shown, there is often a disconnect between what a teacher says and what the teacher actually does in the classroom (Schneider et al., 2005). Therefore, there is a clear need for more studies (e.g., qualitative case-studies)—as this study proposes—that will help explore teachers' experiences related to issues relevant to reform implementation.

In their review, Van Driel and colleagues (1998) focused on practical knowledge, i.e. "teachers' knowledge and beliefs about their own teaching practice [that] is mainly the result of their teaching experience" (p. 138) as an essential factor that influences the way teachers ultimately enact reform. They concluded that understanding and utilizing the practical knowledge of science teachers at the beginning of any reform project is an essential move if reform is to be successful. To that end and in the concluding remarks, Van Driel and colleagues (1998) reminded their readers of the need to involve teachers throughout the entire process of reform. Similar comments by Kleiger and Yakobovitch (2011), Van Driel and colleagues (1998), and Gess-Newsome (2001) cautioned science education researchers against a top down approach, that is teachers being told how implement the reform and what to implement and accounting for little if any of the teachers' own perspectives or experiences during any of the stages of the reform process. Teachers need to feel some sense of autonomy and control over their own learning and they need multiple opportunities in their classrooms to practice implementing and experiencing the standards (Gess-Newsome, 2001; Johnson, 2006; Loucks-Horsely et al, 1998).

Some researchers have even suggested that for teachers to be successful in implementing new reforms, teachers need opportunities to design their own professional development experiences as well as their own standards-based curriculum (Gess-Newsome, 2001; & Klieger and Yakobovitch, 2011). However, there is a dearth of literature on how teachers design their own curriculum and take on new standards in their own classrooms, without the use of standards-based curriculum. Similarly, Putnam and Borko (2000) acknowledged that in science education, in many instances, not enough attention or research has been paid to how teachers are

constructing learning experiences in congruence with science education reforms and/or how teachers themselves learn new ways of teaching.

With this knowledge of past research on teachers and reform, the current study aims to investigate Mrs. D's experience interpreting and enacting the new science standards in the context of one middle school science classroom without the use of a standards-based curriculum. This study covers an in-depth six-month period during which I collected data that reports Mrs. D's perceptions of the NGSS, as well as her experiences working through the NGSS. In addition, this study uses classroom observations to describe what the reform (the NGSS) actually looked like in her classroom. Through this lens—the teacher's self-reported experience in addition to the researcher's classroom observations—the reader is provided with an inside look into the challenges the teacher reported when utilizing these new standards. With this information in mind, the education community—education researchers, teacher educators, and curriculum developers—are provided a small window into some of the possible challenges other teachers may encounter as they begin to grapple with these new standards. In addition, I hope this study will provide insight into the kinds of support curriculum developers might want to consider as they create reform-based curriculum around the NGSS. For this reason, this study is an important step forward as the field of science education implements a new science education reform agenda (NGSS). Based on the previous studies on reform, I believe it is critical to understand how teachers are taking on this new kind of three dimensional learning if the science education community wants the NGSS to be successful.

In this section, I have attempted to argue that the research related to teachers' beliefs and experiences with education reform—much of it from self-reported surveys—should be augmented. More research is needed that is orientated towards more classroom observations and

other data collection methods like document collection, and de-briefing interviews. As noted, various researchers acknowledge the need to investigate reform-based teaching within the actual classroom. Cohen and Ball (1990), in their research on math teachers and reform, comment on the plethora of information about teacher implementation of standards from self-reports, but they lament that:

> …little is known about how teachers perceive instructional policies, how they interpret them and how different kinds of policies influence teaching and learning. Many policies and programs have been aimed at the classrooms, but what we know about those policies stops at the classroom door, for policy research has seldom investigated the effects of policies on the actual work of teaching and learning. (p. 234)

Additionally, Anderson and Helms (2001) stated, "If the intent is to understand how the new Standards (NSES) can be implemented, it will be necessary to conduct research in ordinary school settings" (p. 12). The current study aimed to do precisely that; qualitatively examine the experience of one teacher implementing the new NGSS in a real-world classroom. By observing and reporting the experience of a 7th grade health/science teacher implementing various dimensions of the NGSS standards into her own curriculum and lesson plans, the science education research community has a more nuanced view of how other science teachers may experience these new standards. This more nuanced view of science teachers' experiences with NGSS will be critical to analyze as we think about the kinds of support science teachers will need and why they might need this support to be successful at implementing the NGSS. Ultimately, what we would like to see is that science teachers' successful implementation will correspond to students' gaining the scientific and engineering knowledge they need to proficiently explain phenomena, design solutions and become more scientifically literate citizens.

Teachers and Planning

Creating a two-phased study of teacher planning *and* teaching provides added insights into the teacher's decision-making processes. More specifically, for this study, looking at the planning and teaching provides a window into the kinds of decisions Mrs. D was making about how to utilize the various dimensions of the NGGS at both time points. In her longitudinal study of novice secondary teachers, Sardo-Brown (1996) defined teacher planning as the "instructional decisions made prior to the execution of plans during teaching" (p. 519). John (2006) in his study of novice and expert teachers planning extends Sardo-Brown's idea of teacher planning to include the points before and during instruction when he stated, "Planning also occurs during the interactive phases of teaching as the teacher reflects on situations as they arise and plans ahead accordingly" (p. 488). For this study, I combine both Sardo-Brown's (1996) and John's (2006) definition of planning to include the decision-making that occurred both prior to teaching and during the interactive phase of Mrs. D's teaching.

In the literature cited previously on teacher and education reform, what seems to be missing are more in-depth teacher experiences planning with new reform. Others in teacher education have also noted the need to look not only at teacher practice in the classroom but teacher practice as they plan and their decision making processes (Peterson et al., 1978; Zahorik, 1970; Sardo-Brown, 1988; Rusznyak & Walton, 2011). This study purposefully aimed to look at and document Mrs. D's experience making sense of the NGSS as she both planned and taught her drug and alcohol unit. Taking an in-depth look at her experience planning with the NGSS would provide insights into her decision making prior to teaching the lessons. Additionally, observing Mrs. D teach the planned lessons would provide information about what the NGSS supported lessons actually looked like in the classroom. Finally, the de-briefs were critical to

fully understanding how Mrs. D experienced the NGSS in her practice because it gave her time to reflect on what she had planned and what had actually occurred in her classroom.

Theory of Sensemaking and Situated Learning

I used theories of sensemaking and situated learning to frame this study. Both lenses helped me better understand Mrs. D's experience utilizing these new and complicated science standards: a) sensemaking theory, which contends with how individuals make sense of situations and experiences; and b) situated learning, which posits that learning occurs in context as individuals participate in some activity. I begin here with a short exploration of sensemaking first and then move on to situated learning. The theory of sense-making offers a particularly useful framework for analyzing science teachers' experiences utilizing the NGSS. Sensemaking, in its simplest form is "making something sensible" (Weick, 1995, p.16). Sensemaking describes "reality as an ongoing accomplishment that takes form when people make retrospective sense of situations in which they find themselves and their creations" (Weick, 1995, p. 15). Sensemaking, to be successful, requires a process of reflection that takes time and a level of involvement by sensemakers (Allen and Penuel, 2015; Coburn, 2001; Weick, 1995). In this case Mrs. D was highly involved in the process of making the NGSS "sensible" through the process of reflecting on her own experience in planning and teaching with the NGSS.

As described above, sensemaking has both an individual and social component. The current study focused, to some extent, on both the social and individual component of sensemaking as Mrs. D worked to make sense of and attempted to weave the NGSS into her practice. Information gleaned from this study could help inform the ways in which teacher educators and professional development coordinators could develop teacher support for the NGSS that contain a more collective sensemaking process.

Teachers and Situated Learning and Sensemaking

Situated learning is the learning that occurs while participating in some kind of activity, within a particular context; this learning context is inextricably tied to the social practices within a culture (Brown, Collins, & Duguid, 1989; Cobb & Bowers, 1999; Greeno, 1997; Lave & Wenger, 1991). Situated learning is compatible with sensemaking in that it embodies some of the seven processes of sensemaking that Weick (1995) proposed: (a) grounded in identity construction; (b) retrospective; (c) enactive of sensible environments; (d) social; (e) ongoing; (f) focused on and by extracted cues; and (g) driven by plausibility rather than accuracy. Weick (1995) described one facet of the sensemaking process as *enactive of sensible environment*. That is, people make sense by actively participating in that environment. This sensemaking idea is similar to situated learning; learning is embedded within some kind of defined environment. Further, the theory of sensemaking, involves a level of social interaction in order to make something sensible. Social interaction is also an essential component that makes up situated learning. Situated learning helps frame this study around Mrs. D's experience of sensemaking as she was learning about and working with the NGSS through the planning and teaching of the health unit focused on drugs and alcohol's effects on the brain. She was working with the NGSS within the real-world context of her classroom (see Brown, Collins, and Druit, 1989; Lave and Wegner, 1991; Putnam and Borko, 2000).

Lave and Wegner (1991) in their seminal piece view situated learning as *legitimate peripheral participation.* That is, a learner will increasingly gain knowledge about a topic, moving—at the beginning—from a more peripheral or novice level of participation to a more insider expert level of participation (Lave, 1991). Lave and Wegner (1991) further suggested that learning occurs as a result of "increasing participation in a social activity in communities of

practice" (p. 49). A community of practice in this study would be science teachers as a community within the practice of teaching. These science teachers form a community of practice as they participate in the common endeavor to teach science with similar social activities, ways of doing, similar language, values and beliefs (Lave, 1991; Eckert & McConnell-Ginet, 1992). Greeno (1997) and Cobb and Bowers (1999) expand the idea of social activities to include the materials and other resources that groups may use. For this study the materials and resources would be the NGSS or curriculum materials Mrs. D utilized to create her Alcohol, Tobacco, and other Drug (ATOD) unit.[4] Brown and colleagues (1989) highlight the importance of the learner participating in *authentic activities* (the actual work that practitioners of a profession do) as key to situated learning. Cobb and Bowers (1999) add that even those individuals working alone—such as a teacher planning and teaching in her classroom—are still participating in the activities of a community of practice because they are still enacting the practices of that community (e.g., how they talk, their beliefs and values are still congruent with the community of practice).

As I will describe in the methods section, Mrs. D was a highly experienced and motivated teacher. However, from a sensemaking and situated learning perspective, and within the context of this study; planning and teaching with the NGSS for the first time, Mrs. D was a novice (or peripheral) participant, participating in the authentic activity of working with the NGSS. Mrs. D was attempting to make sense of the NGSS and the *Framework* documents, through the context of planning and teaching in her own classroom with her students, an authentic activity that all science teachers as practitioners do. The study provides valuable insights into some of the possible experiences science teachers might encounter as they work with the NGSS in their own

[4] Alcohol, Tobacco, and Other Drugs Unit, the unit Mrs. D created for this study which will be explained further later in this chapter.

classrooms. These insights can be used to help science teacher educators and professional development developers as they work to create support with and for science teachers to be successful in utilizing the NGSS as intended. More qualitative case studies of this kind are needed that continue to look in-depth at teachers' experience with the NGSS as well as examining teachers' sensemaking processes. More studies are needed that consider the authentic activities that science teachers are enacting related to the NGSS and situated within real-world contexts like science classrooms. Although this study was not a study of how Mrs. D learned to become an expert with respect to using the NGSS (i.e., a study examining teacher learning over time), future studies might further the discussion of studying teachers' development from novice to expert utilizing the NGSS through the lens of situated learning and sensemaking theories.

Scientific Literacy

Supporting students to become scientifically literate citizens who can contribute positively to society because they have a level of awareness of science to make informed decisions is a fundamental goal of science education. At the heart of the debate over increasing students' scientific literacy skills lies a desire to foster students' understanding of science in a way that will lead them through the 21st century equipped with the knowledge and skills to make informed decisions about issues such as their own health. However, equipping students with this ability to obtain and utilize science knowledge has continued to be a challenge in science education. Many science education researchers say the challenge lies in the lack of relevancy in the classroom to students' lived experiences (Aikenhead, 2011; Roth, 2014; Bricker et al., 2014; Zeyer and Dillon, 2014).

Although the focus of this study was not on student achievement, characterizing science literacy and student engagement, beginning with science literacy, provides more context for this

study. Because the aim of this study was to observe and report the experience of Mrs. D utilizing the NGSS for the first time, it seems appropriate to utilize the definition of science literacy utilized by the NGSS documents. As noted previously, the *Framework* was used as a guiding document to create the NGSS. Likewise, the *Framework* used other sources as guides during its creation. One of those documents utilized to define scientific literacy was S*cience for All Americans* (AAAS, 1990). In the *Science For All Americans* document, a science-literate person is:

> One who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (Introduction, Recommendations, second paragraph)

Most importantly, whereas other science education reform documents have concentrated scientific literacy as a focus on knowledge, this definition focuses on the importance of *knowledge in use*. Knowledge in use means, "Students' knowledge is not static, and proficiency involves deploying knowledge and skills" as is championed in NGSS through the weaving of the three NGSS dimensions (NRC, *Taking Science to School*, 2007, p. 38). Although this definition of scientific literacy is quite thorough, it does require further clarification. Specifically, what does it mean to use scientific knowledge and ways of thinking at the individual and social level? Additionally, what does it mean to "make science engaging to learners" and how do science teachers do this?

Bybee (2012), reports on findings of various international surveys done to look at students' interest in science. Bybee reports that, overall, interests in topics such as human biology and topics that could most directly be made relevant to students' lives were of top

interest to students. In most instances, these topics related to health and safety issues. Understanding that students find science most interesting and relevant when they can see connections to their own lived experiences is important for teachers and others involved in science curricular planning to take into consideration as they plan lessons and curriculum. Specifically, in the United States where the NGSS have been released and are being adopted by various states, understanding how to incorporate the new standards in ways that draw the interest of students will be important to its success in the classroom. Although the NGSS were not specifically created with health education in mind, if we look with an eye towards relevancy to students' lives, some of the performance expectations—like the focal performance expectation described previously and that was utilized in this study—lend themselves well to health issues that many students can relate to.

I assert that health issues might be integrated with NGSS core ideas in ways that not are not only of interest to students' lives but in ways that are in alignment with the NGSS. The NGSS (NGSS Lead States, 2013) states:

> Given the importance of science and engineering in the 21st century, students require a sense of contextual understanding with regard to scientific knowledge, how it is acquired and applied, and how science is connected through a series of concepts that help further our understanding of the world around us. (Appendix A, p. 1)

The potential for this contextual alignment of health and science is supported by researchers in both the health and science education fields. Bybee (2012) suggests that educators tap into the daily and personal issues, such as health, that confront people as a way to experience and understand science knowledge and ways of thinking through contexts that are meaningful. Zeyer (2012) suggests that one of the ways in which health and science can support one another is through the idea that students with strong science knowledge will have the "ability to form sound

situational constructions and to critically judge health situations" (p. 158). Referring to findings from a 2004 study related to conceptual understanding and reasoning about HIV myths, Keselman and colleagues (2012) found that students' biological reasoning around issues related to HIV was dependent on their depth of biological knowledge. They concluded that deep biological knowledge was important to students' ability to critically reason and evaluate information related to real-world health issues. As will be explained further in the methods chapter, Mrs. D utilized a district-sanctioned, drug awareness curriculum to implement the NGSS.

Teacher Implementation of NGSS

To help address some of the challenges described by Anderson and Helms (2001), it will be important for the science education community to try to understand some of the difficulties and dilemmas science teachers are faced with as they implement the NGSS. While I have presented past research that illustrates that researchers have a fairly good idea of the kinds of challenges teachers report facing when enacting reforms such as the inquiry-based teaching supported by NSES, because of the newness of the NGSS, researchers have limited understanding of the kinds of challenges teachers are facing when implementing and enacting the new standards that require three dimensional teaching and learning. In thinking about the kinds of challenges teachers will be facing utilizing the NGSS standards, it would be equally valuable to understand their perceptions or beliefs around these new standards and their implementation.

Here, I present some of the more current scholarly discussions taking place about teachers and NGSS implementation. Additionally, I use some of the previous literature to further make the case for a need to understand teachers' experiences related to NGSS implementation. Osborne (2014), acknowledged that science teachers will be working to make sense of the NGSS

and the changes it is asking teachers to take on in their own practice. Others in the science education community have also acknowledged that the NGSS focus on science and engineering practices and three dimensional (3D) learning is going to be challenging for teachers and that they will need plenty of support to be successful in the classroom (Wilson, 2013; Reiser, 2013; Osborne, 2014; Krajcik et al, 2014). Wilson's (2013) review on the kinds of support that will be necessary for science teachers enacting the NGSS states,

> A more complex view of teacher learning is clearly needed, one in which professional learning is seen as more dynamic and iterative, connecting teachers' experiences in their classrooms with formal opportunities for collective reflection and for acquiring new knowledge that targets genuine problems of practice (p. 311).

From this statement, Wilson understands the important role teachers will play in the successful implementation of the NGSS, but Wilson also acknowledges that teachers will need support to do this important and complex work.

Similar to Putnam and Borko's advice in their 2000 seminal piece regarding inquiry-based teaching and the skills teachers would need to have in order to implement that kind of science teaching and support that kind of learning, most teachers working to implement the NGSS will also most likely need to develop a new set of skills and knowledge in order to be successful. Just as inquiry-based learning was new to many science teachers when the NSES were first introduced, the performance expectations and this weaving of the three NGSS dimensions into a teacher's lessons and teaching will require support. Teachers will need to develop expertise not only in the components of the three NGSS dimensions—disciplinary core ideas, practices, and crosscutting concepts—but also in in creating and enacting lessons that weave those dimensions. Additionally, teachers will need expertise to guide their students to attain mastery of the various grade band performance expectations. In order to fully be able to

support teachers to take on this challenging task it would be wise for researchers, curriculum developers, teacher educators, and administrators to first understand the experiences and challenges teachers might face in attempting to implement these new standards into their own practice.

Why are teachers such an important piece of the NGSS? As science education researchers, if we want science teachers to be successful utilizing the NGSS, we must make every effort to figure out how we are going to support science teachers to make sense of the new standards and be successful at implementing the NGSS. This focus on teachers is critical because as Sarason (1996) was keenly aware, teachers are ultimately the agents of implementation of education reform and he cautioned that ignoring or "not being sensitive to what and how and why [teachers] think as they do" (p. 232) would make it unlikely that change, as prescribed by education reform, in the classroom would occur. Smith and Southerland (2007) echoed Sarason's (1996) sentiment that teachers are critical agents of change within schools and understanding their responses to education reform is important to study and try understand if real change is to happen in schools.

Finally, while there has been extensive research on understanding teachers' implementation of reform-based curriculum as noted earlier, there is less research on how teachers, utilizing their own resources, work to integrate and enact reform on their own, that is, without the support of a reform-based curriculum. Having some understanding of the kinds of experiences teachers have utilizing the NGSS on their own, without the guidance of a reform-based curriculum would ideally provide some insight into how teachers are interpreting and experiencing the standards. Such an understanding—through the eyes of the teacher—might then lead to better informed standards-based curriculum that teachers might then be more successful

in implementing. An in-depth study that explicitly investigates teachers' initial experiences with, understanding of, and implementation of the new standards is needed in order to begin creating effective and supportive professional development and pre-service teacher supports for teachers.

Proposed Contribution

Professional development materials and reform-based curriculum suitable for supporting teachers to plan and teach with the new standards must first be consistent with the reform goals and aim to be effective in supporting student learning. However, an understanding of what constitutes effective teacher support materials will continue to pose a challenge without first exploring and trying to understand some of the experiences and initial challenges teachers might face. This study aims to add to the literature documenting these experiences and challenges. Additionally, creating a link between the NGSS, teacher practice, and health education as this study proposes to do, has not been thoroughly explored, but has the potential to expand our understanding of how science teachers might incorporate the newly state adopted NGSS into existing health curricula to support student engagement and learning in these critical health and science areas. This study will contribute to the science education and health education communities by purposefully looking at Mrs. D's experience as she created and integrated lessons utilizing various dimensions of the NGSS into the middle school health issue of alcohol and drug use and its effects on the human brain. To guide my research, I asked: How does Mrs. D work to make sense of the three NGSS dimensions and weave them into her existing anti-drug health curriculum so that the three dimensions work together in accordance with the vision of the NGSS?

The literature reviewed here begins to help me respond to this research question. In the following chapter, I present the research methods and design that I utilized in my study. I include

the research context, which consists of a detailed description of the focal participant, Mrs. D., as well as an explanation of my own role in the study. Finally, I include a description of the data set and the methods of analysis that guided this study.

CHAPTER III
RESEARCH METHODS AND DESIGN

This study documented Mrs. D's experience during the planning and teaching of a revised anti-drug curriculum utilizing the Next Generation Science Standards (NGSS). The overarching research question of the study was:

> How does one 7th grade science teacher work to make sense of the Next Generation Science Standards' (NGSS) three dimensions of practice, disciplinary core ideas, and cross-cutting concepts (hereafter referred to as the *three NGSS dimensions*), and weave them into her existing anti-drug health curriculum so that the three dimensions work together in accordance with the vision of the NGSS?

In this chapter I present the research methods and study design I used to investigate this question. I begin with the theoretical framework that guided my methods and design, followed by a description of the research context. In the research context I include a description of the study location and, more importantly, the teacher participant and focus of the study, Mrs. D. Following the description of the research context, I introduce the research design including a description of and rationale for the data sources collected and utilized. I conclude the chapter by detailing the study's methods of analysis.

Study Background and Data Sources

This qualitative case study of Mrs. D occurred over the course of six months, during the 2013-2014 academic year. During this time, I collected teacher notes and lesson plans, observed and videotaped classroom enactment, collected student work related to the anti-drug unit, and audio recorded Mrs. D's self-reported experiences during planning and teaching the lessons. I

chose the qualitative case study design (Yin, 2014) because it was most useful for my purpose of understanding and describing, in depth, the *why* and *how* of the phenomenon of one teacher working with the newly released science standards for the first time. The use of a case study afforded me a more complete and focused understanding of the discussions Mrs. D was having with me as she planned and taught using the new standards in her own classroom.

This study was designed to take an intense look at how Mrs. D planned and enacted her anti-drug unit using the three NGSS dimensions in her health class. By placing myself primarily as an observer and only minimally as a participant or collaborator, I aimed to obtain a more realistic view of the kinds of issues a teacher might face as she worked, on her own, to implement these new standards. To attain this goal, I used as a model the four ethnographic methods of data collection as outlined in Eisenhart (1988): participant observer, ethnographic interviewing, search for artifacts, and researcher introspective. While not ethnography in the full anthropological or sociological sense of spending extended periods of time in the community of interest (Eisenhart, 1988; Erickson, 2011), this study benefitted from using the four methods because, as I elaborate below, each method provided me a different perspective and thus a more complete picture of the teacher's experience.

My role as participant observer had varying levels of participation and changed from participant to observer within the study (Eisenhart, 1988; Erikson, 2011; Maxwell, 2005). At times, I was "both involved in and detached from the topic of study" (Eisenhart, 1988, p. 105). As I will explain further in this chapter, in the first phase of the study my role was that of participant and observer. In the second phase of the study, my role was that of an observer. This dual participant-observer role was important because both roles afforded me different perspectives of Mrs. D's experience using the NGSS. As a participant, I was an insider working

with Mrs. D and experiencing some of the challenges she was experiencing using the NGSS. As an observer, I was an outsider *watching,* and trying to understand the challenges she was facing as she taught with the NGSS (Eisenhart, 1988; Erikson, 2011; Maxwell, 2005).

For this study it was crucial to understand both the teacher's subjective views as well as the historical context of her experience (Eisenhart, 1988) using the new standards in a health context. With this in mind, ethnographic interviewing was appropriate and necessary. As such, the primary data sources for this study were the audio recordings of Mrs. D talking through her thought process as she worked with the new standards. In order to gain a more subjective view of Mrs. D's experience, interviews were fairly open-ended and sometimes covered several topics (Eisenhart, 1988). In addition, our informal interviews also provided me with useful information beyond the topic of the NGSS and contributed other valuable information such as historical context about the political situation and climate of the school and the district (Eisenhart, 1988; Erikson, 2011; Patton, 2002).

To provide a broader lens for this study, as well as a better understanding of the study's context (Miles & Humberman, 1994; Patton, 2002), data collection included various artifacts (Eisenhart, 1988). Data included lesson plans and drafts of Mrs. D's unit outlines as well as student artifacts such as photos of activities and the students' final unit presentations. I use the artifacts throughout the dissertation to provide an important visual connection with the work Mrs. D and the students were doing.

Data collection included notes about researcher role and introspection (Erikson, 2011; Maxwell, 2005; Miles & Huberman, 1994; Patton, 2002). By reporting my experiences, I was able to more readily check and understand my role throughout the study (Maxwell, 2005). These

notes about my insights and interpretations, feelings, and reactions (Eisenhart, 1988 Maxwell; 2005) during the study also assisted me at the end of the study, as I worked to transcribe and analyze the data.

Two Phase Study

As mentioned in Chapter I, the goal of this study is to provide a full view of Mrs. D's implementation of the NGSS, planning and teaching. Therefore, the study design included two phases; Phase I Planning, which focused on Mrs. D's planning and revising her anti-drug unit to include the NGSS dimensions, and Phase II Classroom Enactment, during which Mrs. D taught her revised unit in the classroom. Designing the study in two phases provided important insight into how and why Mrs. D was planning (Phase I) and how that planning inevitably became the unit she enacted in the classroom (Phase II). Table 3-1 shows the two phase study design.

Table 3-1 Outline of Phase I and Phase II Design

	Phase I December 13, 2013- April 10, 2014	Phase II May 1, 2014- May 28, 2014
Purpose of the phase	Planning the ATOD Unit using the three NGSS dimensions	Classroom Enactment of the ATOD Unit to demonstrate the use of the three NGSS dimensions in a health related unit
Role of Researcher	Learning goal creation collaborator, materials support, and observer	Observer
Role of Participant	Primary ATOD lesson planner	Teaching the ATOD unit

Research Context

I conducted the study between December 2013 and May 2014 at the Greater City Magnet School[5] in California. The population of the school's neighborhood, according to the Census 2010 (California Department of Finance, 2010), was approximately 74,000 people.

[5] The name of the school and the names of all of the people referenced in this study are pseudonyms.

Approximately 50% identify as Latino, 30% White, 4% African American, less than 1% Native American, 12% Asian, and 4% Other.

The Greater City Magnet School was considered an "integrations magnet" school, and it was the largest magnet school in one of the largest school districts in the nation. The school was considered an integration magnet because of its diverse student population; the school purposefully looked for ways to diversify its student population. Being a magnet school supported this aim because it meant that students were bused from areas all around the school district. Compared to other schools within the district, it was considered very diverse with roughly 35% Latino, 15% Asian, 5% African American, 40% White, and 10% identified as Other. Fifty percent of the students were identified as Gifted and Talented. The school was a single track school and has a population of approximately 2,100 students in grades four through twelve.

According to the district website on school demographics, the school had a very high attendance rate, one of the highest in the school district at over 95%. Students were bused from the various neighborhoods that make up this large city, which meant students not only came from neighborhoods that were culturally and racially diverse, but they also came from a range of economic levels. Roughly 50% of the student population was identified as economically disadvantaged as determined through students' eligibility for free and reduced lunches. However, the school did not qualify for Title 1 funding, meaning the school did not have an overwhelming large *neighborhood* population of low-income families to qualify for federal assistance. The fact that the school did not qualify for Title 1 funding proved to be a challenge for school funding. Although students were bused to school from all over the school district, for those bused students who did qualify for Title 1 funding, that funding did not travel with the student to the magnet

school. Instead, the funding was maintained at their neighborhood schools. According to Mrs. D, this lack of funding meant many teachers had to purchase classroom supplies out of pocket and it had created a culture where teachers were expected to request that parents make "donations" so that teachers could buy classroom and science lab materials. Mrs. D reported that it took her two years before she gained the courage to ask parents for money to help offset her out of pocket expenditures on classroom materials (personal communication, April 10, 2014).

Mrs. D

Mrs. D and I were former colleagues who worked at another middle school from 2005-2007. As I will describe shortly, she represented an "information rich case" (Patton, 1990, p. 46) for this study with a breadth of experience in both the education and public health fields. The goal of purposeful sampling, according to Forman and colleagues (2008) is "intentionally sampling cases that can best help the investigator understand the central problem under study" (p. 766). Because of her knowledge and experience in teaching, her willingness to participate, and the fact that she had never used the NGSS, Mrs. D represented a purposeful sampling and her participation permitted me an in-depth understanding of the phenomenon of how one teacher grapples with the NGSS for the first time.

Our collaboration began during informal discussions about the NGSS. California had recently voted to adopt the NGSS and Mrs. D knew that in the next year she would be expected to integrate the NGSS into her life science course. She was motivated to participate in this study, "It's like a good thing for me to do [participate in the study], because it takes me out of the mundane, and making it better for the kids, so it's definitely a passion" (Interview, December 13, 2013). Together, Mrs. D and I agreed this study would be a tremendous opportunity to explore a set of problems that already existed (understanding the NGSS) and supporting adolescents to

understand the effects of drug use on their bodies). The idea of bringing in more science to support the health skills was something Mrs. D had been thinking about for a while. She stated:

> I don't know I've been thinking about it a lot. What as a 7th grade student do you need to know in order to not do drugs? I mean I don't know, what can we do to improve the chances that they put it off or don't start drugs, and alcohol or use drugs and alcohol? (Interview, February 26, 2014)

The two passages above demonstrate that Mrs. D thought that by participating in this study it would be a good change of pace for her and for her students. She also thought it would be good to participate to take her out of "the mundane" and to make the science better for her students. Mrs. D felt using the NGSS would be a good way to present the issue of drug and alcohol use and its effects on the brain so that her students might be less likely to use drugs and alcohol. I believe the findings will also show she certainly did show a passion for her work on this study.

Mrs. D was a middle school 7th grade life science and health teacher who taught life science during the first semester of the school year and health during the second semester. As required by her school district, she was licensed to teach health and biology. Mrs. D had been teaching in the district for 9 years. Her credentials included an undergraduate degree in biology, a master's degree in public health, a master's degree in science education, and a preliminary administrative credential. Mrs. D was involved in many school activities that ranged from serving as a member of the school's hiring committee, chairing the science department and co-chairing the school's Technology Committee, as well as co-sponsoring student clubs: the Gay Straight Alliance, Writer's Student Club and Inside Out (an after-school arts program). Mrs. D has written and received grants for her classroom well as for the school. Mrs. D has worked on several curriculum development projects ranging from leading a group of science teachers at her

school in creating interdisciplinary lesson plans to developing curriculum for pre-teens and at-risk youth in probationary and juvenile hall settings.

In addition to Mrs. D's experience in education, she was also highly passionate about issues related to public health and had quite a bit of experience working in the public health sector. Before teaching, Mrs. D was employed in various aspects related to health education. For a time, she was a health education department director of two large counties in California and oversaw the education department. She managed and supported the development of health education programs in these counties, and managed and performed data analysis. At the national level, Mrs. D was national programs coordinator for the Women and Youth Supporting Each Other (WYSE) program where she helped coordinate and organize the mentoring program of more than 200 volunteers at 11 universities.

At the time of the study, Mrs. D had worked at the current school for three years. She was teaching four 7th grade science/health classes, two classes were deemed honors 7th grade and the other two classes were deemed "regular" science. In total, she was responsible for approximately 150 students. Students in all four of Mrs. D's classes participated in the revised curriculum. However, the study took an intensive look at Mrs. D's teaching in just one of her classes, an honor's class that she chose. Mrs. D chose this particular class because:

> They are smaller and supposedly honors but there's a good handful that are just not getting it so it would be great to see them really get it and they are also just a nicer group of people… it's early in the morning. (Interview, March 21, 2014)

Mrs. D also felt her second-period honors class was more likely to turn in their work, "Period 2 would be the best shot at actually seeing something…Period 3 doesn't do their work" (Interview,

March 21, 2014). Period 2 consisted of 33 students, 19 female students and 14 male students, and 64% of the class was designated as gifted (according to district standards). [6]

The Role of the Researcher

It was during our first Phase I interview, December 13, 2013, that we formally agreed that during the study my role would be much less active with mostly an observer role and, at times, a sounding board for Mrs. D as she revised her drug unit. I describe below in more detail how and why my role as collaborator and support shifted in the two phases. Putnam and Borko (2000) caution researchers to be aware of their roles, especially if they are taking on multiple roles in their research. It was important to be transparent about my role as participant observer in this study so that my influence as a researcher and collaborator was clear. Putnam and Borko (2000) state, "Rather than pretending to be objective observers, we must be careful to consider our role in influencing and shaping the phenomena we study" (p. 13). As I will discuss in the final chapter, being clear about my role has also helped shape my ideas around the kinds of support teachers might ultimately utilize to support their work in implementing the NGSS.

During informal discussions, and prior to the commencement of the study, Mrs. D and I had initially discussed the possibility of this study being more of a collaborative effort, one in which we would co-plan and possibly co-teach and we drafted a rough outline of what an anti-drug unit, utilizing NGSS, might look like. However, Mrs. D and I ultimately agreed it would be a much more realistic study into the thought process and experience of a science teacher working to implement the NGSS without the direct influence of a researcher on her planning. Mrs. D did

[6] I obtained consent from 83% of the participating class and I only utilized student work from those students who I had obtained consent (meaning I had consent from both the student and a parent/guardian).

use pieces of the rough outline to guide the revision of her existing anti-drug unit; however, the lesson plan details were wholly the product of Mrs. D's planning. Therefore, during Phase I, my role involved minimal collaboration, supporting Mrs. D in creating the learning goals that would guide the creation of the lessons and also providing materials she might need (e.g., I provided an article on the Pyramid Activity, described later, because she was unable to access the article).

During Phase II, my role shifted to become that of an observer of the unit enactment and a sounding board for Mrs. D as she made changes and edits to her lesson. I attended all of the lessons and video recorded all but one due to technical issues with the recording equipment. As a sounding board, I made every effort to limit my own opinion and involvement that might influence Mrs. D. Mrs. D clearly knew her students much better than I and I recognized she would make much more informed decisions about planning and teaching in her classroom. In the end, I did make a suggestion or two about student support to Mrs. D and provided materials when necessary[7]. This understanding, that I was an outsider, helped me keep perspective as I collected and analyzed data.

Research Design

This section describes how the study was designed and why this was the appropriate design given my interest in understanding how Mrs. D experienced planning and teaching with the new standards. As described in Table 3-1, this was a two-phase study. A two phase study was necessary because first, I wanted to document how Mrs. D *planned* lessons to include the new standards and observe and record her talking through her thought process as she revised her

[7] I loaned Mrs. D a book on graphic organizers after she discussed the need to support students with how to use the scientific language.

existing anti-drug unit. Second, I wanted to document her talking through her thought process and observe as she *taught* those revised lessons in her classroom.

Phase I: Teacher Planning and Revising the Anti-drug Unit

During Phase I—December 13, 2013 thru April 10, 2014—I collected a total of seven planning discussions via telephone, plus one in-person planning discussion which occurred on April 10, 2014. Although we had planned to meet twice a month leading up Phase II, due to other previous obligations that Mrs. D had, this was not always possible. Calls were scheduled for weekdays after school when Mrs. D was home and had time to talk. Each discussion was recorded and lasted approximately forty five minutes to one hour. Mrs. D's unit plans and logic models were also collected. Phase I data also included researcher notes from the discussions.

Phase I planning discussions centered on Mrs. D's experience of revising her existing anti-drug unit to include the three NGSS dimensions and parsing through the various curricular support she had available to her. Mrs. D had acquired resources from the National Institute of Health as well as U.S. Department of Health and Human Service's SAMHSA (Substance Abuse and Mental Health Services Administration) branch of National Registry of Evidence-based Programs and Practices (NREPP). At the time of this study, Mrs. D's main health curriculum for this unit was a district approved curriculum called Project Alert (PA) which comes from National Registry of Evidence-based Programs and Practices. Below I describe in more detail the rationale for using a drug unit and specifically Project Alert because it was one of the driving forces behind Mrs. D's decision to include the new standards in her revised health-based anti-drug curriculum. She called her revised unit the Alcohol, Tobacco, and Other Drugs Unit, hereafter referred to as the ATOD unit.

Project Alert

Mrs. D felt that utilizing Project Alert as the base curriculum for her ATOD unit, along with the integration of the recently adopted NGSS was one way to support adolescent health. Project Alert (PA), a nationally used health curriculum, was initially the foundation of Mrs. D's original ATOD unit (before she included the NGSS dimensions). Project Alert was introduced in 1995 and is now used by more than 50,000 middle school teachers across the United States (NREPP, 2013). As indicated by the Project Alert website, the 11 lesson curriculum aims to "help motivate young people to avoid using drugs and to teach them the skills they need to understand and resist pro-drug social influences" (NREPP, 2013). According to research by the RAND Corporation (2013), Project Alert helps prevent middle school students from beginning the use of alcohol, tobacco and marijuana, and decreases the use of those substances by middle school students already using them. This anti-drug curriculum is highly relevant because of the continued high incidence of drug and alcohol use by adolescents which leads to a multitude of negative life outcomes (NIH, 2012). A National Research Council-Institutes of Medicine report (2013) describes how early drug use exposes adolescents to a myriad of future physical and mental health issues. With this information in mind, it was imperative that we take a look at ways to support adolescents to become better educated about their health and therefore make better health discussions. The Project Alert curriculum was dedicated to supporting teachers in efforts to help middle school students obtain the skills they need to say no to drugs and alcohol as well as avoiding these unhealthy behaviors.

"Brain Power!" by NIDA

Project Alert is focused on behaviors and refusal skill-building. Mrs. D has developed expertise teaching the Project Alert curriculum over the course of several years. Therefore, it

becomes an interesting study to investigate what happened as Mrs. D worked to utilize parts of Project Alert and, in addition, endeavored to supplement this skills-based health curriculum by weaving in the NGSS dimensions. The National Institute on Drug Abuse (NIDA), which is a branch of the National Institutes of Health, created Brain Power! in 2007. Brain Power! is a science-based, grades 6-9 curriculum consisting of six modules aimed at supporting teachers and students in learning about the effects of drugs on the body. The curriculum was free and it was accompanied by several online activities as well as resources for teachers, students, and parents (NIH, 2007). In addition, because it was science-based, Mrs. D found it easier to adapt the Brain Power! curriculum than the Project Alert curriculum so that it more closely corresponded to the NGSS performance expectation, MS-LS1-8, outlined below.

NGSS performance expectation—MS-LS1-8

The three dimensions—disciplinary core ideas, science and engineering practices, and the crosscutting concepts—are the essential and foundational pieces of the NGSS, and they form the basis for the performance expectations (PE). The NGSS performance expectations weave the three dimensions into a coherent statement that outlines what students should be able to know and do at each grade level and within each science domain (NGSS Lead States, 2013). Each NGSS performance expectation is then broken down into their three dimensions with specific details aimed at helping guide teachers' planning and teaching (see Figure 2-1 in Chapter II). The performance expectations in and of themselves are not curricula. The NGSS make it clear that the performance expectations should be used to help guide science teachers with their lessons and support curriculum designers in creating appropriate lessons and activities that weave the three NGSS dimensions. Below, I describe the NGSS performance expectation that guided Mrs.

D as she revised her existing ATOD unit. You may also refer back to Figure 2-1 in Chapter II for the NGSS Performance Expectation layout for MS-LS1-8.

For this study, Mrs. D focused her planning to incorporate the NGSS Performance Expectation, MS-LS1-8 which states: *Students who demonstrate understanding can- Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories* (NGSS Lead States, 2013). When broken down into the three dimensional components this performance expectation was comprised of the science and engineering practice of *obtaining, evaluating, and communicating information*, the crosscutting concept of *cause and effect*, and the disciplinary core idea of *structure and function* (NGSS Lead States, 2013). Although the findings indicate Mrs. D ultimately used more dimensional components, the three listed above guided her initial planning. During Phase I, I was primarily interested in investigating Mrs. D's experience planning with this performance expectation. I observed how Mrs. D used her existing anti-drug curriculum that included the Project Alert program materials; she also incorporated the Brain Power! curriculum for its science core ideas and that guided her when weaving the dimensions into the revised ATOD unit.

Phase II: Teaching the Revised Anti-drug Unit

During Phase II—May 1, 2014 thru May 28, 2014—I collected sixteen hours of classroom video recordings and student artifacts (worksheets, pictures of in-class student activities, and final student presentations) from the nine class meetings (the first day was not recorded due to difficulties with the recording equipment). After each lesson enactment, I audio recorded a total of nine debrief interviews with Mrs. D, each lasting approximately 25-40 minutes. Following one of her lessons, Mrs. D was unavailable to do a one-on-one debrief, therefore I left a series of questions for her to answer and she audio recorded her responses

which I later transcribed with the other debriefs. I also wrote observer notes during classroom observations and teacher debriefs.

Member checking (Creswell, 1998; Creswell & Miller, 2000; Eisenhart, 1988; Lincoln & Guba, 1985) occurred during data collection and post-data collection as I worked on data analysis. Member checking during the study involved asking Mrs. D for clarification after classroom observations or after listening to the debriefs. Post-study member-checking involved e-mail exchanges and some phone calls in which I asked for clarifying information about Phase I and Phase II discussions and unit planning teacher artifacts. Frequent member checking enabled me to verify I was representing Mrs. D's thoughts and experiences as she had reported them and it allowed me to double check my understanding of the events of the study (classroom observations, Mrs. D's comments during enactment, during planning discussions, and debriefs) .

Overview of Data Sources

This section describes the various sources of data collected and employed during data analysis for this study. I describe the data as two different sets of data, Phase I planning and Phase II teaching. The complete data collection timeline, including Phase I, Phase II and post-study interviews occurred between December 13, 2014 and June 5, 2014. See Table 3-2 for an overview of the data.

Table 3-2 Overview of Data Sources

Data Source and Phase Data Were Collected	Number of Files	Format of Data
Phase I Interviews	6	Audio (Transcribed)
Phase I Researcher Notes	6	Word Files
Phase I Teacher Planning Files	2	Word Files
Phase II Debrief Interviews	9	Audio (Transcribed)
Phase II Researcher Notes	9	Notebook Journal Entries
Phase II Planning Notes	2	Word Files
Phase II Classroom Video	9	Video (Transcribed)
Phase II Student Work (43students*9 lessons)	387	Paper

In order to study how Mrs. D planned and taught the new standards, focusing on her own thought process and experience, data analysis focused on her Phase I and Phase II interviews and classroom observations. These were the most information rich data sources for what actually occurred in the classroom and revealed Mrs. D's thinking as she planned and taught with the new standards. However, teacher lessons, researcher notes, and student work were also necessary to provide context and to help refine data analysis.

Phase I Interviews and Researcher Notes

In Phase I, teacher interview data included researcher notes and audio from planning discussions. This data helped reveal Mrs. D's rationale behind the kinds of activities to be included in the modified curriculum. I purposefully kept the interviews loosely structured because I did not want to constrain what Mrs. D had to say about her planning process or the experience she was having planning with the new standards (See Figure 3-1). Because the aim of

the NGSS is to support students in developing critical thinking skills in order to be able to explain phenomena and design solutions to problems *through the weaving of the three NGSS dimensions*, the interview questions did privilege the idea of weaving. That is, I asked about the specific places in the unit where she thought she would see the three dimensions coming together in her lessons. Those were places I could go back and verify in my notes and in the debriefs as places Mrs. D had identified where she thought she might see the three dimensions working together. I used the three interview questions as a starting point and probed as necessary to gain a better understanding of Mrs. D's experiences planning with the NGSS. As the data will show, in some instances Mrs. D was able to identify specific instances where the three NGSS dimensions came together in her teaching. At other times, this coming together of the three NGSS dimensions was a process that occurred over several lessons.

Figure 3-1 Phase I Interview Protocol

Teacher Planning Discussions (semi-structured discussions)

1. How was the planning going?
2. Are there areas in the lesson(s) where you see the three dimensions?
    a. Where?
3. What challenges are you seeing in the planning
    a. Why?

Phase I Teacher Planning Notes, Logic Models, and Unit Outlines

Phase I teacher planning notes, logic models, and unit outlines were collected as the planning of the unit proceeded. These pieces of data provide physical evidence of the various changes and modifications Mrs. D made as she worked to revise her anti-drug unit to include the new standards. Mrs. D created the logic model (see Appendix B) as a way for Mrs. D to visualize all of the inputs and activities that would guide the creation of the ATOD unit. The logic model included the short term student outcomes (knowledge, skills, and behaviors) and long term

student outcomes (knowledge, skills, and behaviors). The logic model was the vision of the health and science knowledge, skills, and behaviors she hoped students would gain from the unit. The logic model identified various NGSS dimensions that Mrs. D aimed to utilize in her ATOD unit. The ATOD unit outline contained the specific learning goals Mrs. D created that each contained the three NGSS dimensions (see Appendix A). The unit outline contained a more detailed path by which she would help support students' attainment of those long and short term goals from the logic model, while also gaining proficiency in the focal NGSS performance expectation, MS-LS1-8.

Phase II Interviews and Researcher Notes

Phase II data were collected during semi-structured teacher interviews after each lesson enactment; I call these interviews debriefs. Similar to the Phase I interview questions, the debrief questions were also semi-structured and involved a set of 5 questions that were consistently asked along with appropriate probes (See Figure 3-2). Audio recordings of these debriefs were collected at the end of each day, during Phase II enactment. The debriefs were transcribed at the end of the study. These debriefs were an essential way to document Mrs. D's thoughts about implementation immediately following classroom enactment rather than waiting for Mrs. D's reflection about the lessons at the end of the study. These debrief discussions were also a way of member-checking (Creswell, 1998; Eisenhart, 1988; Lincoln & Guba, 1985) for clarity and accuracy of the observation data I collected.

Figure 3-2 Phase II Interview Protocol

Daily Teacher Check-In (semi-structured discussions)

1. How do you think the lesson went today?
2. What went well?
3. What went less well?
4. Were there instances where you thought you saw the three dimensions playing out today?
    a. explain
5. Did you make changes to what you had originally planned?
    a. What?
    b. Why?

Phase II Classroom Video

I collected and transcribed classroom video for 8 of the 9 lessons. I supplemented the missing video (the first day of the unit) with my own researcher notes as well as Mrs. D's debrief interview. The classroom video provided me the opportunity to revisit those classroom instances where Mrs. D had identified noticing the dimensions coming together during the debriefs. I will discuss *coming together* further in the chapters that follow.

Phase II Student Work

As noted previously, Mrs. D selected one of her honors classes to be the focal class in this study. All student work related to the anti-drug unit was collected from the selected class. Student work provided a physical piece of data that I could review, after debriefs with Mrs. D, where she had identified noticing the three NGSS dimensions coming together through student work.

Post-Study Interview

Two semi-structured, post-interview discussions were collected at the end of the study. These post-enactment teacher and researcher interviews provided Mrs. D's final insights and thoughts about the overall implementation of the entire unit. These final interviews were much longer, lasting approximately 2 hours each. The discussions provided us the time and space to

really reflect on the entire experience as well as providing important insights that later helped inform the final discussion chapter of this study.

Methods of Analysis

To manage the corpus of data collected for this study, I organized data sources by Phase I and Phase II of the study as well as by source of the data. All audio and video data were stored on a password secured university laptop as well as on the university's secured data storage cloud. All transcribed video and audio were also stored in these two secured areas. To make data management more workable, I organized and archived all audio and video as they were collected. To the extent that was possible, student artifacts and researcher memos were also organized and archived as they were collected.

I analyzed data by Phase I and Phase II data sources separately. Analyzing data first by phases separately allowed me to observe and analyze incidents as they occurred as Mrs. D planned and then taught the ATOD unit. As I examined each phase, I identified various categories in the ways Mrs. D was discussing her experience revising her health anti-drug unit (Phase I) and then teaching with the ATOD unit with the new standards (Phase II). When I analyzed interview data across phases, I attended to the similarities and differences in categories that were surfacing between the two phases. Observing and noting Mrs. D's experiences across the two phases allowed me to consider how similar categories changed between Phase I lesson planning and Phase II unit enactment. I will withhold presenting the categories here and I will present and elaborate on the categories that emerged from the data analysis in Chapter IV.

As I present my findings, I focus on and expand upon the main themes that emerged as a result of Phase I and Phase II analysis. Three important themes emerged from the data which will

be discussed further in the next two chapters: a) the various ways in which Mrs. D talked about, understood, and utilized the dimensions; b) the various ways in which Mrs. D described the three NGSS dimensions *coming together* occurring; and c) the ways in which Mrs. D contextualized the science and health core ideas to make it engaging and relevant to her students.

The primary data sources for this study were the teacher interviews and classroom observations. However, utilizing Constant Comparative Analysis (Strauss, 1987) to include the teacher interviews, teacher unit plans, classroom observations, researcher notes, and student artifacts provided a more robust analysis. That is, as categories (presented in Chapter IV) emerged from the interviews, I was able to compare and verify the data through various data sources. For example, when I identified places in the debriefs where Mrs. D was talking about the three NGSS dimensions coming together in her teaching, I could compare her debrief with the classroom video, student work and researcher notes from that same day. This method of analysis afforded me a broader lens with which I was able to compare what Mrs. D was discussing during her interviews with various other data sources such as her lesson plans, student artifacts and classroom video. Analysis of the Phase I and Phase II teacher interviews occurred in three iterative stages: a) transcription and coding; b) creating representations; and c) interpretation. Below, I describe each of these stages in detail.

Transcription and Coding

I transcribed the majority of the Phase I and Phase II interviews and a small number were transcribed via outside sources. I did spot checking of the outsourced transcripts to ensure reasonable fidelity to the original interview. Once transcription of the interviews was complete, I used the coding method outlined in Auerbach and Silverstein (2003) to separately code Phase I and Phase II interview data: (a) raw text; (b) relevant text; (c) repeating ideas; and (d) themes.

This form of coding the transcribed interview data helped me not only to manage and organize the interview data of the two Phases but also provided structure as I did open coding (Strauss, 1987) to identify categories and patterns related to Mrs. D's self-reported experiences working with the three NGSS dimensions and weaving the dimensions. After a first pass through the transcripts, I identified pieces of conversation that referred to Mrs. D's experience with the NGSS. I chose to code at the *meaning* level (Miles & Huberman, 1994). That is, similar to what Miles and Huberman (1994) suggested, I looked for the overall meaning, message, and idea Mrs. D was trying to convey which meant at times it took a short discussion to get there and other times Mrs. D was able to convey her thought in one sentence.

First pass—thinking about research concerns.

I began the first step of open coding by reflecting on the overall research question:

> How does one 7th grade science teacher work to make sense of the Next Generation Science Standards' (NGSS) three dimensions of practice, disciplinary core ideas, and cross-cutting concepts (hereafter referred to as the three NGSS dimensions), and weave them into her existing anti-drug health curriculum so that the three dimensions work together in accordance with the vision of the NGSS?

Next, I identified the general information I was looking for in the data; Auerbach and Silverstein (2003) refer to this step as *identifying your research concerns*. During the first pass of coding, the research concerns during Phase I related only to what Mrs. D was saying about her planning using the dimensions.

To begin identifying the research concerns, I looked at the raw text from Phase I identifying places where Mrs. D was making any mention of the NGSS or the dimensions coming together in her planning. Next, I pulled out all of those chunks of text to create one long document from all of the planning discussions. However, as I pulled out these chunks of the

NGSS related text, I realized I needed to take a step back because other categories were emerging that I needed to take into account. This time, I returned to the sub-question of the first research question (related to Phase I) *What happens as the teacher works to revise and create health lessons that weave the three NGSS dimensions (from one performance expectation?) into her existing anti-drug curriculum?* At this point, I realized my research concern was broader and had to do with *all* of those things that were occurring as Mrs. D was planning her ATOD unit. I would need to do a second pass of the raw data.

Second pass—relevant texts.

I went through the raw text once again and identified all of the places where Mrs. D was talking about her planning in general, not only her references to the NGSS and the dimensions; I called these pieces of data "relevant texts" (Auerbach and Silverstein, 2003). As I was pulling out these pieces of relevant text, I tried to give names or short descriptions to the issue I thought I was seeing discussed. Next, I went back to the relevant text and started to give them more description, commenting on what I thought each passage was saying, describing why each piece of relevant text was addressing my research concern, and what was happening as Mrs. D was planning. At the end of this coding iteration I had one large document with all of the Phase I pieces of relevant text that addressed my research concern.

Repeating ideas.

During the next iteration of coding, I looked for "repeating ideas" (Auerbach and Silverstein, 2003) within the relevant texts I had identified. I gathered and organized the repeating ideas so that they formed larger groups of relevant texts with descriptions that seemed similar to one another, what Strauss (1987) would call axial coding. I then created another

document where all of the repeating ideas were grouped into these similar categories. I then went through the document and worked to give names to those repeating ideas and to identify categories (Auerbach and Silverstein, 2003). When repeating ideas did not seem to fit the emerging categories, or I only had one example of that idea, I eliminated that group. Through this process I eliminated the category "Technology Use" because there was not enough evidence to support this idea and it did not fit the more prominent emerging categories. At other times I made decisions about whether or not to collapse repeating ideas into one category. The category "Professional Growth" was the result of collapsing both positive and challenging attributes of participating in the study.

Themes and their categories—Phase I.

As a result of my decision to return to the data a second time to do broader open coding, I was able to identify relevant themes emerging and their various categories that related to her sensemaking around the NGSS. Various categories were identified that inevitably formed the theme Using Health to Support Science Learning (hereafter referred to as Science in Health). Although Mrs. D had specifically chosen the phenomenon around alcohol and drugs' effects on the brain, I had not set out to specifically identify these instances when she talked about health and science together in Phase I data. However, it was an idea that came up repeatedly in our conversations and needed to be identified and investigated further. See Table 3-3 for an outline of Phase I themes and categories that were identified.

Analyzing Phase II data—similar but slightly varied categories emerge.

After creating themes and categories for Phase I, I repeated this coding scheme for Phase II interview data to identify the themes and categories that emerged during unit enactment. I made every attempt to code Phase II data without allowing the Phase I themes and categories to influence how I was seeing Phase II data analysis. I did not return to Phase I themes or categories until after I was finished creating themes and categories for Phase II data. In the end, various similar categories arose during Phase I and II. While some of the categories were similar in nature, the nuances of the categories changed slightly between planning and teaching. Table 3-3 below presents the Phase I and II Themes and Categories that emerged from coding and data analysis.

Table 3-3 Phase I and Phase II Themes with Categories

Phase I Planning Themes and Categories	**Phase II Planning Themes and Categories**

• Factors Affecting Mrs. D's Practice (Professional Climate)
  o Professional growth
  o Relationships
  o Tensions
• Using Health to Support Science Learning (Science in Health)
  o Political tensions
  o Importance of science in health
  o Relevance to students' lives
• Planning with and Making Sense of the NGSS (Incorporating the NGSS)
  o Creating learning goals
  o Resources
  o Teacher knowledge of the NGSS
  o Working through the NGSS
	• Planning with and Making Sense of the NGSS (Planning)
	  o Pedagogy
	  o Plans change
	• How Mrs. D Made Sense of and Identified the Three NGSS Dimensions Coming Together in Her Teaching (the NGSS in Motion)
	  o Three dimensions coming together
	  o Practices
	  o Challenges
	• Using Health to Support Science Learning (Science in Health)
	  o Connection to students' lives
	  o Science meets health

Creating representations.

Following the creation of the themes and categories for Phase I and Phase II, I created a graphic representation of the analytical themes and categories to visually represent what I understood to be occurring during these phases. The representations were a key piece of analysis that guided me to a deeper understanding of various phenomena occurring in this study. I present the Phase I and II representations in the following chapter as a visual overview of the findings that subsequently led to more focused analysis, the results of which will be presented in the two findings chapters that follow.

Video Transcription and Coding

After the discussion data were transcribed and coded, I returned to Phase II video recordings and did what Jordan and Henderson (1995) call core ideas listing. As I watched each video, I created a very brief overview of events that were occurring along with time stamps (Jordan and Henderson, 1995). These brief overviews allowed me to go through all of the videos in a fairly timely manner and also note areas of particular interest that I could return to and transcribe in more detail once I had a better idea of the data as a whole. Upon finding categories of interest in the debrief interviews and my observation notes, I returned to the video core ideas listings to identify places in those listings where the phenomena seemed to appear. Returning to the video and reviewing Mrs. D's actions, I then transcribed those instances that were representative of the categories verbatim so they could be used as evidence confirming or disconfirming that phenomena had occurred as I had remembered and noted it in my observations, or as Mrs. D had recalled it in her debriefs.

Interpretation

Interpretation of the data was especially dependent on the video and interview data, and the other sources of data were essential to support those interpretations. As a result of using this method of analysis, I arrived at several interesting interpretations. Detailed analyses of these interpretations are discussed further in the chapters that follow. The interpretations and analysis have important implications for improving the way we prepare teachers to take on these new science standards and the varied way in which we may need to consider as teachers work to integrate the new standards into their existing science curricula. Further, analysis suggests the need to consider how fringe courses like health might have the advantage of making science more engaging and connected to students' lives as supported by the NGSS and the *Framework,* because it directly relates to their lives.

In this chapter, I presented the research methodology and study design that guided this qualitative case study. Chapter IV is a short chapter that provides a brief summary of the findings based on my coding and analysis of the data as described in this methods chapter. Chapter V presents the first of two more refined and detailed findings chapters. Specifically, Chapter V presents the findings related to Mrs. D's description of her experience utilizing the three dimensions. The chapter includes how she described her understanding of each of the three dimensions and descriptions of how those dimensions were ultimately observed in her teaching. Chapter VI, the second major findings chapter, presents the findings related to Mrs. D identifying when and how the three NGSS dimensions came together in planning and teaching. The chapter also includes instances where I identified Mrs. D working to make the science and health ideas more accessible and engaging for students through the practice of contextualization. Chapter VII, the final chapter, presents an in-depth discussion that aims to bring the findings

together to highlight the significance and contribution of this study as it relates to science teachers implementing the NGSS.

CHAPTER IV
BROADER STUDY FINDINGS

This chapter aims to provide a brief overview of the overall findings of this study. I begin with a succinct presentation of the findings from Chapters V and VI, then present and discuss the broader findings of this study. These broader findings were the result of the methods of coding and analysis described in the preceding chapter, Chapter III. More importantly, these broader findings were critical to shaping the two findings chapters that follow. As a result of the in-depth coding and analysis, I was able to create two representations that illustrate major categories that emerged from the data for each phase of the study, which then guided the creation of the three main themes of the findings. I present both representations here with a narrative of my interpretation and how that interpretation ultimately led me to defining the main themes and boundaries of the two findings chapters.

To be clear, this in-depth case study of Mrs. D was not a study of how her understanding of the NGSS changed over time, but instead it was about observing how Mrs. D was making sense of and experiencing putting the NGSS into practice. Therefore, there were few instances in which I observed micro-changes in her understanding of the NGSS (two examples follow in Chapter V in the discussion on crosscutting concepts and the practice of modeling). Future studies might focus on teachers' change in understanding of the NGSS over time, but that was beyond the scope of this study. Likewise, the focus of this study was not to measure student outcomes. Granted, understanding student learning with regards to the NGSS will be an important area to explore, but it was beyond this scope of this study. Student data—work and

students' comments—are used solely to support the findings related Mrs. D experience making sense of and utilizing the NGSS.

Chapter V Findings

The overall findings show that Mrs. D was thoughtful as she worked through making sense of and making decisions about the NGSS and how to incorporate three dimensional learning into her practice. Chapter V will focus only on the findings related to how Mrs. D was working through her understanding of the three dimensions as separate entities. I recognize that the purpose of weaving the three NGSS dimensions is to purposefully use them in concert so that they complement one another and build a deeper understanding so students will be able to explain phenomena and design solutions to problems. When three dimensional learning occurs, all three dimensions should be present and working together. However, in order to gain a better insight into how Mrs. D was making sense of the NGSS I chose to describe and analyze how she was experiencing and making sense of each separate dimension.

Mrs. D reported not having any doubts or worries about her understanding of the NGSS core ideas utilized (see Table 4-1, green print) to support students' acquisition of proficiency in the focal NGSS performance expectation. She did, however, report some confusion about the significance of the crosscutting concepts. The data show that she was in fact incorporating the crosscutting concept as envisioned by the NGSS and she was able to identify them in her learning goals (see Table 4-1, orange print). Although the learning goals Mrs. D created focused only on one crosscutting concept, cause and effect, the struggle for Mrs. D seems to have been in an inability to specifically identify the aim and significance of the crosscutting concepts as they relate to the weaving of the three dimensions. Additionally, the data show that Mrs. D used various practices that she saw as best supporting the learning goals for her students (see Table 4-

1, blue print). And, she often noticed that more than one practice might be necessary to attain those learning goals.

The kind of work Mrs. D was attempting to do here—utilizing various dimensions—to attain the goals of her unit and ultimately the goal of supporting students to reach proficiency in the NGSS performance expectation seems not unlike the work that Krajcik and colleagues (2014) describe as *lesson level PE's (performance expectations)*. At the lesson level, performance expectations are created by teachers, or curriculum designers, utilizing a blend of several different dimensions "beyond those specified in the individual PE's" (Krajcik et al., 2014, p. 162). The goal of these lesson level performance expectations is to provide various learning opportunities for students to reach proficiency at the NGSS performance expectation level (Krajcik el al, 2014). Table 4-1 outlines the various learning goals Mrs. D created for her ATOD unit. I have included them to show the kind of work Mrs. D was producing as she worked with the NGSS for the first time. The blue print describes the practice, the green print describes the crosscutting concept, and the orange print describes the core idea. The learning goals are presented in the order that they were taught over the 11 day lesson plan. The school participated in block scheduling so each class lasted approximately 2 hours.

Table 4-1 ATOD Unit Learning Goals

ATOD Unit Learning Goals	ATOD Days
1. Students will gather, read, and evaluate online or print data that describes how marijuana consumption affects behavior due to the manner by which it was processed in the brain.	2, 3
2. Students will analyze and interpret data about drug effects (short-long term) that describes how drug consumption affects behavior and memory.	4, 5, 6, 7
3. Students will create models to describe the structure and function of neurotransmission (transmitting signals that travel along the nerve cells). The signals are then processed in the brain, resulting in immediate behaviors and memories.	8
4. Students will construct explanations and design solutions for drug addiction based on their knowledge of neurotransmission and how the drugs cause changes in behavior and memory.	9, 10, 11
5. Students will create models to describe the structure and function of neurotransmission (transmitting signals that travel along the nerve cells). The signals are then processed in the brain, resulting in immediate behaviors and memories.	9, 10, 11
ADDED 6. Students will gather, read, and evaluate online or print data that describes how methamphetamine and alcohol consumption affects behavior due to the manner by which it was processed in the brain.	10, 11

Mrs. D was clearly on her way to utilizing this kind of lesson level performance expectation planning for her own lessons. This kind of lesson level support for teachers to create various lessons utilizing various dimensions as suggested by Krajcik and colleagues (2014) will most certainly be needed and will be beneficial to other teachers doing their own planning and to support students in acquiring proficiency at the NGSS performance expectation level. Additionally, utilizing various practices, as Mrs. D seemed to be doing, would align with language found in the NGSS Appendix F. The NGSS Appendix F refers to work by Bell and colleagues (2012), where they state that practices "can and, in some instances, have a tendency to overlap and interconnect" (p. 3). However, it's significant to note that at those moments where she described the practices overlapping or utilizing various practices, it's not clear that she truly saw them as instances of overlapping or working in concert. Or rather, it may be the case that Mrs. D did not have the opportunity to fully articulate how and why the practices overlap. As with her understanding of the crosscutting concepts, the data show that she utilized different practices to support student learning. The difficulty for Mrs. D was being able to identify those

instances. This is important because, as described in the methods chapter, Mrs. D was a highly experienced and motivated teacher. Understanding that even a highly experienced teacher such as Mrs. D might struggle with making sense of the NGSS means that less experienced teachers will most likely also have similar struggles as they work to makes sense of and be able to identify the NGSS in their own practice and thereby more fully implement the NGSS dimensions in their own planning and teaching.

Chapter VI Findings

In the second findings chapter, Chapter VI, I continue the discussion on Mrs. D's experience with the NGSS, specifically, the ways in which Mrs. D was making sense of the idea of weaving the three NGSS dimensions in her planning and teaching. As I discussed in Chapter I and II, the idea proposed by the NGSS—supporting students to develop deep critical thinking skills to be able to explain phenomena and design solutions to problems through weaving the three NGSS dimensions—is something quite new in science education. According to the NGSS, to support students' learning, the three NGSS dimensions of practice, disciplinary core ideas, and crosscutting concepts "must be woven together in the standards, curricula, instruction, and assessment (National Research Council, 2012, p.29-30). This weaving of the three dimensions is both a critical aspect of the NGSS and a unique concept to national science standards (NGSS Lead States, 2013). The newness of the NGSS and the unique nature of the weaving of the NGSS dimensions make it a compelling topic to investigate; specifically, how science teachers talk about, understand, and ultimately attempt to do this weaving in their planning and teaching. Consequently, Chapter VI focuses on the findings related to the ways in which Mrs. D talked about (as reported through interviews) making sense of and identifying the three NGSS dimensions being woven together in her planning and teaching and how that understanding

subsequently manifested itself in her planning and teaching (as seen through classroom observations and student work).

In this study, in place of using the terms utilized by NGSS, "weaving, or woven together," I use the terms *coming together* or *bringing together*. I utilize these two terms because these were the terms Mrs. D and I consistently used in our discussions. Other terms are being used to characterize this weaving described by NGSS; Krajcik and colleagues (2014) have called it "blending" as well as "integration," and Reiser (2013) called it "coherent sensemaking science practices." The NGSS' use of the term *weaving together* connotes the idea of something that was fluidly intertwined and effortlessly incorporated. As the findings in Chapter VI will show, this was not necessarily the case. For this study, *coming together* and *bringing together* seemed to more effectively describe Mrs. D's experience.

While some in the science education community might argue that the NGSS dimensions must come together each day of each lesson, I would argue, and the data from this study suggest, that the weaving of the three NGSS dimensions can sometimes take time to occur, over various days and lessons. It is not impossible that the three NGSS dimensions can come together during one day or lesson. The point of Chapter VI is not to advocate one over the other, and I believe the data here suggest both are possible and successful. More important, the point of Chapter VI is to provide examples that present the ways in which Mrs. D was describing making sense of the three dimensions together, how she was describing how she saw this process occur in her classroom.

Finally, although Chapter VI focuses a lot of attention to how Mrs. D was making sense of the three NGSS dimensions coming together, another equally important and interesting set of

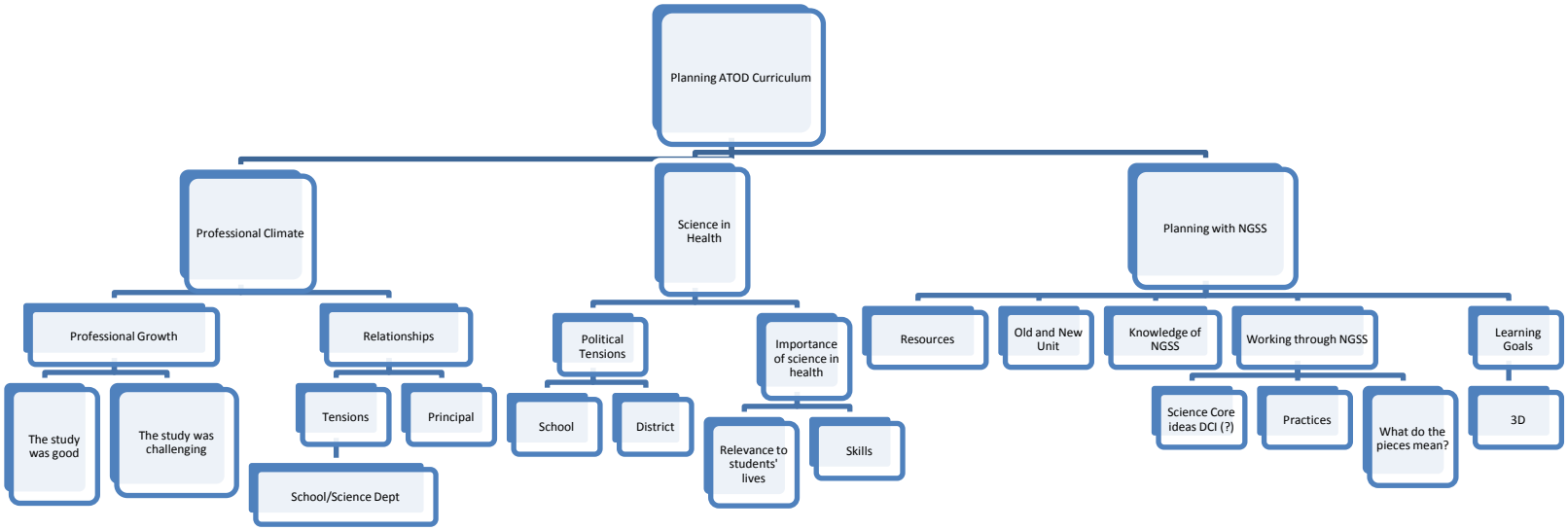
findings will be presented in Chapter VI; these findings show the way in which Mrs. D employed contextualization in order to engage students more authentically with the science and health ideas. In this study, contextualization refers to the different ways Mrs. D attempted to incorporate students' lived experiences into the science classroom to support students' engagement with the health and science core ideas of the ATOD unit. I use the term contextualization to describe the science classroom practice of using socio-scientific issues as a way to engage students in the science ideas. I draw my definition from Sadler (2009) who uses the term socio-scientific issues (SSI) to describe issues that both help students understand science from a professional point of view (concepts and procedures) but also make the connection to those social (or community) issues that students are facing every day, such as the effects of drugs and alcohol on the human body. The examples presented in Chapter VI show that Mrs. D had a deep understanding of her students and their communities. The data will show how Mrs. D was able to engage her students through her use of real-life stories that relate to the science concepts and procedures as well social issues that relate to students' lived experiences.

Overview of the Findings from Phase I Planning

In Chapter III, Methods, during coding and analysis of Phase I data, I noted three major themes: a) professional climate as a factor affecting Mrs. D's practice (hereafter referred to as professional climate), b) using health to support science learning (hereafter referred to as science in health), and c) the ways in which Mrs. D was planning with and making sense of the NGSS (hereafter referred to as planning with NGSS) (see Figure 4-1 below). Professional climate was a theme that emerged several times during our planning interviews, and under different categories: professional growth, relationships, and tensions. However, upon further analysis, I realized that professional climate influenced many of the reasons Mrs. D was motivated to participate in the

study. This motivation was important to her participation but it did not necessarily address the research question and explain her experience planning with the NGSS.

Figure 4-1 Analytical Categories for Phase I



Under the category professional growth, Mrs. D talked about the rewards of participating in the study, noting "I think it's good for me [to be a part of this study] because I feel like I am burning out a little this year. It's good for my boss to see this [her work and participation in the study]" (Interview, December 13, 2013). Additionally, Mrs. D stated, "I have written down a lot, it's very inspiring, I like getting everything written down and using this curricula that I have had sitting around forever" (Interview, February, 26, 2014). Mrs. D also talked about how challenging it was to participate in the study. She said, "It's just a lot more work than I had anticipated" (Interview, December, 13, 2013). And, later in the planning stage she stated, "So yeah, this [planning] was a lot to think about" (Interview, March 25, 2014). Mrs. D also discussed the challenges she was facing in her department and district related to health education: "I really do want to bring in the science part of it, but it was a struggle because you know health people don't like to spend a lot of time on deep science details" (Interview, February, 26, 2014). Mrs. D also outlined challenges from the science perspective, as she said "I'm sorry but some science teachers are not comfortable talking about vaginas and penises and some of them are just not going to do it [teach these health issues]" (Interview, April 10, 2014). Although these points were very important and they did influence her motivation to participate in the study and use health as the vehicle through which she taught the science core ideas, ultimately, they did not fully represent her experience utilizing the NGSS.

The two remaining themes did, however, more fully represent Mrs. D's experience working with NGSS during Phase I. Science in health was a theme that was identified throughout Phase I. Mrs. D had early on identified the science phenomenon that she wanted students to know and be able to explain: the effects of drugs and alcohol on the brain (neurons) and the subsequent physical and social effects of their use. Because of this, Mrs. D consistently worked

to integrate the science and health ideas in her ATOD unit. The following comment by Mrs. D is representative of the consistency that she displayed in working to focus her planning on the science phenomenon described above. Mrs. D states:

> How do we mesh the new health standards plus the standards you have as a [science] teacher what you want them to know before they leave and then plus these NGSS and how it relates [to health], especially because the NGSS was so biology driven and not health driven. Then I looked at the health standards and thought about what are the skills, because that was how they have structured the health standards, to be skills-based. (Interview, March 25, 2014)

When Mrs. D stated, "…the NGSS was so biology driven…" she understood that the NGSS middle school life science performance expectations were focused on science phenomena. Mrs. D felt that health, with its focus on changing behavior, or as she called it "skills-based," would be a great compliment and support to the science phenomenon for her unit. The theme of health and science ran through both phases of this study and this will become especially apparent in the second findings chapter where I present data related to Mrs. D's experience working to weave the three dimensions of the NGSS. Additionally, the way in which she worked to combine the health and science core ideas to make it relevant for her students was one of the more compelling findings of this study; it was also a major category in both phases and will also be discussed in the second findings chapter.

For the Phase I planning with NGSS theme, I realized she was working to make sense of the NGSS and she demonstrated some trepidation with the NGSS on several levels. During one of our interviews she stated, "I don't think I know a lot about the NGSS. I think that was why I am also doing this, so that I get better acquainted with it [NGSS]" (Interview, March 21, 2014).

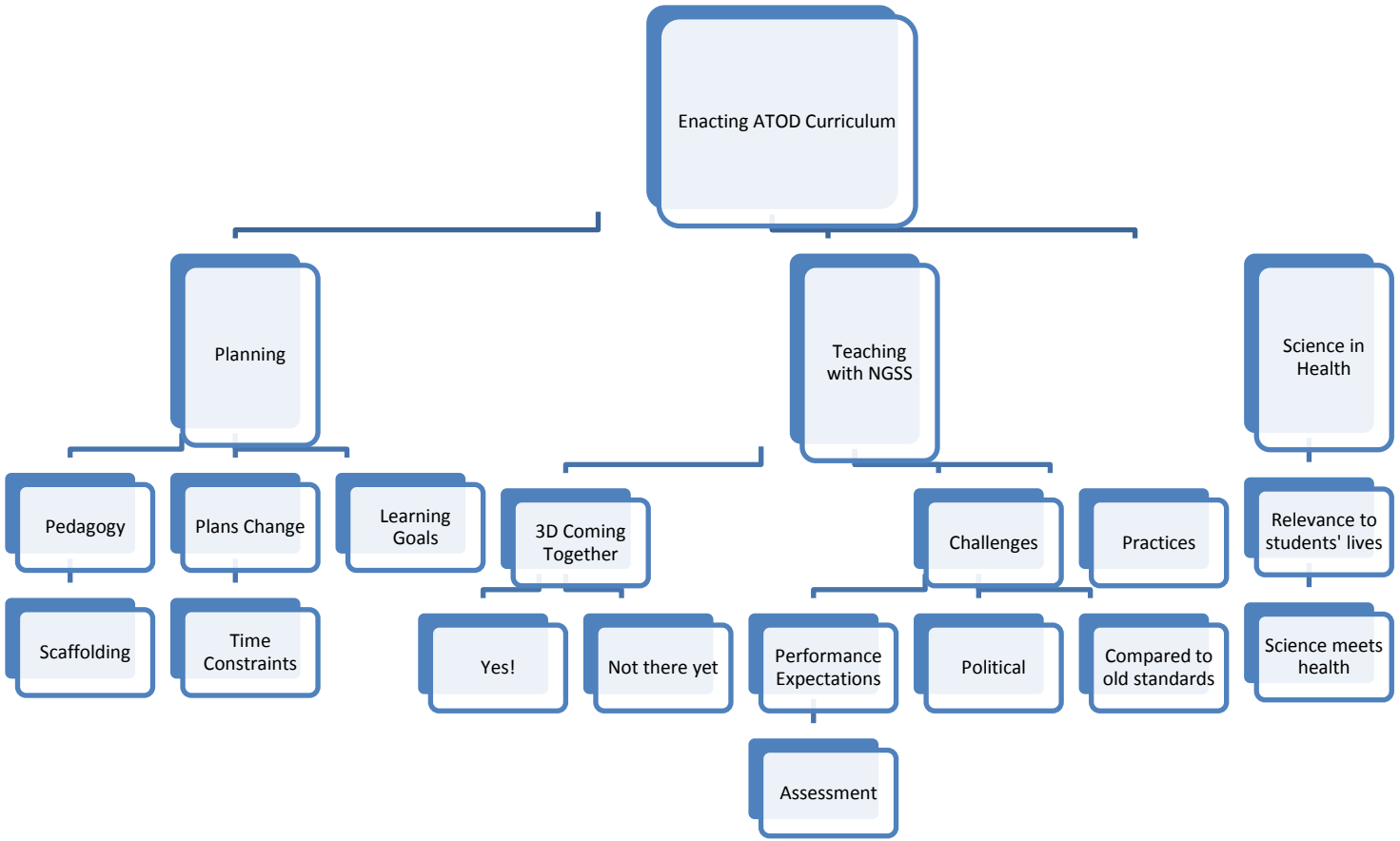
In another interview she talked about needing support to understand the various NGSS dimensions and how they come together. She stated:

> But then it also feels as if we should make giant puzzle pieces of each thing, the 'CCC,' and practices and whatever the other one was, and like piece them together like I could totally see this in a PD [professional development session] to help them [other teachers] understand [the NGSS dimensions and how to weave them]. (Interview, April 3, 2014)

Overview of the Findings from Phase II Teaching

During coding and analysis of Phase II data, I noted three major themes: a) Mrs. D's experience planning with the NGSS (hereafter referred to as planning, b) the ways in which Mrs. D saw science and health intersecting (hereafter referred to as science in health, and c) Mrs. D's experience teaching with the NGSS in her health unit (hereafter referred to as teaching with NGSS). See Figure 4-2.

Figure 4-2 Analytical Categories for Phase II



In Phase II, as Mrs. D was teaching, she was also constantly thinking about the challenges of planning with NGSS. She stated:

> Oh, I think it's [planning and teaching with the NGSS] such a huge challenge, because it's so complicated because instead of just one standard there's this one standard and there's 3 parts to the standard and now holding teachers accountable for engineering and science practices. I think we're definitely trying to do that but to actually name it and now hold teachers accountable, that's a whole other ball park and the middle one the 'DCI', that's more core ideas so that's the depth part and then the 'CCC', that's helpful because there was so little time to do interdisciplinary or what do you call it, across grade science and among the different subjects there's just very little to no planning. (Interview, May 14, 2014)

This category called "Challenges" (found under the theme Teaching with NGSS in Figure 4-2) identified the instances during which Mrs. D described the challenge of learning to use one standard—or performance expectation—with the three NGSS dimensions is a category that was identified and is discussed in both of the findings chapters. The following two findings chapters present evidence to support the conclusion that one of the challenges was in trying to clarify each of the dimensions as well as clarifying about how to weave those three dimensions as envisioned by the NGSS.

Finally, health in science turned out to be a substantial theme in both phases. Mrs. D consistently worked to focus on the science phenomenon and incorporate the science (the NGSS) into the ATOD unit. She did this so that the science was accessible to her students and they would be able to explain how drugs and alcohol affect the brain, and ultimately could make informed decisions about whether or not to use drugs or alcohol. This was by far the biggest section of Phase II. In the following passage, Mrs. D explicates her intent for utilizing health and science:

> It [the lesson she was planning] makes, it helps explain and prove all this stuff that, it's kind of where health and science meet to work together to help show students that I am not just preaching to them or like repeating stuff to them from Project Alert, they just have such blatant information without a source cited and it's, or a mechanism that explains it. I just feel as if they have the background knowledge [science knowledge] then they'll understand the effect and danger [of drugs and alcohol] and maybe hopefully perceive the consequences of their health behavior in a more real way. (Interview, May 7, 2014)

This sense of urgency to help students understand both the physical, mental, and real-world consequences of drugs and alcohol, through the ATOD unit, was an important idea that formed the basis for the second findings chapter.

Summary

In this chapter, my aim was to provide an overall view of the findings from Phase I and Phase II. The intent was to provide some context for the next two findings chapters that combine findings from Phase I and Phase II. In the next two findings chapters, my aim is to do an in-depth analysis of the two main themes that emerged from Phase I and Phase II data: a) Mrs. D's experience planning and teaching with the various dimensions of the NGSS, and b) Mrs. D's experience linking science and health in her ATOD unit. In Chapter V, I present findings that illuminate Mrs. D's understanding of the NGSS dimensions as illustrated through her interviews, classroom observations, and student work. In Chapter VI, I present findings that highlight how Mrs. D was talking through her experience of weaving the three NGSS dimensions as envisioned by the NGSS and what the weaving looked like to her. The theme of science in health is also highlighted in Chapter VI, and I present instances where Mrs. D was tapping into her knowledge about her students to engage them with the science and health core ideas.

CHAPTER V
THE NGSS DIMENSIONS

This chapter focuses on the findings related to the ways in which Mrs. D talked about and was attempting to make sense of her understanding of various components within each of the three NGSS dimensions and how she used them in her planning and teaching. Ideally, the three dimensions should work together to support three dimensional learning so that students gain the critical thinking skills needed to explain phenomena. However, for the purpose of this study, looking at how Mrs. D was making sense of the NGSS, I chose to first examine how she was making sense of each dimension separately. Then, in Chapter VI, I will discuss how Mrs. D was making sense of the weaving of the three dimensions, or how Mrs. D saw them coming together. In the final chapter, Chapter VII, I will explore how these separate discussions—the individual dimensions and then the weaving of the dimensions—provide a better understanding of Mrs. D's sensemaking as she worked to utilize the NGSS.

In the previous chapter, I presented a broad overview of the findings which were split into Phases I and II. In the next two, more detailed, chapters, I use the findings from both phases to present an in-depth view of the findings. These next two chapters include references to both Phase and Phase II data throughout the chapter in a way that was not necessarily chronological by date but sequential in the story it tells about Mrs. D's experience using the NGSS. A deep appreciation and understanding of the findings would not be possible without discussing both phases simultaneously as both were necessary in order to inform critical points of the findings.

As has been discussed at various points throughout this study, the main goal of the NGSS is to support students in developing critical thinking skills that allow them to explain phenomena and design solutions to problems. The three NGSS dimensions–the disciplinary core ideas (DCI), the crosscutting concepts (CCC), and the science and engineering practices (practices)–and the weaving of the three NGSS dimensions are the essential and foundational pieces of the NGSS that support teachers and students in developing the skills needed to explain phenomena and design solutions. That is, students will acquire a deeper level of understanding of the science because they are exposed to the three NGSS dimensions. The three NGSS dimensions form the basis for the performance expectations that outline what students should be able to do and know at each the end of each grade level (NGSS Lead States, 2013). Because the three dimensions are the essential components of the NGSS, it makes sense that various educational professionals—science education researchers, curriculum developers, the NGSS team, administrators—would be interested in understanding how science teachers make sense of and talk about their understanding of the three NGSS dimensions. It is equally important to investigate how teachers weave the various NGSS components that make up the three NGSS dimensions in their planning and teaching. This chapter aims to begin the conversation of teacher understanding of the NGSS by presenting data related to how Mrs. D understood each of the NGSS dimensions.

The data show that the majority of our interviews centered on how she was talking about her understanding of and use of various NGSS practices, therefore the science and engineering practices section makes up a large part of this chapter. However, I begin Section 1 by first presenting data related to how Mrs. D viewed her understanding of the disciplinary core idea that drove the Alcohol, Tobacco, and other Drugs Unit (ATOD unit). Included in this section are descriptions of what Mrs. D wanted the students to know and be able to do at the end of the unit

based on her knowledge of her students' needs and prior knowledge. Overall, the findings in this section show that Mrs. D was confident in the science and health content that made up the ATOD unit. Section 2 follows and provides some insight into Mrs. D's thinking around the second dimension, the crosscutting concepts (CCC). Included in Section 2 is the NGSS vision of what crosscutting concepts should do to support student learning and the crosscutting concepts used for the ATOD unit. Mrs. D presented her thoughts about the crosscutting concepts as they cross the science disciplines as well as her thoughts about the possibility of a more encompassing or global role of the crosscutting concepts. Overall, this section presents instances that show that Mrs. D knew what the crosscutting concepts were but was somewhat unclear about the purpose and significance of the crosscutting concepts. The remainder of the chapter, Section 3, is dedicated to unpacking how Mrs. D was talking about her experience utilizing various practices in her planning, and describing how she ultimately used those practices in her teaching of the ATOD unit. Below, I provide a brief description of what drove the creation of the ATOD unit (See Appendix A).

As I noted in Chapter I, Mrs. D chose to engage students with three dimensional learning through the health phenomenon of alcohol and drugs' effects on the brain (neurons) and the subsequent effects on physical and social activities. It was a theme that ran consistently throughout the unit and formed the basis for all of the activities Mrs. D created. As the data will show, Mrs. D was consistent in her goal that students should develop a level of understanding about the effects of drugs and alcohol on the brain and ultimately that her students would be able to explain the potentially negative effects on the adolescent brain to other students. Mrs. D wanted students to be able to explain both from a scientific point of view (the neurological effects) as well as from a health and social point of view.

During initial planning, Mrs. D focused in on the NGSS performance expectation, MS-LS1-8 (see Figure 2-1 in Chapter II), because it seemed to more accurately align with the science phenomenon she had chosen and it reflected the overall science goals that students would be able to gather and synthesize valid, credible, and reliable scientific information about the ways in which drugs and alcohol affect the neurons of the brain and subsequently behavior and memory. Mrs. D planned that the health portion of the unit would then tie into behavior and memory because it would address things such as the many possible consequences of using drugs (impaired motor skills, bad grades, trouble with the law, addiction, etc.). Table 5-1 outlines the performance expectation and the dimensions that Mrs. D used to create the ATOD unit. The box with each dimension also includes the section of this chapter where that dimension will be discussed. The performance expectation and dimensions are in Table 5-1 to provide a visual tool of the dimensions that are addressed throughout this chapter.

Table 5-1 Overview of the NGSS Middle School Life Science Performance Expectation and a Breakdown of the Dimensions that Guided the Creation of the ATOD Unit

<table>
<tr><td colspan="5">NGSS Performance Expectation MS-LS1-8
Students who demonstrate understanding can:

Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.</td></tr>
<tr><td colspan="5">Dimensions</td></tr>
<tr><td>Section 1
Disciplinary Core Ideas</td><td colspan="2">LS1.A
Structure and Function:
a) All living things are made up of cells…;
b) Within cells, special structures are responsible for particular functions… ; and,
c) In multicellular organisms, the body was a system of multiple interacting subsystems…</td><td colspan="2">LS1.D
Information Processing:
Each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain, the signals are then processed in the brain, resulting in immediate behavior or memories.</td></tr>
<tr><td>Section 2
Crosscutting Concepts</td><td colspan="4">Cause and Effect:
Cause and effect relationships may be used to predict phenomena in natural systems.</td></tr>
<tr><td>Section 3
Science and Engineering Practices</td><td>Obtaining, Evaluating, and Communicating Information</td><td>Writing Scientific Explanations and Designing Solutions</td><td>Analyzing and Interpreting Data</td><td>Modeling</td></tr>
</table>

Section Layout

The layout of each of the NGSS dimensions sections begins with a brief definition and description of the focal dimension as detailed by either the NGSS or the *Framework* document. I then include a description of the facets of the dimension that were used in the ATOD unit. Next, I present instances that reflect Mrs. D's understanding of that dimension. Finally, I present instances that illustrate how Mrs. D was using the dimension in planning and teaching. In these next two chapters, and as necessary, I will reference some of the existing literature related to

various instances I note. However, I will withhold a deeper discussion of the findings for Chapter VII, the final chapter.

Section 1—The Disciplinary Core Ideas

The NGSS front matter (NGSS Lead States, 2013) state that the disciplinary core ideas are a "small set of core ideas in science and engineering" (p. 3) that, in essence, can be taught with increasing depth over the K-12 grades, are relatable to students' lives, have "broad importance across multiple sciences or engineering disciplines" and provide an essential "tool for understanding or investigating more complex ideas or solving problems" (p. 2). The core ideas span four main disciplines including physical science, the life sciences, earth and space sciences, and engineering, technology and applications of science (NGSS Lead States, 2013, Front Matter).

For this study, there were two disciplinary core ideas that guided Mrs. D during the creation of the ATOD unit. The disciplinary core ideas were taken from the NGSS middle school, grades 6-8, Life Sciences, MS-LS1, From Molecules to Organisms: Structures and Processes (NGSS Lead States, 2013). The first disciplinary core idea is titled Structure and Function (LSI.A) and it has three subcomponents, which were all addressed to some degree in the ATOD unit: a) "All living things are made up of cells…; b) Within cells, special structures are responsible for particular functions…; and c) In multicellular organisms, the body was a system of multiple interacting subsystems…" (NGSS Lead States, 2013, NP). The second disciplinary core idea, titled Information Processing (LS1.D) states, "Each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the

brain, the signals are then processed in the brain, resulting in immediate behavior or memories" (NGSS Lead States, 2013).[8] Mrs. D used these disciplinary core ideas to guide her planning:

"Just understanding the basic neuron anatomy will help them understand how addiction works."

As she planned the ATOD unit, Mrs. D was not only thinking about how to include the three NGSS dimensions but more specifically, she was thinking about the content that would represent those core ideas and really support students' understanding and ability to explain the phenomenon of the effects and consequences of drug and alcohol use. During planning she outlined some of the major core ideas she wanted students to take away from the unit. In this discussion she was thinking about the NGSS disciplinary core idea LSI, and focused on the cell membrane. Mrs. D stated:

> They were talking about the cell membrane and how it controls what goes in and out of the cell but I thought it could also be applied to how the cell membrane in the neuron is, where the neurotransmitters are released and they communicate across the synapse. Just understanding the basic neuron anatomy will help them [her students] understand how addiction works and um, the damage that can happen through the use of drugs in those neuron cells. They just destroy the neuron connections. (Interview, March 25, 2014)

Mrs. D was thinking about the NGSS core ideas and how they applied and supported her learning goals, even if they did not specifically detail which kinds of cells. Mrs. D was also thinking of other possibilities that would support students in understanding how cell membranes work and specifically how the effects of drugs and alcohol on the neuron can then have life-long impacts of drug and alcohol use. As this instance and many others will show, Mrs. D was consistent in her approach to the planning and teaching of the ATOD unit and she always

[8] A full discussion of these disciplinary core ideas was included in the *Framework for K-12 Science Education*.

focused on the phenomenon and the ways in which the science and health were intersecting and supporting one another to promote student learning.

In this next part of the discussion, Mrs. D was continuing to think about how the NGSS fit into her health content as well as the health standards the school district expected her to use. Mrs. D saw the connection between the science of drugs' effects on the neurons and brain development as something paramount for students to know in order to really understand the health and emotional consequences. The following excerpt shows she was quite adept at bringing the NGSS and health together. Mrs. D stated:

> I tried thinking about our outcomes that I wanted, the basic knowledge that I would want this health student to have as they are leaving. So, number one, know the major drug categories. I mean they have no idea. And then the brain, the neurotransmitters, how their brain is fragile and in a state of development…and then the next thing is to understand dependence and addiction and then how much your life sucks when you use drugs and get addicted. So that is the basic knowledge, and then I looked at the health standards, to be skills based. So they want big assertive strategies… I wanted them to understand the emotional, like the costs to them… the family… the ripple effect. Credible health sources, that is big in the new health standards. (Interview, March 25, 2014)

Mrs. D understood that for students to really understand and be able to explain why drugs and alcohol could be so damaging to the brain and human body they had to be presented with real-world consequences such as social consequences and familial consequences, "Your life sucks… the emotional costs to them [the students]… the family… the ripple effect". This may be what Bricker and colleagues (2014) meant when they stated, "There was a growing call in science education for the design of curricula and instruction that engage youth with personally consequential and relevant issues" (p. 1457). Mrs. D was consistent as well as thoughtful and purposeful in what and how she wanted students to engage with the science and health content. Mrs. D was consistent because she was always focused on the importance of students being able

to explain the phenomenon of alcohol and drug's effects on the brain. She was thoughtful in the way she articulated why she wanted her students to be able to understand and explain the science and health ideas, to "understand the emotional costs". Mrs. D was purposeful in that she was always thinking about how these issues also touch upon the NGSS and health standards that she was expected to cover and she showed confidence in her content knowledge of the NGSS core ideas she identified for her health unit.

From the planning discussions to the debriefs, there was never a moment that Mrs. D noted any skepticism or lack of confidence that she had a firm grasp on the content. Additionally, in my own observations during the planning and teaching of the unit, I never noted any doubts about her content knowledge. In one of the debriefs, she was discussing her thinking about the NGSS practices and I asked her, "So it's the practices? You feel like you have the content fine?" She immediately stated, "Yes" and the discussion continued related to her use and understanding of the NGSS practices (Interview, May 21, 2014). Her simple and quick response indicated, to me, that she had no doubts and was quite confident that she had the appropriate level of content knowledge to guide her students to understand and develop the skills to explain the focal NGSS disciplinary core ideas that was the focus of this science and health unit and outlined in Table 5-1.

Not only did Mrs. D report confident about her own content knowledge related to the focal core ideas, but she also expressed an understanding of the content needs of her students. During planning she decided she would use both the middle school and high school Brain Power! curricula from NIDA (described in Chapter III) to create her ATOD unit. She used portions of each curriculum that she found best met the needs of the students as well as helped her achieve the learning goals for the unit. In the ninth grade curriculum students were asked to

look at a set of CT scans and make predictions about how the brain was being affected by drugs. As she planned she realized and commented that she had to take two things into consideration if she decided to use this ninth grade CT scan activity: a) because it was the end of the school year, the amount of time she had to spend on the activity was very limited; and b) given the limited amount of time, this ninth grade activity might pose a challenge to her middle school students who would probably require more time to complete the task. As Mrs. D was thinking about all of the other activities she had planned, the time constraint, and what students would be able to do she stated:

> Let me see if I can determine on these CT scans, if I can determine the difference between them, if I can't figure it out [in a relatively short amount of time], they [the students] won't be able to either. (Interview, May 13, 2014)

The concern for her was not that the students would not be able to decipher the CT scans but thinking about her students and the amount of time she realistically had, she understood the content was going to be difficult for students to grasp in a relatively short amount of time.

Having a firm grasp of the core ideas as well as a thorough understanding of one's students is important for science teachers as they plan and teach utilizing the NGSS. A deep knowledge of the focal core ideas and the students would most certainly support science teachers in creating lessons that are thorough in their core ideas and also support students ability to gain the critical thinking skills they need to explain phenomena and as they work to design solutions to problems. Mrs. D understood and felt confident about her knowledge related to the focal core ideas, and she understood her students. Because of this dual knowledge, she was able to ascertain how she wanted to address the focal core ideas as well as the realistic needs of her students. Mrs. D chose those activities that would support students to explain the phenomenon and work

towards gaining proficiency in the NGSS performance expectation MS-LS1-8. And, equally important, she knew the time constraints would mean less time for students to gain a deep understanding of the concept (CT scan) and therefore, that particular content should not be used for her unit. Mrs. D was able to take all of these factors into consideration and make a decision about content that was appropriate for her students and her learning goals.

Summary

The instances above show that Mrs. D was thoughtful about the important science *and* health content that students need to understand about drugs' effects on the body and how those components related to the focal core ideas. Of the three dimensions, the data show that Mrs. D reported that she was most confident in her understanding and use of the focal core ideas related to the ATOD unit. Van Driel and colleagues (1998) might agree that Mrs. D had a solid level of *Craft Knowledge*. Her prior experience, or "accumulated wisdom" (p. 674) developing curriculum for pre-teens and at-risk youth as well as her work developing health education programs during her time working in the public health sector most likely helped inform the content to be included in her ATOD unit. The extensive knowledge of her students, the context in which she taught, the subject matter, pedagogy, as well as her personal background, all formed a part of her craft knowledge thus allowing Mrs. D to feel confident in her content knowledge.

Finally, a deeper analysis of her understanding of the focal core ideas may have been warranted and may have brought to light other areas around core ideas that needed support. However, because she noted that her understanding of the focal core ideas was not a stressful issue related to her understanding of the NGSS, it was not a topic that she referenced as often as the other two NGSS dimensions. To be effective in supporting students' development of critical thinking skills to be able to explain phenomena and design solutions to problems, teachers will

need deep knowledge of all three dimensions. Future studies should look in-depth at teachers' knowledge within each dimension.

Section 2—The Crosscutting Concepts

The idea of the crosscutting concepts is not new and similar language can be found in documents such as *Science for All Americans* and *Benchmarks for Science Literacy*, among others (NGSS Lead States, 2013, p. 2 Appendix G). The purpose of the seven NGSS crosscutting concepts is for students to understand that there are concepts that span both the science and engineering disciplines that can be used to illustrate unification of core ideas across and within those disciplines, and ultimately deepen students' understanding of the core NGSS ideas (NGSS Lead States, 2013, Appendix G). What is new is that in the NGSS documents, the crosscutting concepts play a significant role in creating the standards and they are woven into the performance expectations at all student levels (NGSS Lead States, 2013 Appendix G). This purposeful inclusion of the crosscutting concepts into science standards has not been seen before, nor have teachers been specifically compelled to include them in their planning and teaching. Because of the new and considerable role the crosscutting concepts take on in the NGSS, it becomes necessary to understand how teachers are experiencing utilizing these concepts in their planning and teaching.

The focal crosscutting concept associated with the NGSS performance expectation was cause and effect. According to the NGSS, cause and effect mechanisms and explanation can be explained as follows: "Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by

which they are mediated" (NGSS Lead States, 2013, Appendix G, p. 1).[9] Ideally, Mrs. D could have utilized other crosscutting concepts as she was building lessons that moved students towards proficiency in the focal performance expectation. Mrs. D ultimately focused only on cause and effect because she felt it was very important for students to understand the causes and effects of drugs and alcohol on the brain, especially the developing adolescent brain. Mrs. D stated:

> Understanding the basic neuron anatomy will help them understand how addiction works and the damage that can happen through the use of drugs in those neurons…then the brain the neurotransmitters, how their brain was um, fragile and in a state of development. (Interview, March 25, 2014)

The crosscutting concept of cause and effect can be observed throughout this discussion. First Mrs. D mentions cause and effect at the neuron level, where the students were learning about the effects of drugs on the neurotransmitters. Second, cause and effect is discussed at the developmental level, where students were learning about the effects of drugs on brain development. Third, cause and effect is discussed at the social and environmental level where students were learning about the possible effects of drugs on one's life, "I wanted them to understand the emotional, like the costs to them, you could even put this aside, maybe the individual, the family, like the ripple effect" (Interview, March 25, 2014). This is yet another example that demonstrates that Mrs. D was very clear and consistent throughout her implementation about the phenomenon she wanted students to be able to explain. That is, she was consistent throughout this study about the importance that her students needed to understand and be able to explain the science and health causes and effects of using drugs and alcohol.

[9] A full discussion of these crosscutting concepts is included in the *Framework of K-12 Science Education*.

“I Am Not Quite Sure What the Crosscutting Concept was Supposed to Do”

When Mrs. D and I first talked about creating the learning goals to help guide her planning, she seemed to understand the purpose of the NGSS practices and disciplinary core ideas as I outlined in Section 1. However, she seemed less certain about the role of the crosscutting concepts. She stated:

> That’s the content they need to know and the engineering and science practice is how you would do it (build towards the performance expectation) and the crosscutting concept, I guess is like somehow, yeah, I am not quite sure what the crosscutting concept is supposed to do. (Interview, March 25, 2014)

Although she knew the crosscutting concepts formed one part of the three NGSS dimensions, she admitted that she did not really understand their purpose. This uncertainty would not be uncommon given, as discussed previously, the crosscutting concepts have not previously been used so directly in science standards.

In a subsequent planning meeting, there was another discussion about using the crosscutting concepts as she was creating the learning goals for the unit. Mrs. D stated, “Would that be the crosscutting concept of stability and change? Or, was it cause and effect? Over time, you know, the teeth yellow, or over time, motivation was lost, so that would be cause and effect” (Interview, April 3, 2014). Mrs. D ultimately settled on the crosscutting concept of cause and effect but it’s not clear whether she understood why one crosscutting concept might be a better fit than another. It was also not clear if she understood why the crosscutting concepts were an integral part of the three NGSS dimensions or how they support the creation of the standards. Understanding the significance of the crosscutting concepts would most likely have allowed Mrs. D to make more informed decisions about which crosscutting concepts best suited her planning needs and the learning needs of her students. More probing might have helped illuminate her

thinking about and confusion with the crosscutting concepts. Unfortunately, I did not probe further and the discussion continued onto another topic. This is clearly an example of a missed opportunity for me to have gained a better understanding of Mrs. D's sensemaking process.

Interestingly, while teaching the ATOD unit, her understanding of the crosscutting concepts shifted and seemed more in line with the NGSS vision of crosscutting concepts. This change could be due in part to her participation—during the course of this study—in a half-day, school district sponsored, professional development session specifically focused on the NGSS dimensions that helped her better understand the three NGSS dimensions. Mrs. D stated:

> And the crosscutting, it was nice to hear her [the professional development leader] kind of elaborate on what you had told me and how it [crosscutting concepts] can cross between, within, within one science but then it can also overlap into the different areas of science, so different classes of science; Physical science and earth science and life science, or chemistry, physics, astronomy, that kind of stuff" (Interview, May 9, 2014).

During a subsequent debrief, there was another discussion of the crosscutting concepts and Mrs. D began describing the purpose of the crosscutting concepts as being more global and encompassing rather than simply limited to the disciplines of science and engineering. She stated:

> The 'CCC', that's helpful because there is so little time to do interdisciplinary or, what do you call it, across grade science and among the different subjects there's just very little to no planning. Or, just one day out of the whole year so you just end up chit chatting with the history teacher and maybe finding out what they're doing. But there's no requirement. They're actually trying to do something for next year centered around the election in November I guess there's um if there's issues that we can all figure out and then vote and teach and have projects about... That's big, I mean it's [NGSS was] a higher standard for sure. (Interview, May 14, 2014)

Mrs. D's impression at this point was that the crosscutting concepts encompassed a much more global idea that these kinds of concepts—patterns, cause and effect, models, etc.—were important concepts seen in many disciplines, not just science and engineering. In this instance she was thinking about the ways in which more collaboration, between disciplines and even across grades, could occur to support students to become more aware of and more active participants in real-world issues such as the election process. This view of the crosscutting concepts as a more global dimension seems to speak to the efforts of NGSS to make cross-disciplinary connections with the Common Core Standards in math and literacy. NGSS makes a very brief mention of using the crosscutting concepts in a more encompassing manner in Appendix D—"All Standards, All Students" (NGSS Lead States, 2013). However, it is unclear why this more global connection with the crosscutting concepts is not made more visible in Appendix G—Crosscutting Concepts (NGSS Lead States, 2013), in the NGSS or the *Framework*. More importantly, Mrs. D was able to see the possibility of the crosscutting concepts reaching beyond the science realm to support student learning across all disciplines.

Summary

Mrs. D's vision of the crosscutting concepts in the first two instances clearly show that there was uncertainty in her understanding the purpose of the concepts, and her thinking about which concept best represented her learning goals. Perhaps with a better understanding of the purpose and significance of crosscutting concepts, Mrs. D might have utilized more crosscutting concepts that would have worked to build student proficiency towards the focal performance expectation. However, Mrs. D's understanding of the crosscutting concepts seemed to show growth, perhaps as a result of the district sponsored professional development. Perhaps the sensemaking process about the significance of the crosscutting concepts was supported during

her participation in the professional development. The social interaction with peers and professional development coordinators may have helped her make more sense of the purpose of the crosscutting concepts. She showed a better understanding of the purpose of the concepts that moved beyond just the NGSS to include a more global idea of how the crosscutting concepts might be seen as interdisciplinary.

However, despite a clearer articulation of the crosscutting concepts, it is not clear, in the end, that she truly understood the purpose or significance of the concepts. Perhaps her uncertainty lay in an incomplete explanation or lack of concrete suggestions by either the NGSS or *Framework* documents, or in her experience in the professional development session for how to best utilize the crosscutting concepts. Both documents leave interpretation and use of the concepts in the hands of the teacher and curriculum designers. This is the first time the crosscutting concepts have been used so prominently in creating standards and they form such an integral part of the NGSS standards and performance expectations. It could be suggested that more support is necessary for teachers to understand the purpose and significance of the crosscutting concepts and how the concepts can inform teacher planning. A deeper understanding of the crosscutting concepts would ultimately help teachers support students to build proficiency in the focal performance expectation.

Interestingly, the data suggest that indeed Mrs. D was utilizing the crosscutting concepts as envisioned by the NGSS. First, her global and interdisciplinary vision of the crosscutting concepts is evident in her decision to use health as the vehicle to support student learning around the science phenomenon. Second, in the first example of this section (Section 2, Crosscutting Concepts) where she is discussing the "Understanding of the basic neuron anatomy…" she is clearly articulating the ways in which cause and effect are evident in the phenomenon. The

complication and confusion may arise from the fact that Mrs. D was simply unable to identify the crosscutting concepts.

As discussed previously, Mrs. D had attended two NGSS focused professional development sessions, one a year before this study and one during this study. During one our conversations, she commented that the main focus of the two sessions was on the practices and not the other two NGSS dimensions. It would not be unusual then, that Mrs. D's understanding of the purpose and significance of the NGSS crosscutting concepts and her ability to identify the crosscutting concepts in her planning and teaching may have been limited given her limited exposure to the concepts. Further consideration of the crosscutting concepts and Mrs. D's struggle to identify the crosscutting concepts in her practice will be taken up in the discussion chapter that follows.

Section 3—Science and Engineering Practices

The instances highlighted in this section show Mrs. D was actively working to understand how to utilize various science and engineering practices as envisioned by the NGSS. I present instances that demonstrate how Mrs. D was talking about utilizing various NGSS practices. In some instances the planning and teaching aligned well with the NGSS vision of the science and engineering practices, in other instances there was some variation from the NGSS vision. In still other instances, Mrs. D presented an interesting and alternative view of the practices in light of the NGSS revised health unit she was using. Overall, the findings suggest that multiple layers exist within the NGSS and specifically within the NGSS dimension of practices. That is, a) there are three NGSS dimensions: practices, crosscutting concepts, and content, b) those dimensions

are made up of several components: there are eight practices such as modeling, and c) those components may be further dissected into layers: modeling can be represented in many different ways, such as representations to describe an unobservable phenomena, or to predict phenomena. I argue that for teachers to utilize the practices to their fullest, teachers will need to understand these multiple layers of the NGSS practices. In this section, my aim is to illustrate instances where Mrs. D was describing how she was working to understand these multiple layers of the NGSS practices.

In alignment with the vision of the NGSS and the *Framework*, and for the purposes of this study, I use the term practices to describe practices used by scientists that "help students understand how knowledge develops and gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world" (NRC, 2012, p, 3). Mrs. D discussed using four of the eight NGSS science and engineering practices to plan and teach this health unit: (a) obtaining, evaluating, and communicating information; (b) constructing explanations and designing solutions; (c) analyzing and interpreting data; and (d) developing and using modeling. Mrs. D chose these practices because she believed they were the most appropriate practices to support the attainment of the NGSS performance expectation that guided the creation of the ATOD unit (see Table 5-1 in Chapter V). [10]

"I guess the science and engineering practices are what we could do in real life."

One year prior to participating in the current study, Mrs. D attended a two-day, district sponsored professional development event? introducing the NGSS. At the time of this professional development, California had not yet officially voted to adopt the NGSS. However,

[10] A full discussion of the practices are included in the Appendix F of the NGSS and the *Framework for K-12 Science Education*.

Mrs. D realized she would soon be expected to implement the NGSS into her own planning and teaching. She also understood the need to get acquainted with the new standards and she therefore volunteered to attend the professional development.

In one of our first discussions, Mrs. D described her experience attending this district sponsored professional development on NGSS and she described her understanding of the importance of the NGSS practices. She stated:

> I know these science and engineering practices are supposed to get students ready for the 21st century jobs and skills which they don't really have. I guess the science and engineering practices are what we could do in real life. (Interview, March 21, 2014)

Mrs. D went on to describe a video they showed at the professional development session where a young girl goes for an interview but cannot answer the questions because she has no one to pair share—share out with another person—with and she only knows how to choose an answer from a multiple choice selection. Mrs. D felt that the science and engineering practices would really help teachers better prepare students for life in the real-world, "21st Century jobs and skills," where it is not all about pair sharing and choosing an answer from a multiple choice test.

During this same discussion, Mrs. D continued to talk about about the science and engineering practices and her experience at the professional development session. Mrs. D indicated that she had been thinking about how she utilized the NGSS practices in her teaching. She was attentive to her need to make sense of how to utilize the practices as envisioned by NGSS. Mrs. D acknowledged that, of all of the NGSS practices, she utilized the practices of modeling, and analyzing and interpreting data most often in her classroom. This is important to note because, as will become clear later in this chapter, she described utilizing the practice of modeling quite often and in various ways in her ATOD unit activities. Mrs. D stated:

> I think the big one that stuck with me was the, what are the practices. These practices, that and also the engineering part too. The practices were what should be happening in the classroom and then I think everyone, I think what everyone missed doing in that room was figuring out what they do and if what they do matches what they (NGSS) want. I think the big one that I like to do is analyze and interpret data… and models. (Interview, March 21, 2014)

In our discussions, Mrs. D focused a lot of thinking around the science and engineering practices, both in the selection of the practices and how these practices would best serve her learning goals and the learning needs of her students. The instances illustrate Mrs. D was not only attentive to the idea that she was utilizing the practices, but also mindful about whether the way she was using the practices aligned with how NGSS wanted teachers to implement them.

"But I am just trying to see where that would be pulling in NGSS [practices]."

During one of our planning discussions, Mrs. D was looking at her proposed unit plan and talking through what she had planned. For one of the days, she wanted students to make a time-chart that depicted the effects of both cigarette and marijuana use over various periods of time. She stated:

> So, first time, after a while, and after a long time. I am just looking at lesson 2 of Project Alert and then they watch the video Pot; The Party Crasher, and it looks like I want to do something with claim, evidence, and reasoning. So that and more of the citing of the resources, so that seems like that would be interpreting the data. (Interview, April 3, 2014)

This excerpt shows some of her feelings of uncertainty in deciding which NGSS practice fits the lesson. In the beginning of the discussion she wanted students to use the practice of writing scientific explanations, but at the end of the discussion she suggested the practice of analyzing and interpreting data. From this portion of the discussion it was unclear why she mentioned the two practices at once.

Throughout her unit, Mrs. D refers to scientific explanations as CER. CER stands for claim, evidence, and reasoning and refers to the framework developed by McNeil and colleagues (2006). Their CER framework was created specifically for middle school teachers and students because they saw a need to make scientific explanations more accessible to this group of teachers and learners. They utilized the Toulmin's (1958) model for argumentation as their main model. According to McNeill and colleagues (2006):[11]

> The claim is an assertion or conclusion that answers the original question. The evidence is scientific data that supports the claim. These data can come from an investigation or from another source such as observations, reading material, or archived data. The data need to be both appropriate and sufficient to support the claim. The reasoning is a justification that shows why the data count as evidence to support the claim. In the reasoning component, we encourage students to articulate the logic behind why they believe the evidence supports the claim, similar to Toulmin's warrant. Furthermore, students may need to back up that link between the claim and evidence by including the appropriate scientific principles, similar to Toulmin's backing (p. 158).

Mrs. D utilized the language of the CER framework outlined by McNeill and colleagues (2006). However, as I will point out in Chapter VI, Mrs. D did not always utilize the CER framework as envisioned by the group or how it is currently utilized in science education. The fact that Mrs. D did not always utilize the CER framework as envisioned by the creators of the CER framework is interesting and important because it adds support to the findings of this dissertation that teachers will most likely need better support to fully understand the NGSS practices.

[11] For more in-depth information regarding the CER framework, I would advise referring to the McNeill and colleagues (2006) article referenced here. Or, more recently you may refer to the McNeill and Krajcik (2012) book, *Supporting Grade 5-8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talking and Writing*.

Further into the discussion, we gained a better understanding into her thinking about using the two practices as she outlined a few days' activities. She stated, "…So, Monday it starts the lesson and we do ground rules… And then the next part, Wednesday, claim, evidence, and reasoning…" I asked her about the placement of the claim, evidence, and reasoning (CER) activity and she stated:

> I have it on May 1st. Looks like I have first time, after a while, after a long time so I guess they could do it [CER, scientific explanations]; take some of this [students' online drug resources] and figure, like find evidence for it [their claim]. (Interview, April 3, 2014)

I then asked if the practice might be creating scientific explanations and Mrs. D took a few moments to look over the different NGSS practices. She seemed to be troubled by the engineering piece of designing solutions that accompanies the practice of writing scientific explanations. Clearly, more probing was necessary to really get at what was troubling Mrs. D and why. Unfortunately, the discussion continued without me taking note of the significance of her pause and I missed the opportunity to probe further.

The discussion returned to claim, evidence, and reasoning. There was a shift and Mrs. D began describing how students were using and evaluating their online drug resources as in the NGSS practice of obtaining, evaluating, and communicating science information (See section 3.7 below). The discussion then mentioned the practice of analyzing and interpreting data and how students were making a chart of the short and long-term consequences of cigarette and marijuana use. The final piece of the discussion turned back to the practice of obtaining, evaluating, and communicating science information. She stated:

> So let's go back to the lesson. So claim, evidence, and reasoning, what they're going to do is take their Google results and put them into a first time, after a while, after a long time chart for cigarettes and marijuana. So we're kind of tweaking Project Alert to, it gives them practice on learning their Google search results back from what they have to do for their homework… and they'll put them on the chart and we'll bring the issue of time so they understand short term consequences and long term consequences. But I am just trying to see where that would be pulling in NGSS [practices], it seems that it would also be analyzing and interpreting data because it's, their evidence is a scientific study on marijuana and health, then they have to analyze and interpret data, right?... and also gather and obtain again too; obtain, evaluate, and communicate science information. (April 3, 2014)

In this instance, she seemed to be grappling with three different NGSS practices: a) scientific explanations, b) analyzing and interpreting data, and c) obtaining, evaluating, and communicating science information. The discussion demonstrates the ways in which Mrs. D was working through the complexities of the NGSS practices, trying to ascertain the best fit of the NGSS practice for her activities that would support the learning she wanted for her students. The discussion also shows that there might have been multiple practices that occurred to support the learning goals Mrs. D set forth for her students. More clarity about the nuances and affordances of each of the NGSS practices would likely have helped Mrs. D make a more confident decision about which practices best suited the goals of the ATOD unit and supported student learning.

In another instance, Mrs. D was talking through an activity where she wanted students to create a Public Service Announcement (PSA) about using drugs and alcohol and she offered her thoughts on how the CER framework would fit this activity. Mrs. D stated:

> Because the PSA activity would fit in, um, with constructing explanations and designing solutions. Well, because their PSA should talk about the dangers of drug addiction and explain how it hurts you and can hurt your life and hurt others so which one would that be? Obtaining, evaluating, and communicating information? (Interview, April 10, 2014)

As with the previous instance, Mrs. D was working through various NGSS practices; in this case she mentioned the practices of writing science explanations and designing solutions, and obtaining, evaluating, and communicating science information. Mrs. D was clear that the science phenomenon that students needed to explain was the effects of drugs and alcohol on the brain. Further, she wanted students to be able to explain how the dangers of alcohol and drug use not only had neurological consequences but other physical and social implications as well. Mrs. D seemed to want her students to use the practice of writing scientific explanations to attain this goal but then she suggested the practice might also be obtaining, evaluating, and communicating science information.

The discussion continued and I responded to Mrs. D's question that it depended on how she was thinking about constructing the learning goal and ultimately the activity. Mrs. D responded:

> They're finding a solution but it's not an engineering solution, it's more a social solution… I'm thinking what they meant by designing solutions because they are trying to think of science and engineering, trying to get us to be more problem solvers. (Interview, April 10, 2014)

The engineering portion—designing solutions—posed an interesting challenge and she envisioned the students designing social solutions but she feared that might not be what NGSS envisioned as *designing solutions*. However, I would posit that her *social solution* was indeed *designing a solution*, and an important social solution. Although not explicitly discussed in the

NGSS Appendix F, Science and Engineering Practices in the NGSS document, designing social solutions seems to be taken up in the NGSS Appendix J, Science, Technology, Society, and the Environment. Appendix J indicates that teachers can help students become more engaged in science and engineering when they work to make connections between home, community, and schools. NGSS Appendix J suggests connections can be made through "engaging students in defining problems and designing solutions of community projects in their neighborhoods (typically engineering)" (NGSS Lead States, 2013, Appendix J, p. 3). Ultimately, she did not use the Public Service Announcement activity but instead created a final group project that retained some of the Public Service Announcement characteristics. In this instance, Mrs. D brought up interesting possibilities for the use of *designing solutions*, a possibility that perhaps other teachers would also think about. The challenge would be helping teachers to understand that designing solutions can take on many different forms, from a focus on engineering design to designing solutions that are socially situated. Again, the point goes back to the need for teachers to be able to understand the three NGSS dimensions on multiple levels.

Mrs. D first talked through which practice to use, thinking about how to include both the science and engineering pieces of the practice into her planning. She had a clear vision of what she wanted students to know and be able to do but she was unsure if her thinking was really in line with the NGSS. Mrs. D seemed to struggle for more clarity about what the practices entail in order for her to feel confident about which practice(s) or portions of the practices she was utilizing.

During the teaching phase Mrs. D again referenced the Claim, Evidence, Reasoning framework along with the practice of gathering and analyzing data. In the following excerpt she was debriefing ATOD Day 4 and she was answering the question of whether or not she was able

to see the three NGSS dimensions in her teaching that day. She stated, "…the science and engineering practice which was exactly what we're doing which was analyzing data and gathering it and organizing and analyzing the data. That's exactly where it all came together in filling out the CER worksheet" (May 9, 2014). For Mrs. D, students were applying two NGSS practices: 1) gathering and analyzing the data they collected from online resources about drugs' effects on the brain; and 2) organizing that information into the practice of scientific explanation through the use of the Claim, Evidence, Reasoning model. Mrs. D seemed to be working through her understanding of the practices, how they might be working in combination, and trying to determine which practice best suited her learning goals.

Mrs. D's use of multiple practices recalls the discussion in Chapter IV where I presented work by Krajcik and colleagues (2014) and Bell and colleagues (2012, referenced in the NGSS Appendix F). Both groups of researchers concluded that in order for students to attain proficiency in the performance expectations, it is likely that teachers will need to draw from multiple dimensions and practices. As the data have shown throughout this chapter, Mrs. D, as an experienced and motivated teacher, understood the need to utilize multiple dimensions. The struggle for her seemed to come with the idea that she was not clear if that is what NGSS really wanted teachers to do. This uncertainty suggests that teacher support should be clear in its encouragement to utilize multiple dimensions to address the performance expectations.

Up to this point, I have presented data that describe how Mrs. D was making sense of each of the three NGSS dimensions. Mrs. D reported she was confident in her understanding of the core ideas. Mrs. D noted uncertainty in her understanding about the significance and aim of the crosscutting concepts as they related to the NGSS. And, she sometimes struggled to determine which NGSS practices best fit her learning goals, even though utilizing multiple

dimensions would have been recommended (e.g. by Krajcik et al., 2014 and Bell et al., 2012, referenced in the NGSS Appendix F). The discussion moves forward, in the section that follows, and I will present data that focuses on how Mrs. D was talking about and utilizing of one particular NGSS science and engineering practice: modeling. The data show that although Mrs. D sought to create modeling activities to support students to develop a deeper understanding of the phenomenon of the effects of drugs and alcohol on the brain, she demonstrated a limited understanding of modeling as envisioned by the NGSS.

Multiple Layers to the Dimensions; Four Ways to Explain Modeling

Modeling is one of the eight practices of the NGSS dimension of scientific practices. Modeling itself is also a practice with several sub-components. There are several ways NGSS hopes teachers and students will appropriate the use of models: as representations that help describe unobservable phenomena, to help predict phenomena, to explain phenomena, to help generate data (NGSS Lead States, 2013). Interestingly, during this study, Mrs. D described using the NGSS practice of modeling in four different ways. However, although she described modeling in four different ways, the instances presented here illustrate how Mrs. D's appropriation of modeling more closely embodies *representations*. While models as representations are a vital part of science learning—they provide an important visual example of otherwise unobservable phenomena—they are limited in the kind of learning they can support. The intent of NGSS is that modeling as a practice should embody much more than just a physical replica of the science to be explained; the NGSS encourages teachers to use models as a way to support students to develop the skills to explain phenomena. Representations serve as the very beginning point of the practice of modeling. Although Mrs. D's intent may have been to use

modeling that was more in line with the NGSS vision, she seemed to be using modeling in limited ways that suggested a more novice level understanding of models.

The instances below suggest that perhaps with more awareness of the various uses of models, Mrs. D could have broadened the way in which she used modeling activities to include different interactions with models—such as using the models to predict the phenomenon related to drug's effects on the brain—and beyond their use as representations. For example, according to Appendix F—Science and Engineering Practices in the NGSS (NGSS Lead States, 2013), models and model building should take on the following properties: "Students can be expected to evaluate and refine models through an iterative cycle of comparing their predictions with the real world and then adjusting them to gain insights into the phenomenon being modeled" (NGSS Lead State, 2013, p. 6). With these ideas about modeling in mind, I present the four instances of modeling as described by Mrs. D. To clarify, I will use "modeling" to signal when I am describing instances of Mrs. D's interpretation of modeling because her description did not always represent the full intent of modelling as envisioned by NGSS.

First Instance of Modeling—Diagraming Drug Groups

In this first modeling instance, Mrs. D asked her students to manipulate a set of drug cards to create a visual diagram or "model" that was intended to represent the students' understanding of the different kinds of drugs and the drug groups to which they belong. Prior to this activity, students had been learning about the different kinds of drugs and the different drug categories. In this activity, Mrs. D wanted to see that students could, in groups, accurately identify and categorize the different drugs they had been learning about. The students would demonstrate their understanding by creating a visual diagram or model of how they understood the different drugs and drug categories. Classroom video and observation data show that during

the course of the activity students were first asked to work in groups and discuss how they were organizing the groups and drugs. Each group then shared their group's answers and as a class they discussed the appropriate category for each drug. In our debrief discussion, I asked her if she considered the card activity as a practice of modeling. "Yes," she stated and specifically the "modeling" was diagraming. The conversation then turned to another topic and I did not ask any follow-up questions about why Mrs. D considered the card activity as creating a "model" through diagraming.

Further probing would have been helpful to illuminate Mrs. D's thinking about the diagraming activity as "modeling". Mrs. D seemed to imply that she was thinking about the use of cards as a model that helped students manipulate science vocabulary and create visual diagrams. One way that Mrs. D might have been able to bolster the "modeling" activity to better align with the NGSS vision of modeling would have been to create opportunities for students to revise and explain the diagram to one another or to someone else outside of the class. It was not evident from our brief discussion about the activity or classroom video and observation data whether students were given the opportunity, at a later time, to revise or explain their diagram/model as a way to support the knowledge building of drugs and their corresponding drug groups.

However, I would argue that one part of the activity did embrace one of the other NGSS practices. In-line with NGSS practice of communicating science information, this activity could have been seen as one way that helped students communicate their ideas about the ideas with one another and with the teacher (NGSS Lead States, 2013). As they worked in groups to create their drug "model" students were actively involved in discussing and communicating science information amongst one another.

Second Instance—Creating Physical Models of the Neuron

During planning, Mrs. D worked to organize her new anti-drug health unit to include important science and health content. She used pieces of the Project Alert health curriculum as well as portions of the National Institute on Drug Awareness (NIDA) middle school and high school anti-drug curriculum called Brain Power!. From the middle school Brain Power! curriculum, she initially wanted to use the activity where students create a neuron game to help students understand the various parts of the neuron as well as how the neurons function to send messages to each other. In the planning discussions below Mrs. D was talking through her lesson and thinking about which practice would be represented in this lesson. Mrs. D stated:

> Although I guess it's developing and using models… they are creating games. …They'll have to create the synapse space so that's the model, and they'll have to explain how that neurotransmitter gets across. …They're doing the board game that shows the process of neurotransmission, covering all the major processes of neurotransmission. …So the game that they design will be an example that they are creating a model, an actual physical thing. … [To describe how] neurotransmission occurs or to describe the structure and function of neurotransmission, how that occurs in the brain. (Interview, April 10, 2014)

Mrs. D's planning demonstrates that she had a desire for students to create something physical to help them understand the various parts of the neuron as well as helping them understand how neurons communicate and pass messages throughout the body. She stated that she wanted students "to explain how that neurotransmitter gets across…" there was an interest in providing students the opportunity to discuss the models so they could form a deeper understanding of how neurons function. This description of the use of models would be in-line with the NGSS practice of developing models as "…physical replicas…used to represent a system, to aid in the development of questions and explanations" (NGSS Lead States, p. 6 appendix F). She referred to the board game being "an actual physical thing," she wanted students to be able to touch the

neuron to help them understand the different parts. She explained what she wanted students to get out of the "models:" "to describe the structure and function of neurotransmission". Although, due to time constraints, Mrs. D was unable to include the board game, the discussion above indicates that she understood the need for students to be able to create models to help them *see* and explain unobservable mechanisms and phenomena. Although perhaps this shows beginner knowledge of the practice of modeling, I would argue that this line of thinking by Mrs. D was indeed in line with the NGSS vision for the practice of model building. This example further implies the need to create opportunities that ensure teachers develop a deeper understanding of the NGSS practices in order to utilize the practices in a way that more fully corresponds to the intent of the NGSS.

Instead of the board game, students created physical models of neurons at home and they later brought them in to share. Mrs. D talked about students creating models so they would have something physical to help them understand and explain the neuron and its parts. I asked her about the neuron model assignment and she stated:

> Yes, I wasn't planning on that but then I just thought gosh let's get them doing something, like they need to make something with their hands so that they understand this neuron and it has like some concreteness cause like I can hold my hand up a million times and do cell body. (Interview, May 20, 2014)

I then asked if the neuron building assignment was the practice of model building and she confirmed, "Yes, they are model building" (Interview, May 20, 2014). This sentence echoes her previous sentiment that students could create something physical to help them understand and explain the parts and function of the neuron. Building the physical representation was "modeling" to Mrs. D so that students could "make something with their hands so that they understand this neuron…" According to NGSS, the neuron model by itself would not fully

represent the intent of modeling because students were not asked to use the models to explain anything.

On the day the neuron models were assigned to be turned in, Mrs. D had students participate in a gallery walk; students and the teacher walked around the room and admired and commented on the neuron models. In the classroom video and observation data, students can be seen explaining what the different pieces of their neuron model represent. Students created neuron "models" from all manner of home supplies; from pipe cleaners and plastic wrap, to pasta noodles and licorice pieces (See Figure 5-1). Students were visibly proud of their models as I observed from their smiles as they shared their models with friends and classmates. These physical representations of the neurons did support the goal of creating models of unobservable mechanisms as envisioned by NGSS. However, Mrs. D's vision of the neurons as "models" would fall short of the NGSS intent because students were not really asked to use the neurons for more than just physical visual representations.

Figure 5-1 Pictures of Neuron "Models" Created by Mrs. D's Students

Mrs. D understood the need for students to have physical models of these unobservable mechanisms as she described here when I asked if she had been thinking about the three NGSS dimensions when she planned this neuron building activity. She stated, "Well, the modeling part

for sure." She continued to describe how the model could support students' understanding of neuron structure and how neurotransmitters work, and ultimately neurotransmitters' connections to drugs effects. Mrs. D stated:

> Yeah, for sure because if they can get that basic understanding of what the cell (neuron) is through the model then we're, that will be, get us so much closer to then moving on and learning about neurotransmitters. There are just so many new parts with new names and it's hard. (Interview, May 20, 2014)

Mrs. D described why it was so important for students to be able to put these pieces together and she recognized the difficulty students might encounter trying to understand all of the pieces and functions of a neuron; creating physical models was one way to support student understanding of this complicated idea. Mrs. D was able to articulate the path towards model building that she envisioned for the students and their neurons. In the conversation above, Mrs. D is showing the beginnings of a deeper understanding of models as more than simply representations as in the first example with the diagraming. However, in the end, many familiar with modeling and the NGSS practices would argue that the neuron models the students created in Mrs. D's class—although very creative and beautiful—were simply representations.

Third Instance—Hand and Arm Model of Neurons Communicating

During planning, Mrs. D described learning about the hand and arm "model" as a way to demonstrate neurons' structure as well as representing how two neurons communicate with one another.

> I saw in a conference to do the neurons like this (putting up her arms to connect her left elbow to her right hand), axon to dendrite then axon to dendrite. So that is how we send the signal that like 'oh look there is a scary dog barking at me, should I run should I say…', you see it with your eyes and that is how the message gets sent. (Interview, April 10, 2014)

She talked about wanting to introduce this "model" to students when she taught the unit. Similar to the physical models students built as described in the second instance of "modeling", the hand and arm "model" was another physical model of an unobservable mechanism, neuron structure and function.

In the classroom, Mrs. D introduced the hand and arm "model" to the students on ATOD Day 5. During the debrief of that day, Mrs. D once again identified the hand-to-arm neuron as a "model" when she stated:

> So, yeah, with the hands they were using the hands to make a model of the brain so they understand the different parts of the nervous system and the other model are the pictures of the brain that I gave them" (Interview, May 14, 2014).

And, further into the discussion, she elaborated on the important content she wanted students to understand in using the hand and arm "model." Mrs. D stated:

> I think if they can identify how signals are sent through the brain that are electrical and chemical they understand that as the electrical charge flows from one neuron to the next neurotransmitters are released they bind to receptors on the other dendrites and then, oh that's another model. The finger to the elbow and the dendrites cell body axon, and that's how the message travels. (Interview, May 14, 2014)

Mrs. D thought it was important for students to experience multiple representations of the neuron structure and function, by creating "models" and by using their own body to represent the neurons. This kind of thinking shows Mrs. D displayed good teaching practices by presenting the science and health ideas through multiple representations. Classroom video shows students were engaged in the activity and talking with one another as they created the arm and hand model. My observations suggest this was an engaging, easy, and effective visual representation or analogy

of a neuron. However, in the end, the use of the hand-and-arm "model" would not be considered modeling by NGSS because it did not give students opportunity to explain any phenomena.

Fourth Instance—Cartoons as Models

Mrs. D was constantly working to revise and improve her unit, even while she was teaching the unit. Here, Mrs. D was working to revise her plans for the final ATOD assignment. Initially, she had been thinking about having students present posters about each drug type and how it affects the brain and ultimately memory and behavior. She had previously had students work on these kinds of group activities and, by her own admission, she and the students seemed to enjoy the group work and group presentations. Mrs. D first discussed her plans for the final project during initial planning in Phase I.

She described some of the NIDA middle school drug curriculum activities she was thinking of using; one of those activities asked students to create a poster. Consistent with her planning and thinking throughout the entire study, the following discussion also demonstrates that she was actively thinking about how to utilize the materials, in light of the NGSS. Mrs. D stated, "I am trying to think of engineering practices. Although I guess it's developing and using "models" if they are creating posters" (Interview, April 10, 2014). Further probing, might have illuminated why she thought the posters were models, although perhaps it was again the idea of creating the poster as something physical or visual to represent this unobservable mechanism of the neuron process.

Mrs. D continued to refine and revise this poster lesson so that it ultimately became a cartoon that groups would create as their final ATOD activity. During the exchange below, which occurred during enactment, she talked through the revised poster/cartoon assignment as

another way of “modeling”. Mrs. D explained several things below: first, she described how she would be doing more “modeling” when her students were put into different drug groups. Second, I then asked her why she thought this was an example of “modeling” and she talked about the change from the poster lesson to the cartoon. At the end of the dialogue, she continued to elaborate on the cartoon lesson by providing a detailed explanation of what she envisioned for this cartoon assignment. Mrs. D stated:

> I think we’re definitely going to be doing more modeling, especially with the drug groups that we’re going to break into.…So I was thinking originally a poster to describe what happens at the neuron. But then I read somewhere the idea of doing a cartoon. That would be neat, like a cartoon that shows what is happening at each step of neurotransmission and how the drug affects it. So like cocaine, you would show the normal neuron in the first (step),…step two will be the neurotransmitter being released at (step) three you introduce the drug, step four is the end result and then they have to list like the long term effects of the drug. Wouldn’t that be kind of cool? I could totally see big cartoons. Each cartoon window is like this big picture, a little bigger than a piece of paper. (Interview, April 10, 2014)

Similar to how she described the poster activity during the planning phase, Mrs. D related the cartoon activity to the practice of “modeling.” It seemed from her explanation the cartoon was a “model” because students were creating physical and visual representations of how neurons function both normally and under the influence of drugs and alcohol. The discussion above reveals that her understanding of “models” contained some of the NGSS modeling dimensions: a) Developing or modifying a model to match what happens if a variable or component of a system was changed. In the cartoon, students were asked to show how a normal neuron functions and then how a normal neuron functions when a drug or alcohol was added, thereby adding a variable; b) The cartoon “model” could have been developing a model of simple systems, how neurons communicate with one another and how that system was disrupted when a drug or

alcohol was added; c) In a sense, the cartoons were asking students to show the relationship among the variables: how do the different parts of the neurons work together and how is their function and relationship affected when drugs and alcohol are introduced to the system; and d) The "model" was certainly being used to describe an unobservable mechanism of how the phenomenon works, how neurons function and communicate with and without drugs and alcohol. However, the cartoon may have been missing other similarly important facets of model use as suggested by NGSS; evaluating limitations of the model, revising the model to reflect new understanding of the model, and utilizing the model to generate data and test ideas were facets that were not readily visible in the cartoon activity.

In each of these four modeling instances, we get a sense of what Mrs. D's rationale was for using models to support student learning. Although this study was not a study of change over time, we do see that perhaps how Mrs. D is talking about modeling does seem to change over time. In essence the examples show she is moving towards a more NGSS aligned vision of modeling. The instances demonstrate that Mrs. D had an understanding that models could take on several different forms and could be used to understand various facets of a very complex idea. These instances also illustrate the multiple levels of knowledge we are asking teachers to have around the NGSS dimension of practices. Teachers will benefit from having a deeper knowledge of these levels and the possibilities of uses for the NGSS practices. Without a deeper understanding of these multiple layers, using models, for example, as envisioned by NGSS, might pose a challenge to science teachers, even more expert teachers like Mrs. D.

Perhaps support for how to further utilize these physical representations to maximize their learning potential would be helpful for teachers like Mrs. D who have the foundational understanding that physical models do help learners understand unobservable mechanisms and

explain phenomena. But teachers will need more support and examples of exactly how to maximize the use of representations so that they align with the intent of the NGSS. In Krell and Kruger's (2015) study of teacher knowledge around models and modeling, they found teacher knowledge to be quite limited, similar to findings by Van Driel and Verloop (1999). Justi and Gilbert's (2010) study also found similar results. Further, Justi and Gilbert (2010) found that even teachers with a scientifically acceptable view of, and a high level of understanding about models and modeling did not mean they understood how to *use*, or the *importance of*, models and modeling in science education. The findings here add to these studies' (Justi & Gilbert, 2010; Krell &Kruger, 2015) suggestions that creating support to help science teachers understand the importance of and ultimately utilize the practice of modeling to its fullest would be wise given that models and modeling are important tools and an integral part of understanding science and the natural world.

Summary

This chapter presented the various ways in which Mrs. D was thinking about the three NGSS dimensions and her level of confidence working with each one. Overall, findings of this chapter suggest there are multiple layers or levels of teacher knowledge that will be necessary to successfully implement the NGSS. Teachers will need to know that the NGSS consists of three dimensions—core ideas, crosscutting concepts, and scientific practices—at the simplest level. Subsequent levels of understanding are going to require professional development that supports teachers in more deeply understanding what each of those dimensions entails—components and sub-components—and how to effectively implement those dimensions in a way that supports students development of critical thinking skills to be able to explain phenomena and design solutions as envisioned by the NGSS performance expectations at each grade level. I refer you to

the discussion chapter for a more comprehensive deliberation about these findings and how they are in conversation with the literature and add to the science education community's dialogue on teachers implementing the NGSS.

As I noted in the introduction chapter, it was critical to report Mrs. D's experience fully implementing the NGSS, both her planning and teaching with the NGSS. I have attempted to do that in this chapter by including Mrs. D's dialogue of how she was describing and experiencing each of the three dimensions. The next chapter, Chapter 6, is the second findings chapter and I continue to report Mrs. D's full implementation of the dimensions. I present various instances where Mrs. D was describing the three dimensions being *woven* (coming together is the term we used in the study) in her planning and teaching and how that *weaving* (coming together) of the dimensions eventually presented itself in her teaching through contextualization.

CHAPTER VI
COMING TOGETHER AND CONTEXTUALIZATION

Chapter IV established that I would use the terms coming together and bringing together purposefully. I chose to use these terms to describe instances, during our discussions, where Mrs. D identified the three NGSS dimensions were all present and working collaboratively. The NGSS state that the three dimensions working together help to deepen students' knowledge related to phenomena and ultimately, help students gain proficiency in a NGSS focal performance expectation. I will present instances which show the three NGSS dimensions coming together during one class time and I also present findings that show the three dimensions do not always come together in one instance (one class session) but that coming and bringing together also takes time to develop. While some in the science education field might disagree, I will argue here that coming together will not happen every day and in every lesson, but rather it will most likely be a process that occurs over time.

To confirm these instances where Mrs. D identified the three dimensions coming together, I looked for and present evidence here from the classroom observations as well as the classroom video and student work. In some instances, the three dimensions came together in one day's lesson. In other instances that I present, the findings suggest Mrs. D described the three dimensions came together as a process, occurring over the course of two or more days. Finally, and of equal interest and significance, I identify and present various instances where Mrs. D was working to bring the three NGSS dimensions together through contextualizing the science and

health core ideas as it relates to students' lives around the issue of the effects of drugs and alcohol use on the brain. I further elaborate on the term contextualizing below.

Contextualization to Support Student Learning

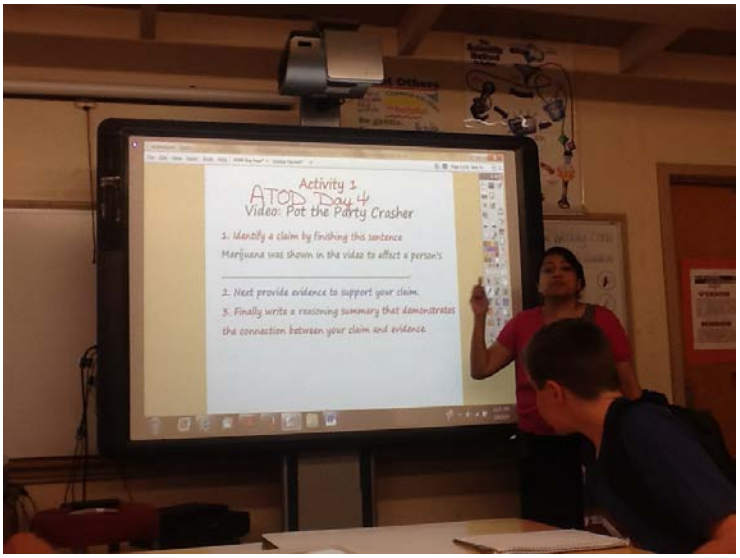
In Chapter IV I referenced Sadler's (2009) definition of socio-scientific issues which he sees as presenting science issues from both a professional scientific perspective (concepts and procedures) as well as a social perspective (issues that directly impact students' lives). Additionally, similar to Zeidler and colleagues (2005), I purposefully use SSI versus the term Science Technology and Society (STS) because, in my opinion, SSI more accurately reflects how Mrs. D approached contextualization in her ATOD unit as a way to help her students develop ethically and morally and to show that science and society are interdependent. Therefore, for this study, I use the term contextualization to describe the science classroom practice of using socio-scientific issues as a way to engage students in the science ideas. Specifically, for this dissertation, contextualization was the way in which Mrs. D utilized the various NGSS dimensions in concert with current social and health issues to support students' development of critical thinking skills to be able to explain the phenomenon related to the effects of drugs and alcohol on the brain (neurons). Current health and social issues involved ideas that Mrs. D believed were relevant and engaging and helped her students develop ethically and morally around science and health issues related to the effects of drug and alcohol use on the brain. Through contextualization Mrs. D aimed to demonstrate to her students that science and society were interdependent and could directly impact their lives. In creating lessons that endeavored to bring the three NGSS dimensions together, Mrs. D presented conceptual and procedural connections to science around social issues that she believed were significant to her and her students. Thus, in addition to an awareness of the ways in which the three NGSS

dimensions were coming together in her teaching, Mrs. D showed awareness of the importance of and ability to contextualize the science for her students. That is, she presented different real-world examples about drug and alcohol use that she believed were relevant and interesting to students, in order to help students better understand: a) the science of neurons' structures and functions within in the brain; b) how drugs and alcohol affect the neurons of the brain; c) how by being more informed about the science and health core ideas, students can make more informed decisions about drugs and alcohol; and finally 4) some of the NGSS crosscutting concepts (i.e. cause and effects) and practices (writing scientific explanations and modeling). The excerpts presented in this chapter stand out because they are exemplars of how she was thinking about helping students understand the consequences of their decisions. Mrs. D wanted them to think about the consequences not only from a science and health perspective, but equally important through issues she believed students were interested in and could relate to.

A Typical Day of ATOD Enactment

Classroom video and observations during the study showed that each ATOD day typically began by presenting and discussing the learning goal that would support the day's activities, followed by various activities. Some days, because of time constraints or because activities from the day before have taken longer than expected, it was necessary to extend the class time spent working on activities associated with one learning goal to the following day. Figure 6-1 shows Mrs. D working with students to write a scientific explanation using the Claim, Evidence, Reasoning (CER) framework.

Figure 6-1 Mrs. D in the classroom, working on writing scientific explanations



"I think it [NGSS] is such a huge challenge because it is so complicated."

As noted previously, this was Mrs. D's first attempt to integrate the NGSS into her planning and teaching. She did not use a curriculum specifically written with NGSS in mind; she utilized her existing health curriculum as a starting point. Mrs. D recognized the complexity of the new standards and weaving the three dimensions. She acknowledged the concern that she and other science teachers would be held accountable through student testing associated with these new and complicated science standards. She noted the challenges in one of our debriefs:

> I think it's [the NGSS] such a huge challenge because it's so complicated. Because instead of just one standard, there's this one standard and there's three parts to the standard and now holding teachers accountable for engineering and science practices. I think we're [science teachers in general] definitely trying to do that [use the three dimensions in their practice], but to actually name it and now hold teachers accountable, that's a whole other ballpark…That's big, I mean it's definitely a higher standard. (Interview, May 14, 2014)

While she was not shying away from the new standards, she recognized the need for more support to implement them as they were envisioned by the NGSS creators. When I probed further and asked what she meant by "higher standard," Mrs. D recognized the changes the NGSS were asking for: more in-depth coverage of the core ideas and practices, a new focus on science *and* engineering, and, finally, the inclusion of the crosscutting concepts.

Mrs. D also understood the importance of these changes to better prepare students for their own future endeavors. And, she was cognizant of her various roles and responsibilities as a teacher and science chair; the need to support both the students' understanding of what was expected of them as well as thinking about the ways she might have been able to support her fellow teachers in understanding and implementing the NGSS more effectively. Mrs. D stated:

> Based on the 1989 science standards, these are totally different. I mean these [the NGSS] are, it's the same material but it's so much more in-depth. But then it's adding elements about engineering and the crosscutting concept. So, I mean, I get the point, I mean it definitely makes sense we are preparing our students for it. In my mind, I am thinking about what could I put around the room… it would be so helpful to have it [NGSS dimensions] and keep going back to it and pointing it out to students… throughout the year. … And then also thinking… how I would do a PD [professional development session] for a team of science teachers… because I'm the science chair for next year. (Interview, May 14, 2014)

It's also important to note that, at the time of the study, the NGSS had just been adopted by the state of California and teachers were not expected to implement the NGSS into their teaching. Mrs. D was attempting to do this challenging and complex work without having received a lot of professional preparation. In both excerpts above she acknowledged some of the challenges she and other teachers were going to face in implementing and integrating the NGSS into their practice. The instances that follow show Mrs. D was taking on this challenge as a professional, and working to understand how these three dimensions might come together in her planning and

teaching. The instances also show she was working to make the information accessible to students through the ways she contextualizes the science and health core ideas.

Presentation of the Findings for ATOD Days 3-6

I have purposefully chosen four sequential days of the nine ATOD days[12] to represent the various instances of coming together and contextualization; each day includes her thoughts about coming together as well as contextualization. The data come from the planning and debrief interviews as well as video transcripts and classroom observations. The selected days present the most complete instances of Mrs. D articulating how and where she saw the three dimensions coming together, and how she described contextualizing the unit. Complete days meaning there was enough evidence in both the planning and teaching to tell a more detailed account of her thinking about contextualization and the three dimensions coming together. See Appendix A for a calendar of the daily ATOD activities, lesson goals, dimensions covered.

ATOD Day 3

This section presents a description of coming together and contextualization as it occurred on ATOD Day 3. The ATOD Day 3 instance—as I observed and is described by Mrs. D in the debrief—suggests that coming together could occur as a teacher led activity. The findings also show how important contextualization was to Mrs. D around this important science and health ideas.

[12] Although there were technically eleven instructional days, days nine, ten, and eleven were essentially the same because student were presenting their final projects.

ATOD Day 3 began with students showing Mrs. D their completed homework so they could receive credit. The learning goal for that day's activities was on the Promethean board.[13] Once homework was checked, students were directed to take out their health journals so they could begin the day's lesson by discussing and writing down the day's learning goal. ATOD Day 3's learning goal was: *Students will analyze and interpret data about drug effects (short-long term) that describes how drug consumption affects behavior and memory*. Mrs. D utilized the Claim, Evidence, and Reasoning (CER) framework to determine what students would be able to produce as they worked towards the ATOD Day 3 learning goal of analyzing and interpreting data. Mrs. D wanted students to analyze and interpret the data from an online article that she had chosen, and then write a scientific explanation based on their analysis. This was the students' first introduction to scientific explanations in the form of the CER framework. As Mrs. D passed out the worksheet she reminded students that they would practice the CER framework first as a class and then they would be expected to try out this form of scientific writing on their own using the drug articles they found online for homework on ATOD Day 2. She explained to the students that they would analyze and interpret through the CER framework because "this was how science writes" (video transcript, May 7, 2014). For the disciplinary core idea she explained that they would learn about drug consumption and its effects on the brain, and how neuron functioning is affected after exposure to drugs (marijuana). Finally, for the crosscutting concept, she explained they would also discuss how drug use affects behavior and memory (cause and effect).

[13] A Promethean board is an interactive white board that allows the user not only to project images from a laptop/computer onto the board but also allows the user to directly interact with the board through touch and special pens.

ATOD Day 3 Debrief

In the debrief below, Mrs. D was actively thinking about how the NGSS dimensions were playing out in her planning and teaching. She described the three NGSS dimensions coming together during this whole class introduction to the CER framework. Mrs. D stated:

> Yes, Oh my gosh! When we did the actual drug facts article from NIDA that's where all three came together because they were learning how to gather and evaluate data, they were learning about the brain and what happens with drug consumption to the brain and how it affects behavior and memory. All three were in that one where I had them read the article out loud and we did the first CER. That one was like awesome because it [writing scientific explanations] was so complicated… (Interview, May 7, 2014)

Above, Mrs. D envisioned the three dimensions coming together during a teacher-led activity; the focus of the activity was the teacher and students working through the CER framework (NGSS practice: writing scientific explanations) with the drug and brain core ideas and consequences (NGSS disciplinary core idea: sensory receptors in the brain, and NGSS crosscutting concept: cause and effect). This teacher supported activity was an example of how she saw the three NGSS dimensions coming together during instruction. The next excerpt describes this teacher supported activity as it actually unfolded in the classroom.

ATOD Day 3 Teaching

The students were reading material from the National Institute on Drug Abuse (NIDA) website, on marijuana's chemical and behavioral effects on the brain. As students worked through the material they were also working, with teacher support, to build a collective example to help them understand how the CER framework works. Mrs. D first guided students through

the claims portion of the CER framework (NGSS practice), then helped them build the evidence using the core ideas they were given which was marijuana's effects on the brain. Mrs. D stated:

> So this is our claim. Let's say it correctly; marijuana over-activates the endocannabinoid system, causing the high. So what is the evidence that we just read, what is the evidence that we just read, that supports this claim that marijuana over-activates the endocannabinoid system causing the high? Marijuana. OK, so there's one piece of evidence (writing "marijuana contains THC" and "THC acts on the cannabinoid receptors" on the board). [Reading aloud] Marijuana contains THC, THC acts on the cannabinoid receptors, it activates it. OK, describe the high, it's there in that paragraph. (Video Transcript, May 7, 2014)

In the next step of the CER framework, she guided students to use the claim to help them find evidence from the NIDA article. Together they found the evidence in the article that described the effects of marijuana. This evidence represents the NGSS crosscutting concept; the cause and effect of marijuana on behavior includes "altered perception and mood… feeling really good…feeling paranoia." As she worked with students through the parts of the CER framework they were gaining experience writing scientific explanations. Mrs. D stated:

> Altered perception and mood. These perceptions and mood could be good, that's why they call it a high. They could feel really good in that moment, for that high. Or, it could be a panic feeling paranoia feeling there are such things as a bad high. Impaired coordination, what does impaired mean [writing it on the board]? Aaron, what does impaired coordination mean? Yes, you're not able to coordinate your movements correctly. So you tell your brain to move your left leg one way your right leg the other way, you have trouble sending the message. (Video Transcript, May 7, 2014)

Next, Mrs. D guided students to tie it all together through the final piece of the CER framework which was reasoning. She walked students through the logic of working from the claim and evidence, to the reasoning: "we have to show A goes to B, B goes to C, C goes to D". She was

working to build students' ability to use logic to support their scientific reasoning through the science of how marijuana causes a high. Mrs. D stated:

> So, let's follow the logic. Who can tell me a reasoning sentence that puts together our claim and our evidence and right here [pointing to the reasoning portion of the table] shows me the logic of how the high was created? How was this high created when people smoke marijuana? Or take marijuana? How does this high happen? Victor? Victor, are you ready to give me the reasoning? You have to explain your claim using your evidence. So we can start with the claim and we can say [writing part of the claim in the reasoning section] Marijuana causes the high because… what? Because, it… Fill it in Victor. Marijuana causes the high because. Tell me logical. And what does THC do? [Writing on the board- THC acts on the cannabinoid receptors] We have to show, that was excellent Victor, we have to show A goes to B, B goes to C, C goes to D. Right? (Video Transcript, May 7, 2014)

In this final piece, Mrs. D brought the activity back to the purpose of why students were learning the CER framework. She gave students a sense of purpose for the CER framework aside from the science core ideas that helped students make the connection to the kinds of work that scientists do and the way scientists think. She stated, "Scientists love that! You have to explain it, it has to have logic… Scientists love that! Engineers love that! Right?" (Video Transcript, May 7, 2014)

In the instance just described, the dimensions came together as a teacher supported activity with the students and teacher working together through the process of writing a scientific explanation using the CER framework to understand and be able to explain the phenomenon of how marijuana causes a high in people (how marijuana affects the neurons in the brain). The instance provides insight into the ways Mrs. D led her students through this often challenging practice of writing scientific explanations. The way she purposefully walked students through the process also affords them some insight into the ways scientists think and write.

In Chapter V I provided the definition of the CER framework as described by McNeill and colleagues (2006). I reference Mrs. D's use of the CER framework throughout this chapter as well. I also noted that writing scientific explanations is a complicated practice for both teacher and students. In the instance above I observed that Mrs. D and her students seemed to be building towards creating their piece of reasoning. In the beginning of the discussion Mrs. D refers to THC acting on the cannabinoid receptor as evidence when in fact it might more appropriately be used as reasoning. Then, in the end of the discussion, Mrs. D seems to refer back to THC effects on the cannabinoid receptors as the reasoning piece of the CER framework. This example supports the findings from Chapter V that teachers will most likely need support to fully implement some of the more complicated NGSS practices, such as writing scientific explanations, as envisioned by the NGSS.

ATOD Day 3 Contextualization

In the excerpt below, Mrs. D was using the phenomenon of how drugs and alcohol affect the neurons in the brain to support student understanding of both the scientific and health consequences of drugs and alcohol use on the brain. She did not want students to feel like she was "just preaching to them or repeating stuff to them" (Interview, May 7, 2014). At the same time, she did want them to know the consequences of drug and alcohol use on behavior and memory. She accomplished this by using the crosscutting concept of cause and effect to contextualize the science and health consequences of drugs and alcohol. In addition, she uses the practice of scientific writing, using the CER framework, to further contextualize and support student learning of the core ideas. Mrs. D stated:

> I think the big part was the claim, explanation, evidence and then reasoning. So that was pretty big. …it makes, it helps explain and prove all this stuff that, it's kind of where

> health and science meet to work together to help show students that I am not just preaching to them or repeating stuff to them from Project Alert. They just have such blatant information without a source cited [students don't think about where they get their information from, whether or not it is correct information or a valid source of information] and it's, or a mechanism that explains it. I just feel, if they have the background knowledge then they'll understand the effect and danger and maybe, hopefully perceive the consequences of their health behavior in a more real way. (Interview, May 7, 2014)

In the instance above, Mrs. D wanted students to be aware of the health consequences of drug and alcohol use from a science core ideas perspective. She also wanted her students to become good consumers of health information. The CER framework provided the process that she hoped would support students' science knowledge building and she hoped this knowledge would help students be more confident and in control of their decision making.

This section provided an example of what coming together may look like as a teacher led activity. Mrs. D showed she was very thoughtful about the way in which she wanted students to experience the three dimensions, first through a teacher supported activity. Writing scientific explanations is known to be a complicated process for students and teachers to master (Kuhn & Reiser, 2005; McNeill and Krajcik, 2008; Ruiz et al., 2010). It makes sense that Mrs. D wanted this first exposure to the CER framework to be highly scaffolded. It also makes sense that in some cases, coming together, when it involves an initial introduction to complicated core ideas and practices, might be teacher led. Finally, this section also provided insight into Mrs. D's thinking about how and why she found it advantageous to use the practice of scientific writing to help her contextualize the core ideas for her students. It is an important example of the ways a teacher might use the dimensions to support contextualization and ultimately support better student engagement with the science core ideas.

ATOD Day 4

In this next instance that occurred on the following day, ATOD Day 4, Mrs. D described the three NGSS dimensions coming together through the phenomenon of drugs' effects on the human body through a mostly student led activity. Students were continuing to work on the CER framework, as presented in ATOD Day 3, and this time they were sharing their own examples of writing a scientific explanation. In ATOD Day 4, I also present more instances of contextualization. Overall, the findings in this section illustrate that Mrs. D really understood her students and their needs and could make adjustments to her lessons as necessary to support their learning. The findings in this section also show that students were more than capable of producing work that illustrated coming together. Finally, the findings show that Mrs. D understood the power of social media to contextualize the science core ideas in a way that her students could relate to.

Adjusting the plan: "I realized that we weren't ready."

Initially, the plan for ATOD Day 4, from Mrs. D's Unit Outline was to introduce a new learning goal, #3, which states: "Students will create models to describe the structure and function of neurotransmission (transmitting signals that travel along the nerve cells). The signals are then processed in the brain, resulting in immediate behaviors and memories." Mrs. D noticed many students had not done the homework, which was to create scientific explanations using the scientific articles each student found online. She believed that the lack of completed homework indicated that the students needed more practice together and in her debrief for the day. Mrs. D stated:

> I went back and decided that I needed to go over the claim, evidence and reasoning again and make sure they get it and check in about the homework… I had originally planned to

> do lesson one of Brain Power which is all about the brain and neurons and I realized that we weren't ready to do that. (Interview, May 9, 2014)

Mrs. D understood the needs of her students and was willing to adjust her plans accordingly. She realized the importance of understanding the CER framework and believed she needed to take more time for her students to master this concept. Therefore, ATOD Day 4 focuses on reviewing the Claim, Evidence, and Reasoning (CER) model from the previous day.

ATOD Day 4 Debrief

Coming together was visible during the ATOD Day 4 activity during which students were asked to share their own CER frameworks. In the debrief below Mrs. D described coming together in the day's activities through students' CER examples. I have numbered the sentences in the passage below to make reading and explaining the passage easier. In sentences 1-3 and 6 she was thinking about the crosscutting concept of cause and effect with respect to students creating their claim, evidence, and reasoning statements and understanding the information about marijuana's effects on brain development. Sentence 8 describes the disciplinary core idea of structure and function of neurotransmission, which she believed was visible during the class discussion on the various parts and functions of neurons. Then, sentences 10 and 11 describe how it all came together in the claim, evidence, reasoning activity and student sharing. Mrs. D stated:

> [1]The cause and effect with the claim. [2]And the evidence and reasoning. [3]One more time that the marijuana impairs brain development. [4]And what else? [5]That was huge. [6]I thought that you could see cause and effect which was the crosscutting part. [7]The concept, the, let me look this up. [8]That part, the core ideas one, the disciplinary core idea was definitely about areas in the brain being affected and receptors, sensory receptors responsible for learning and for memory and for behavior being affected, definitely. [9]That was there. [10]And also, the, okay, so crosscutting concept, the disciplinary core idea and then the first one, oh, the science and engineering practice which was exactly what we're doing which was analyzing data and gathering it and organizing and analyzing the data. [11]That's exactly where it all came together in filling out the CER worksheet. [12]The next step was for them to do it again but with something that they've never seen before with a particular drug and its effect on the body. [13]They're able to then do the CER, then they are able to present it and teach it. [14]That's the pivotal thing. (Interview, May 9, 2014)

Mrs. D was able to articulate where and how she thought coming together occurred during ATOD Day 4. She also described the next steps; students would once again practice writing scientific explanations but with "something that they've never seen before" (Interview, May 9, 2014). Taken together with the ATOD Day 3 debrief and activities, Mrs. D seemed to be scaffolding the activities for students so that during ATOD Day 3, coming together was described through a teacher-supported activity, and in ATOD Day 4 coming together happened through the product of the students' own work. At the end of our discussion, Mrs. D recognized this scaffolding was important to support students' understanding of the CER framework. And, equally important, "the pivotal thing" was for students to gain an understanding of the science core ideas by teaching the science information to one another. This instance highlights the in-the-moment and forward-moving thinking that Mrs. D displayed throughout the unit planning and teaching.

ATOD Day 4 The Classroom

Below, I present one instance during ATOD Day 4 that showed a student presenting his own work by sharing his scientific explanation. The students had been asked to find a valid and reliable online article that described the effects of alcohol or drugs on the brain. Students were then asked to write a scientific explanation using their article and to answer the question, "How do drugs or alcohol affect the brain?" This particular student talked about the various effects of alcohol on the liver which then affects the brain's function. It stands as an example of the kind of work students in her class were capable of producing while also supporting the debrief discussion explained previously where Mrs. D described the three dimensions were coming together in student work. The student had been asked to repeat his claim so that another student could hear it again. After the student repeated the claim, Mrs. D tried to summarize the main point of the scientific explanation but she misunderstood, at which point the student summarized his scientific explanation for the class. The student had previously presented evidence from the study in the first part of the exchange so the focus of this excerpt was on his claim and reasoning.

As the student worked through his scientific explanation on the causes and effects of alcohol on the liver and the brain (see below), he was articulating both the core idea (long-term effects of drug consumption on the body affect the neurons in the brain) and the crosscutting concept (cause and effect). The instance also included his articulation of the reasoning for how and why alcohol consumption affects both the liver and brain, i.e. alcohol damages the liver cells

which allow more alcohol to the brain which damages brains cells which subsequently causes brain damage [disciplinary core idea].[14]

> Mrs. D: "You tell me John, say it again."
>
> John: "The reasoning?"
>
> Mrs. D: "No, just your claim."
>
> John: "Prolonged liver dysfunction can harm the brain and lead to hepatic encephalopathy."
>
> Mrs. D: "So your liver, which was over here [pointing to her right side] which, can get damaged, those damaged cells can travel to the brain? Did I follow that right?"
>
> John: "Uh, the liver cells can get damaged and allow more alcohol to get to the brain [where it damages the neurons]."
>
> Mrs. D: "Oh! So the damaged liver cells are not doing a good enough job filtering out the alcohol from your blood, the alcohol travels to your brain damaging your brain. Wow, wow! That's pretty cool. I mean not cool that that happens, but cool that John was able to put that together." (Video Transcript, May, 2014)

In the discussion, the student was articulating his knowledge of the core ideas about the effects of alcohol on the body using the NGSS practice of writing scientific explanations. The instance also affords us insight into the kinds of work students were capable of producing following the teacher led activity of writing scientific explanations from the day before. Additionally, this

[14] I only utilized student work from those students who I had obtained consent (meaning I had consent from both the student and a parent/guardian). All student names have been changed to protect their identity.

instance also supports Mrs. D's ATOD Day 4 debrief description of the process of coming together through student work.

Regarding the students complete use of the CER framework; I would argue the example shows the student is building his understanding towards the reasoning piece of the CER framework. The reasoning, to be complete, should have included some scientific principle(s); the student did not include any in this example. Although the example above presents an incomplete scientific explanation, we clearly see students are capable of doing this complex work of scientific explanations but may need added support to fully reach their potential. Perhaps with a better understanding of the CER framework, Mrs. D could have guided John to create a more complete scientific explanation. This instance once again supports my previous claim that teachers will need more support to fully understand and implement the NGSS practices in order to support students' development of three dimensional learning.

ATOD Day 4 Contextualization

The following are two examples of contextualizing that occurred on ATOD Day 4. The first instance occurred during a debrief discussion and the second instance occurred in the classroom. The debrief shows Mrs. D was not only thinking about coming together from a standards point of view, but she was also thinking about the core ideas and how that connected to her students' lives. In her teaching, she contextualized the core ideas around a famous young person the students were familiar with, someone who some of her students might have even seen as a role model. In both instances, the focus was to make the science real and meaningful to the students to support healthy decision-making habits.

In this next passage Mrs. D's comments afford us important insight into both *what* she wanted students to take away from the ATOD unit, as well as *how* she wanted them to be able "to teach each other." Mrs. D shared her thinking about contextualizing health and science to connect to students' lives when she referred to: a) the "whole core ideas knowledge," as the health core ideas; b) the "whole science knowledge," as the science core ideas (NGSS dimensions); and c) the connection to the students' lives which was the "realism…realistic perception and consequences of what drug use does". Mrs. D was very clear about what she saw as key pieces for student understanding. She stated:

> What I want them to do, which is to teach each other what each drug does to the body. And when that happens, if they can do that and teach each other, they're going be in different groups and take turns teaching us, then the big aha moment will be that they have, one, the whole core ideas knowledge, two, the whole science knowledge, and then three, the realism that, or the realistic perception and consequence of what drug use does. And so that's kind of huge (Interview, May 9, 2014).

The instance above shows how Mrs. D often demonstrated complex thinking about contextualizing health and science to student's lives utilizing issues that could be both academically and morally challenging. She showed that she was thinking about how these pieces could intersect to support student learning of, engagement with, and interest in the health and science core ideas and how she hoped this new knowledge would also influence her students' life choices. This use of academically and morally challenging issues was similar to the study by Dori and colleagues (2003) who found that using case studies that were both environmentally and morally challenging supported students' interest and engagement in a biotechnology class and also supporting improved learning across all academic levels of participating students. Academically, she was asking them to develop an understanding of how drugs and alcohol affect the neurons. Morally, she was asking them to take that science knowledge a step further to then

think about the different social implications, “the realistic perceptions and consequences of what drug use does.”

Below is an example in which Mrs. D contextualized the science and health ideas using students’ work on the CER framework as a starting point; a student was sharing her CER from an article she found online about marijuana effects on respiratory illnesses. She used the example of how the real-life choice of using marijuana by a famous young singer who all of the students were familiar with could affect daily life. Not only did Mrs. D want her students to understand the physical effects of marijuana use, she also wanted students to think about the social consequences. She emphasized the disruption drugs can cause in one’s life and the person’s responsibilities. Mrs. D brought the discussion to a social level the students could understand when she stated:

> Yeah, it’s not a coincidence that the singer had to cancel her tour. And again, I don’t know the singer and what’s going on with her life but I know that she has recently come out very pro marijuana and then she lands in the hospital with a major illness. Uh, probably the two are related. And, you can see that it affects her life, she has to cancel her tour and move the tour dates to the summer. So, instead of performing, she’s resting and recuperating. So there was a price to pay for using marijuana: respiratory illness, phlegm… (Video Transcript, May 9, 2014).

This instance from the classroom and the previous example from her debrief show the consistency between her thinking and her practice about teaching “the realistic perception and consequence of what drug use does” (Interview, May 9, 2014). By using a famous young person, who many students admire, as an example, she was attempting to contextualize that “realism” of the consequences of drug use to her students.

This section presented an instance of one student showing he was capable of producing work that demonstrated the three dimensions coming together through his scientific explanation. Perhaps because of the support they received during ATOD Day 3, where coming together occurred as a teacher supported activity, students were well positioned, on ATOD Day 4, to demonstrate coming together in their own work. It might be suggested that teachers guiding students through instances of coming together, followed by instances of coming together through student led activities, might be one way in which the coming together process occurs. Finally, the examples of contextualization on ATOD Day 4 afford us some insight into where, how, and why contextualization occurred in her classroom. The instances highlight Mrs. D's thought process—as she reported in the interviews—as well as present concrete examples of contextualization occurring in the classroom. The teacher dialogue using a real-world example of a person the students' admire demonstrates how Mrs. D was thinking about contextualizing the health and science to connect to her students' lives. This kind of contextualization aligns with Rivet and Krajcik's (2008) characterization of contextualization. In their study on contextualizing instruction, they emphasize that it was not enough that the topic be interesting. Notably, in order to engage students with the core ideas, the instruction must "leverage students' interest or experience," and "encompass worthwhile science core ideas" (Rivet & Krajcik, 2008, p. 80). ATOD Days 3-4 show that Mrs. D was actively working to leverage student interest and experience within the context of worthwhile science core ideas.

Coming Together As A Process Over Time- "I Don't Know if It's There Yet"

The previous instances (ATOD Days 3 and 4) described Mrs. D's awareness of the three NGSS dimensions coming together in her classroom both as teacher supported and student led activities. These next two sections show instances during teaching where Mrs. D acknowledged

that sometimes the three NGSS dimensions were not present each day and coming together of the three NGSS dimensions occurred over the course of several days. The examples below present a shift in the way Mrs. D described coming together during teaching. The findings suggest coming together may also be a *process* that takes time, possibly emerging only after several days.

ATOD Day 5

This section presents instances in which Mrs. D described *coming together* as a process in which she identified only one dimension—just a practice, or just core ideas—occurring in her teaching for the day. This section also presents two compelling instances of contextualization. Overall, the findings in this section suggest Mrs. D saw coming together as a process that did not need to occur all in one day but could take several days. The findings also show Mrs. D was thoughtful about the social and community issues affecting her students and that she was able to use these issues to contextualize the science and health core ideas in a way that was critical to student learning and engagement.

Mrs. D and her students were about halfway through the ATOD unit; they had covered half of the learning goals and were starting on learning goal #3. For part of ATOD Day 5, students continued working on building their scientific explanation writing skills. The remainder of ATOD Day 5 represented a more in-depth introduction into both the vocabulary and the structure and function of neurons.

The day began by presenting learning goal #3 and by having students write the learning goal in their journals. Learning goal #3 states, *"Students will create models to describe the structure and function of neurotransmission (transmitting signals that travel along the nerve*

cells). The signals are then processed in the brain, resulting in immediate behaviors and memories." From my observations, I noted that the focus of the lesson was two-fold: first, students were presented with some background information on the different kinds of drugs within the various groups of drugs; second, students' worked alone or in small groups to find the different parts and functions of the brain. Knowing the different parts of the brain and their function would continue to support students' understanding of how and where in the brain different drugs and drug groups affect the brain.

ATOD Day 5 Debrief

During the debrief, I asked Mrs. D whether she was able to see the three dimensions coming together in her lesson. She also provided a bit of a roadmap for the unit, both in terms of time and core ideas. She knew what she wanted to cover the following day, Friday, and she was thinking about how to combine the middle and high school NIDA curricula. On the one hand, the middle school curriculum was sufficient for her students; on the other hand, she wanted to push them to know more about the neurotransmitters and their associated drugs. More importantly, Mrs. D recognized that the day's purpose was not to focus on the NGSS dimensions coming together but rather on core ideas. Mrs. D stated:

> Not so much, today was more core ideas based. That's Friday. Friday I really want them to know Dopamine, serotonin, and GABA. In the middle school curriculum they just have them knowing like three. In the 9th grade curriculum they have them [knowing more of the neurotransmitters] (Interview, May 14, 2014).

I probed further and asked her if she thought Friday would be the moment she would see the three NGSS dimensions coming together. She made it clear that ATOD Day 5 was really a build-up towards ATOD Day 6 activities in which she hoped to see the three NGSS dimensions

coming together. Mrs. D laid out the science core ideas she wanted to focus on and the resulting causes and effects of alcohol on the brain. She stated:

> Yeah, exactly, what drugs do to the brain and how they affect the sensory receptors and learning and memory and behavior? So memory and behavior, yeah, like GABA's one of the inhibitory neurotransmitter that's affected with alcohol. Alcohol use increases the amount of GABA in the brain which in turn decreases brain activity, so it's like turning off the brain. Decreased attention memory alterations, mood changes and drowsiness, which is so fascinating (Interview, May 14, 2014).

Although, according to Mrs. D, coming together was not present in this lesson, she provided a clear roadmap of where she was going and how it would lead to the three NGSS dimensions coming together in a future lesson, and ultimately lead students towards proficiency in the NGSS focal performance expectation. It was apparent from the discussion that she was thinking about the three dimensions and the performance expectation, but she also understood that she and the students needed some knowledge buildup, over time, to get to that point. Creating the various learning goals throughout the ATOD unit was one way she would help students gain proficiency for the focal performance expectation over multiple lessons and days. She also knew that it would take time for students to attain the individual lesson learning goals. This idea that developing proficiency in the various dimensions over time aligns with the work being done by Krajcik and colleagues (2014) that intends to support teachers in planning instruction to meet the vision of the NGSS. In their article, Krajcik and colleagues (2014) propose teachers create *lesson level PE's* that will, in turn, support students' attainment of proficiency in a bundle of NGSS PE's. They caution against focusing on only one NGSS Performance Expectation at the expense of students' missing opportunities to see connections between the various dimensions. However, I would argue that Mrs. D's work here demonstrates that she was attempting to make many and varied connections through the use of several dimensions over several lessons. In the

examples throughout this chapter, Mrs. D was attempting to present students with opportunities to experience a variety of NGSS practices such as interpret and analyze data, write scientific explanations, and create models. She also wanted students to be exposed to different core ideas such as structure and function (the parts of the neurons and the brain), and information processing (how messages are sent between neurons and then to the rest of the body). I would posit that the examples in both findings chapters show that Mrs. D was attempting to make connections to the phenomenon utilizing several dimensions and, equally important, to make connections to socio-scientific issues that Mrs. D believed were interesting and relevant to her students' lives. All of this, she believed, would help students be able to develop the critical thinking skills to be able to explain the phenomenon of drug and alcohol's effects on the brain and subsequent effects on health and social issues.

Focusing on One Dimension Core ideas

The classroom video shows that ATOD Day 5 does indeed focus on core ideas, mostly through short lectures, small group work, and individual work. The students and Mrs. D concentrated on two ideas during the lesson. First, students looked at the different drug groups (e.g., stimulants and depressants) so they could begin to understand that drugs are classified according to their effects on the brain and body. Second, students began to study the various parts of the brain (e.g., cerebral cortex and the cerebellum) to begin to understand that different drugs affect different parts of the brain and subsequently affect memory and behavior differently. The ideas seemed to be presented separately and I noted in my classroom observation: "Mrs. D covered the drugs and the brain parts [core idea] separately, could she have guided students to put the two ideas together so that cause and effects could have been more apparent between drugs and their effects on the brain parts" (Observation, May 14, 2014)? This was important to

mention because it may have been an opportunity to connect the brain and drugs core ideas (disciplinary core idea) through the crosscutting concept of cause and effect, thereby bringing more of the NGSS dimensions together in one lesson. And, perhaps with more experience using the dimensions, Mrs. D could have planned the core idea and crosscutting concepts around one of the NGSS practices as well.

ATOD Day 5 Contextualization

The next two instances of contextualization that occurred on ATOD Day 5 show the depth of understanding Mrs. D had around the idea of contextualization. In the first instance she makes an important social and community connection between drugs and the students. This instance was both powerful and important because it shows she had an awareness of her students' communities and that she considered herself a part of the students' communities. In the second instance, Mrs. D uses contextualization to show another level of connection between science and health as she discussed the significant connection between mental health to drug use. This was significant because it shows one more way in which Mrs. D was actively thinking about making connections beyond the science to help students recognize there were real consequences to using drugs.

"[Drugs] have really ruined a lot of our communities."

During the course of the ATOD unit, Mrs. D was adept at making connections between health and students' lives; in the excerpt below she makes a powerful connection to the communities from which many of her students come. The statement was powerful for several reasons. First, the reference to drugs affecting major cities was a direct connection to the students

as they are all living within a major city that has a history with drugs. Second, her reference that communities of color are affected by drugs was highly relevant given that over 50% of the school population consisted of students of color. Third, many of those most significantly affected by drug use not only disproportionately come from communities of color but also from communities that struggle economically. The school statistics showed that roughly 50% of the school's student population was identified as economically disadvantaged (as identified through eligibility to receive free and reduced lunches). These unfortunate realities speak to the fact that more likely than not there are students at the school who have been affected, either directly or indirectly, by drugs and alcohol. Finally, although subtle, it is significant that she used the phrase "our communities" because, as a woman of color, she made a personal connection to her students and understood that drugs are affecting "our communities." Mrs. D stated:

> Cocaine has been around for a really long, long time. And then they uh, people developed crack cocaine and they say they the reason for crack cocaine was because it was cheaper and easier to make and they wanted people who were poor and to be able to be hooked on it because they could get a wider amount of people hooked and then they would have them for life and they would, you know, make money off of them. So there's a really sad history there with crack cocaine, like that is, and if you think about it, most of the poor people in major cities are going to be people of color and so it's even more heart breaking because it's really ruined a lot of our communities (Video Transcript, May 14, 2014).

Similar to the work that Sadler (2009) was advocating in utilizing socio-scientific issues in the science classsroom, the passage illustrates how Mrs. D worked to make connections to students' lives, both on a personal and societal level as well as on a science core ideas and conceptual level, and to show how these were real-world issues that are affecting many of her students' communities. Similar to Zeidler and colleagues (2005), the way in which she spoke about the struggles with drugs within their collective community provokes this idea of an ethical issue that students must to grapple with. Finally, her message that drugs had negatively affected "our

communities" sent an important message of the connection Mrs. D saw with her students, especially since she is a woman of color. This idea of "our communities" seems to send the message to the students that it is not *their* problem to think about and solve alone. An issue in "our communities" sends a message that Mrs. D sees the issue of drug and alcohol use as affecting her and her students together; it sends a message of the need to learn about and think about the issue together.

I do recognize that because Mrs. D is a woman of color she is able to relate to her students in a way that, possibly, other teachers of different backgrounds may not be able to do. I recognize that in Mrs. D's case her connection to her students as a woman of color brings a certain set of privileges to her teaching that other teachers may not have. I recognize these privileges and I know it generates a certain set of implications for doing contextualization that are beyond the scope of this study. My aim, in providing examples of how Mrs. D contextualized the science for her students, was to show that contextualization might be one powerful and engaging tool that teachers could utilize to support students to develop the critical thinking skills necessary to explain various science phenomena.

Contextualizing the science of drugs and mental health

During the weeks that Mrs. D was teaching the ATOD unit, she dedicated one day a week to also teach a unit on mental and emotional health. In this example of contextualization, she was thoughtful about how her ATOD unit tied into her unit on mental and emotional health and how, together, the two could support a deeper understanding of the science and health issues. What was so compelling about this passage was that Mrs. D was actively thinking about how she wanted her students to be able to explain not only the science phenomenon of how drugs affect

one's body in the short-term, but also the possible long-term effects. She wanted students to make the connection between how drugs and alcohol affect the neurons of the brain and how over the long-term there are mental and emotional issues that could arise or are exacerbated as a result of drug and alcohol use. She explained the progression of how she wanted students to build their understanding of science and health; if they understood how neurons function they would be better situated to understand addiction and mental illness. She was clear in her thinking about the co-morbidity between mental illness and drug use and how the two affect one another. I asked Mrs. D how she was thinking about connecting the ATOD unit with the mental/emotional health unit. She stated:

> So if they understand, its two things, if they understand how neurons work then they understand how addiction works and then they understand also mental illness. So I haven't explained in great detail I just told them that it's coming, that they'll understand the neurotransmitters so that I can talk about depression and like the drop in serotonin so that's something that connects [health and science or mental health and drug curriculum] (Interview, May 13, 2014).

In the passage above, Mrs. D began by recognizing that students needed to have the science background knowledge about the function of neurotransmitters in order to begin to understand how addiction and some forms of mental illness work or are affected by drug and alcohol use. The discussion continued below with more references to science core ideas and how she intended to connect that to mental and emotional health. Specifically, she made the connection between mental/emotional illness and drug use. Mrs. D stated:

> And then oh the reuptake the pump that is also fascinating because that is how, I will tie that in next Tuesday when we do mental and emotional health I need to tie that in to selective serotonin reuptake inhibitors [SSRI]. So SSRI's anxiety and OCD and all those SSRI's. And because also people with mental and emotional problems will also self-medicate with drugs…Yes, the co-morbidity, cause if you start hearing voices, yes, you

> might be tempted to try drugs and you might feel you are getting better but you're actually getting worse (Interview, May 13, 2014).

The excerpt illustrates not only how she was thinking about contextualizing the science core ideas from a physical health perspective, but also how she was thinking about the intersection of the science core ideas in relation to mental health which is often associated with drug and alcohol use. When I asked her about her thoughts on putting science core ideas and physical and emotional health together she stated, "I just want them to know the basics and then hopefully they will understand how the drug works" (Interview, May 13, 2014). The excerpt shows she was purposeful in her thinking about all of the different angles she could have taken to help students to understand the health and science core ideas and especially the possible consequences of drug use on their lives.

Contextualizing the science of drug and mental health in her teaching

The next instance illustrates how the discussion of physical health and mental health actually occurred in the classroom. Specifically, Mrs. D was discussing how meth addicts often find themselves in a cycle of using methamphetamines to get high and depressants to help calm the high. She was trying to illuminate just how tangled the cycle of drug use and health can become and how one piece—drug use—of the cycle often affects and complicates the next piece (mental or emotional illness). This was another example of the way Mrs. D was thinking about making these connections between health, science, and students' lives, and the ways in which she then enacted those ideas in the classroom. She stated:

> So a lot of times people will be on meth and they will enjoy the high, but then after a while they will start to have those fear-based feelings, like the paranoia and start to lose it. And what do they take to compensate [pointing to depressant on the foldable example

> on the promethean board]? They will actually take a depressant to bring them down. So, they will get too high, they'll take the depressant to help even it out. Do people mix drugs? Yes. Ryan is right, because a lot of people will mix drugs, they'll try to counter-balance. And, here, just to make it even more exciting! And crazy! They have a mental and emotional problem, like depression, or bipolar disorder, or schizophrenia, so they start taking methamphetamines. Then they've got three things going on; they've got an addiction to meth, they've got an addiction to a depressant, and they've got a mental or emotional disorder (Video Transcript, May 14, 2014).

The excerpt above illustrates the kinds of conversations that occurred where Mrs. D was trying to help students see the "crazy" cycle drug use can take in one's life, especially someone with a mental or emotional illness. Students had been learning about the effects of drugs on the neurons and now Mrs. D was taking students outside of the body so they could see how the effects of the drugs on neurons can have consequences to one's physical, emotional, and mental health. This classroom discussion ties back to her debrief discussion about wanting students to realize the "co-morbidity" of drug use and mental health. The science core ideas may not have been the main focus of this particular conversation; however, she was setting students up for their final projects in which each group would present the effects of drugs on the brain, both from a scientific, health, and mental wellness point of view.

The findings in this section show that although Mrs. D described only one dimension occurring on this day, she was able to clearly articulate the process that coming together would take over the course of several days. As this instance suggests, coming together as envisioned by NGSS occurred, but it took one or several days before all three dimensions were actually coming together, in, perhaps a final group project. Finally, Mrs. D invoked a level of thoughtfulness with the two powerful examples of contextualization in this section that showed: a) she had knowledge of her students' communities and saw herself as a member of their community; and b) she recognized the need to make connections between health and science and she was able to

demonstrate a capacity to do that in varied ways. Both instances of contextualization demonstrate meaningful ways to engage students in the core ideas.

ATOD Day 6

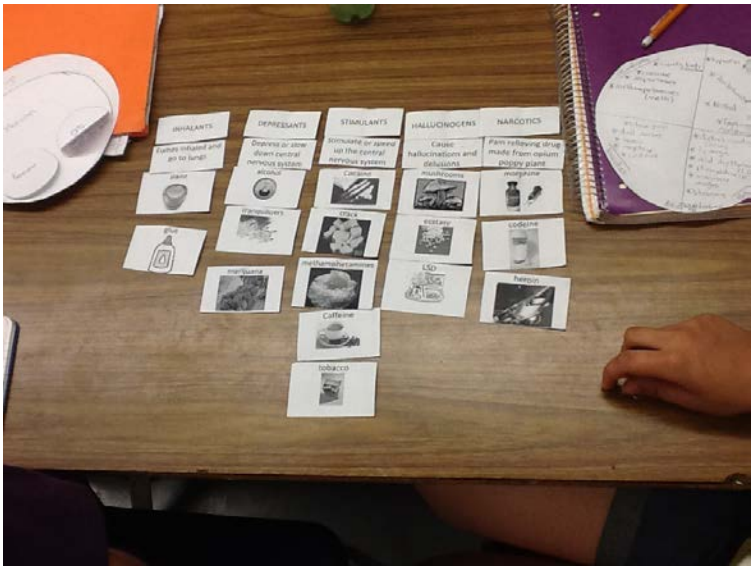
The purpose of this section is to further the discussion that coming together might be a process that occurs over several days. In this section I present instances that show Mrs. D continued to articulate coming together as a process. Whereas ATOD Day 5 focused on the core idea, this time she was helping students to access the core ideas through the practice of "modeling". This section also presents an instance of student led contextualization. Overall, the findings continue to support the idea that sometimes coming together occurred as process that built up over several days.

ATOD Day 6 began with students learning about the various parts of the brain and their corresponding roles in the human body system: the occipital lobe supports vision, the limbic system is the reward center, etc. After the presentation on the brain, the students were asked to do an activity Mrs. D considered as "modeling."[15] Students were asked to sort cards with names of the drugs they had been learning about according to their drug category. They were asked to identify such connections as "LSD is a hallucinogen" and "cocaine is a stimulant". After students completed the drug card sorting they were asked to check their answers with the drug foldable (see Figure 6-2). The drug foldable was a vocabulary tool that each student created with a set of important vocabulary that Mrs. D wanted students to have access to during the ATOD unit. On one side of a section of the foldable tool was a vocabulary word; on the other side was the definition along with examples to help students remember the meaning and use of the words.

[15] Recall from Chapter V I use "modeling" to signal when I am describing instances of Mrs. D's interpretation of modeling because her description did not always represent the full intent of modeling as envisioned by NGSS.

After checking their drug foldables, students were instructed to correct their drug card sorting and added new drugs to the different drug categories on their foldables. The lesson continued with an introduction to the structure and function of the neuron and references to students learning about how drugs affect the limbic or reward system of the brain by the way they interact with the neurons. The lesson progressed from a broader focus of the brain and its parts to the narrower focus of neuron structure and function, and then once again to a broad focus of how drugs target the limbic system of the brain. Figure 6-2 shows the result of the card sorting exercise as well as two examples of the drug foldable students used to help them participate in the card sorting activity.

Figure 6-2 The card sorting activity (center) as well as examples of the drug foldable (right and left side of the photo)



Mrs. D had hoped to see the three NGSS dimensions coming together on ATOD Day 6. Although coming together did not occur on this day, Mrs. D's vision of the progression towards the three dimensions was apparent in the debrief below. Whereas ATOD Day 5 focused on core ideas, ATOD Day 6 represented an instance of core ideas, plus the practice of "model" building.

Building Up to Coming Together—Debrief

Here Mrs. D was once again discussing the build-up to the three NGSS dimensions coming together. According to Mrs. D, she identified two dimensions on ATOD Day 6: core ideas and practice. The next step was for students to understand how all of the information together painted a clearer picture of the effects of drugs on behavior and memory. In this excerpt, she discussed her thoughts about the card sorting activity as the practice of modeling where students were sorting and creating a kind of graphic organizer to help them understand the different drugs of each drug group. She described the buildup of core ideas before the students could put the whole drug picture together:

> Mrs. D: "I thought the card organizing went well,"
>
> CJM: "So they were using like a model, the cards, to"
>
> Mrs. D: "To diagram? Yes."
>
> CJM: "I'm not sure if the part about the transmission was discussed."
>
> Mrs. D: "You mean like which, oh ok, so like stimulants stimulate the nervous system but you mean like dopamine? Affects? Like linking that together, right? No, not yet, so that's the next step. So I think Friday was just for them to just, to have just the basic background knowledge of the different drug groups. Because they really have, it's surprising how little knowledge they have about drugs" (Interview, May 20, 2014).

The next portion of the discussion provides insight into how Mrs. D was thinking about her next steps, and it also shows how she was branching out, perhaps becoming more familiar and comfortable with the NGSS dimensions. She considered the possibility of the connection between the two NGSS disciplinary core ideas under the following titles (see Figure 5-1 in

Chapter V): (a) cell structure and function; and (b) interacting systems. She thought about their connection within the phenomenon of how different groups of drugs work on the nervous system. By the end of the discussion she was moving forward, working to bring the dimensions together by discussing the cause and effect of drugs on the body system and a person's health, for example, causing "heart attacks and sudden death". Mrs. D articulated all of the things she saw were occurring in this one activity. She stated:

> You know what it is good about, what it [the card sorting activity] does get at I didn't even look at this in the disciplinary core idea that the body is a system of multiple interacting subsystems [reading the disciplinary core idea]. I think knowing that the stimulant stimulates the nervous system and that depressants. OK, so definitely I see the disciplinary core idea of cells, gosh there is so much that we go over. Of the cells, um the nervous system and then the effect on the body and then how depressants if someone takes too much depressants it will work on the brain stem and their slow their breathing and even possibly stop their breathing and stop their heart from beating. And then the stimulant can cause the heart attacks and sudden death. (Interview, May 20, 2014)

This instance shows Mrs. D was thinking about several issues including the practice of modeling, the range of core ideas (disciplinary core idea) she was covering in her unit, and how that core ideas would ultimately connect to the cause and effect (crosscutting concepts) of drugs on the human body. This is an important window into her thinking about the various NGSS dimensions and about how she hoped to see coming together occurring in ATOD unit. Most importantly, Mrs. D clearly articulated coming together, in this instance, as a process that occurred over several days.

Finally, this excerpt also shows Mrs. D was looking beyond the planned NGSS performance expectation for the unit. In our planning discussion Mrs. D and I had decided she would concentrate on the NGSS disciplinary core idea structure and function. She focused the ATOD activities on students gaining knowledge in the structure and function of neurons and how

neurons' "special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell" (NGSS Lead States, 2013, p. 61). Although other portions of the NGSS disciplinary core idea, structure and function were not purposely ruled out; we simply did not look at any others. This instance of Mrs. D looking to other segments of the dimensions was important because it shows she was thinking beyond her original plans and about how other pieces of the NGSS dimensions fit into the goal of the unit and further supported student understanding of the science ideas. This kind of forward thinking seems very similar to what Krajcik and colleagues (2014) are proposing with the creation of *lesson level PE's* they describe as important to help teachers support students in becoming proficient in the NGSS performance expectations.

Rudy Contextualizing: Putting It All Together; A Student's Perspective

On ATOD Day 6, the classroom discussion was about the different parts of the brain and their functions. Mrs. D finished discussing the importance of the cerebral cortex as the part of the brain responsible for helping decision-making and problem-solving. The discussion turned to the fact that teens' brains are still developing and she asked the students to explain why they thought it was important to know all of this brain information. One of the students then shared his thoughts on the effects of drugs on the developing brain and a teen's ability to make good decisions:

> Mrs. D: "So your brain is still developing up until you are about 25 years old. Who is more likely to be offered drugs- teenagers or a soccer mom who's coming home from the supermarket? The teenagers! So why is this important for teens to know that your brain is not done? It's like the cake that's in the oven. It hasn't been done baking, why is that

important to know? Because if teens use drugs… yeah… that's like taking the cake out of the pan and throwing it on the ground."

Rudy: "Because if a teen takes drugs while the cerebral cortex is still developing, it can interfere with the growth of the cerebral cortex. So that teen wouldn't be able to, wouldn't be aware of their surroundings and they would lose the ability to solve problems and they could make bad decisions."

Mrs. D: "Beautiful! That was awesome." (Video, May 16, 2014)

This final example of contextualization suggests that the level of contextualizing moved from teacher led at the beginning of the ATOD unit, to a point where students were actively contextualizing the information for themselves in a way that was real to them. The classroom discussion showed the student pulling together the information about the brain, especially the cerebral cortex, and being able to contextualize the information for him and his fellow students. His answer showed that he was actively contextualizing the science core ideas (the function of the cerebral cortex) into a social context (an inability to solve problems that leads to making bad decisions that he could understand. The video shows the other students were attentive to his answer and when he finished sharing out. Mrs. D was quite impressed with his answer as she stated, "Beautiful! That was awesome." Mrs. D was clearly pleased that students were beginning to process the core ideas into a way that spoke to them as teens. These findings continue to support Mrs. D's idea that coming together was a building up process that would occur over several days. The findings also suggest that, just like coming together, contextualization may also be a process that moves from instances of teacher led contextualization to the students being able to contextualize the core ideas for themselves.

Summary

I presented data in this chapter that demonstrated the various ways in which Mrs. D was noting the three dimensions coming together during the ATOD unit enactment. The days where Mrs. D clearly saw coming together as a process raise several questions about the reality of seeing the three NGSS dimensions in every lesson during each day of instruction. I would argue that perhaps coming together takes time for the teacher and students to accomplish as described in this chapter. Perhaps more clarity about the NGSS vision of weaving is needed. Regardless, teacher support will be needed or more examples provided in order to better understand how to bring the three NGSS dimensions together as envisioned by NGSS and the Framework.

Finally, and of equal significance, Mrs. D was attempting to present the science and health core ideas in a way that was engaging to the students through contextualization. The instances show Mrs. D was very thoughtful about how she contextualized so that it was relevant and engaging to students; she used a variety of ways to contextualize the science and health core ideas, from community issues to stories on social media. The findings in this chapter suggest that perhaps an interesting indication that students were grasping the concepts was when they could contextualize the core ideas for themselves as described in the final instance of contextualization. Further elaboration on the significance of contextualization in science will be taken up in the discussion section that follows.

In the next chapter, the discussion, I conclude this work by considering the three main findings of this study and how these findings relate to and move our conversation forward with relation to teachers' experiences taking on science education reform, specifically NGSS. I also discuss implications for the important preparation needed for teachers to understand and utilize the various components of the NGSS. These are implications that call on science education

researchers, professional development leaders, curriculum designers, and teacher educators to think about their work as they design future studies that aim to better understand teachers and reform as well as working to create support that will strengthen teachers' experience with and success in utilizing these the NGSS. Additionally, I consider implications for thinking about and utilizing the concept of contextualization as a way to engage students in their journey to become scientifically literate. Finally, I outline directions for future research.

There is one final note I feel compelled to include before the discussion chapter; I want to commend Mrs. D for taking on this daunting challenge of planning and teaching a health unit using the NGSS dimensions. As mentioned previously, she had received very little training in the form of a two-day professional development but that had occurred the year before, and one half-day training while participating in this study; both professional development sessions were district sponsored and attendance was voluntary. This was the first time she had planned or taught using the new standards and she was the only science teacher in her school attempting to do so. Therefore, these findings chapters are not meant to highlight her shortcomings in attempting to use the NGSS. Mrs. D's professional background and experience, as detailed in the methods chapter, show she was more than capable and qualified. These chapters are meant to draw attention to some of the facets of the NGSS that teachers may benefit from by having more information—perhaps in the form of professional development sessions—about what the NGSS dimension are, what the pieces of the dimensions entail, or why they are important to student learning, and then ultimately, how the NGSS dimensions come together.

CHAPTER VII
DISCUSSION

Working with Mrs. D over the course of 6 months as she first planned and then enacted her ATOD unit, I began to more fully understand the challenging task that she had undertaken in attempting to weave various components of the Next Generation Science Standards (NGSS) into her own practice for the very first time. I began to more fully appreciate her work integrating the standards within an applied science—health—that was not specifically designated as science by the NGSS. In this final chapter, my aim is to analyze and discuss what the findings mean for those science teachers who are expected to utilize the NGSS. I will propose some ways in which the science education community might use this information to support ongoing professional development of science teachers as they work to incorporate and makes sense of the NGSS into their own classroom science curricula.

As we ask science teachers to tackle these new standards, it will be important for the science education community to have some kind of understanding of the experiences teachers may encounter as they try to make sense of the NGSS. Such knowledge can and should help the science education community prepare supports, such as professional development that addresses some of these struggles up front rather than after the fact. This case study is just one piece of the story that begins to describe some of the experiences some science teachers may have implementing the NGSS. By detailing Mrs. D's experience in planning and teaching we gain some understanding of how she was working to make sense of this important, yet complex and challenging science education reform. A solid understanding of teacher experiences around

education reform is also important because, in effect, supporting teachers to be successful at implementing the NGSS is a crucial step in promoting students to forge deeper understandings of science and engineering, develop critical thinking skills, become more engaged with science, and ultimately achieve scientific literacy.

Several interesting themes emerged from our work together and three deserve extended discussion. First, teachers may need multi-level support to understand the three NGSS dimensions of the disciplinary core ideas, science and engineering practices, and crosscutting concepts, as well as their constituent parts (e.g., the NGSS practice of modeling can be used in multiple ways to support student learning). Second, teachers will most likely need more explicit support to do the work of weaving the three NGSS dimensions together as well as support to identify instances where weaving has occurred. It may be that this occurrence of weaving materializes in various ways and over the course of several lessons or days as this dissertation presented. Finally, the third theme to emerge suggests the need to look beyond the NGSS specified science domains, to other academic fields such as health, to support teachers and students to undertake the complicated task of three dimensional learning. Specifically, this study demonstrated that health, a context not typically thought of as a K-12 science domain, was a potentially rich domain to support various NGSS core ideas. Because of Mrs. D's expertise in public health she was able to identify a performance expectation that could be supported by health. There are likely other applied sciences, or ideas within health that could support students to gain proficiency in other NGSS performance expectations. Therefore, there is a need to be open to those possibilities. Likewise, utilizing strategies that encourage student engagement with science and engineering phenomena may allow teachers and students to take on three dimensional teaching and learning more successfully. For example, using the practice of

contextualization, as Mrs. D did, may be an exciting, impactful, and important way for teachers to support student engagement and learning. In the sections that follow, I delve into each of the findings and incorporate some of the relevant literature to articulate how the findings of this study extend our understanding of how teachers might experience utilizing new reforms in science, specifically the NGSS, and suggest areas of the NGSS where teachers may need explicit support.

Three Main Findings

Finding One- Teachers Will Need Multi-level Support to Execute Three Dimensional Teaching

As the findings in Chapter V and VI indicate, Mrs. D had varying degrees of understanding of and comfort utilizing the three dimensions: practices, core ideas, and crosscutting concepts. The findings indicate that she felt confident in her knowledge about the NGSS core ideas within the focal performance expectation (see Table 5-1 in Chapter V). Mrs. D was fairly confident about her knowledge of the scientific practices, but less confident in her understanding of the purpose of the crosscutting concepts. She was confident and consistent in her understanding about the phenomenon. That is, Mrs. D never wavered from the objective that her students needed to be able to understand and explain how drugs and alcohol affect neurons in the brain and the subsequent social and health consequences that are often the result of drug and alcohol use. The data and analysis presented in Chapters V and VI demonstrate that Mrs. D was actively working to makes sense of the three NGSS dimensions and how to weave them in order to support students' development of a deeper understanding of the science and foster their critical thinking skills so that they would be able to explain the phenomenon of the health unit.

Even as a veteran science teacher who was invested in and dedicated to implementing the NGSS, Mrs. D struggled with various aspects of the NGSS. These findings are consistent with previous research reporting that teachers find standards implementation to be challenging (Anderson and Helms, 2001; Klieger and Yakobovitch, 2011; Schneider et al., 2005; & Spillane et al., 2002). With the NGSS, we are now asking science teachers to do something that is quite complex, weaving the three NGSS dimensions into their practice. The findings of this dissertation indicate that all teachers, regardless of experience or level of interest, are most likely going to need support on multiple levels to develop the kind of expertise required by the NGSS in order to engage in three dimensional planning and teaching.

On one level teachers will need support to interpret the three dimensions as single components: core ideas, practices, crosscutting concepts (See Figure 7-1). As the findings indicate, Mrs. D, although aware of the various crosscutting concepts, was not necessarily clear about their purpose and significance. I noted this uncertainty when Mrs. D stated, "I am not quite sure what the crosscutting concept was supposed to do" (Interview, March 25, 2014). Despite the fact that she consistently focused on the crosscutting concept of cause and effect in her ATOD unit, it was not clear that she knew how to make the crosscutting concept noticeable or accessible to her students. This uncertainty may indicate that other teachers will most likely need support to better understand the purpose and significance of the three NGSS dimensions. Likewise, if teachers have a better sense of the purpose and significance of each of the three dimensions they will be better positioned to make the significance of those dimensions visible and accessible to their own students.

On another level, teachers will need support to discern the various constituent parts of the three dimensions, for example, the eight NGSS practices. The in-depth analysis of the ways in

which Mrs. D talked about, experienced, and ultimately utilized some of the practices indicate that the extent to which she conceived of and appropriated some of the practices in class was somewhat limited. Recall the following instance during planning, where Mrs. D was trying to figure out which practice best suited the ATOD unit goals. She stated:

> But I am just trying to see where that would be pulling in NGSS, it seems that it would also be analyzing and interpreting data because it's, their evidence was a scientific study on marijuana and health, then they have to analyze and interpret data, right?... and also gather and obtain again too; obtain, evaluate, and communicate science information" (Interview, April 3, 2014).

In this situation, a better understanding of the two practices—analyzing data and communicating scientific information—and their constituent parts (such as constructing and analyzing displays of data, or critically reading scientific texts) would most likely have helped guide her discussion and lesson. Likewise, Mrs. D's understanding of the CER framework and writing scientific explanations exhibited some need for support especially in creating strong reasoning through the use of scientific principles. McNeill and Krajcik (2008) found similar results when they evaluated teachers' instructional practices around scientific explanations.

As I outlined in Chapter V, Mrs. D mentioned the use of "models" in her drug unit in four different ways: (a) card sorting and diagraming, (b) creating a physical model of a neuron, (c) using the hand and arm to model how neurons send signals, and (d) creating cartoons to model the effects of drugs on the neurons in the brain. Although she described the use of the models differently each time, she was actually utilizing "models" narrowly as representations of the science core ideas. While her intent was to help students develop a deeper understanding of the science through models, Mrs. D's vision of "modeling" did not necessarily align with the NGSS vision of modeling. This struggle to fully utilize models to promote a deeper understanding of

science phenomena was not confined to this study alone, or to Mrs. D. The findings from this study support previous findings about some science teachers' limited use and understanding and use of models (Justi and Gilbert, 2010; Krell and Kruger, 2015; and Van Driel and Verlopp, 1999). Although models as representations are an important piece of modeling, they represent only one aspect of the many uses of models to support student learning (Krell and Kruger, 2015; and Van Driel and Verlopp, 1999).

The limited ways in which Mrs. D envisioned and utilized models suggest that with a more complete understanding of modeling, she might have applied a variety of uses of models beyond representations and more in alignment with the NGSS vision of modeling. For example, Mrs. D might have had students return several times, throughout the ATOD unit, to their physical models of the neuron and had them revise the models in accordance with their increasing understanding of the way neurons function and how the effects of drugs and alcohol might alter the neurons. In this way students would be building a deeper understanding of the phenomenon of how neurons function and the subsequent changes that would occur to the neurons as a result of exposure to drugs or alcohol. Perhaps prior to studying the effects of drugs and alcohol on the brain, they could have used the models to make predictions about the ways in which drugs and alcohol would affect neurons, followed by a lesson on the actual process. Students might then have had an opportunity to revise their predictions based on their understanding of the models and the lesson.

As Svoboda and Passmore (2011) state in their article about the different modeling strategies used in biology education that, "Modeling, like inquiry more generally, is not a single method, but rather a complex suite of strategies" (p. 119) that are utilized and described in various ways within science and within science education. More exposure to the myriad ways in

which she could have utilized models in her unit would have provided Mrs. D with more options, and perhaps a more comprehensive use of models throughout her unit. This more comprehensive understanding is not only important for understanding the practice of modeling, but is important for all the NGSS dimensions and their constituent parts. Ultimately, students should be exposed to a variety of NGSS dimensions and to the variety of ways in which each of those NGSS dimensions are utilized in the real world by scientists and engineers to help students understand and explain science phenomena and make sense of the world.

The findings that Mrs. D sometimes struggled to decide which NGSS practice to utilize and the fact that she often utilized various practices in limited ways align with Osborne's (2014) conclusion that it will be especially important to provide educators with support for those the eight NGSS practices. By her own admission, Mrs. D knew that she struggled with understanding the practices:

> I need help with the science and engineering practices like I need more examples of that and how to do them feasible in a classroom setting… yeah, implementing the science and engineering practices getting them to think like scientists. …I think I would have liked some really good concrete [examples] (Interview, May, 21, 2014).

This suggests a need for the standards to be supplemented with materials or tools that will provide a clearer and broader picture of some of the NGSS practices as envisioned by the NGSS. I would add that this study also demonstrated a need for materials and tools for all three dimensions.

In his article, Osborne (2014) goes to great lengths to detail the kinds of knowledge about the eight NGSS practices that teachers will need in order to make sound discussions about the affordances of each practice. He admits that many teachers are being tasked with a challenging

endeavor, making the shift from inquiry-based teaching that was outlined by the NSES to practice-based teaching outlined in the NGSS. He is clear in his recommendations that in order for the NGSS to be successful, teachers will need support and time; these will be vital to acquire a good knowledge of the eight NGSS practices. Osborne (2014) goes on to suggest there is an additional level of pedagogical core ideas knowledge (PCK) that teachers will need to acquire around the NGSS practices. Krell and Kruger (2015), in their research on biology teachers' utilization of models and modeling, also point to the need to support teachers in their development of pedagogical core ideas knowledge as well as support their further development of core ideas knowledge in the area of modeling. I agree with Osborne (2014) and Krell and Kruger (2015), and my findings support this notion; not only will teachers need to attain a certain level of pedagogical core ideas knowledge around the practices and their constituent parts, my findings presented in Chapter V indicate teachers will most likely need to acquire a level of core ideas knowledge and pedagogical core ideas knowledge around *all* of the NGSS dimensions. As teachers develop and improve their PCK in relation to the NGSS it will be particularly important for teachers to focus their attention on the principal aim of the NGSS three dimensional learning. The aim is that through this weaving of the three dimensions, students deepen their understanding and develop the critical thinking skills to explain phenomena and design solutions to problems in order to help them make sense of the world around them.

Finding Two- Weaving the Three NGSS Dimensions was a Process

As stated previously, the weaving of the three NGSS dimensions as way to support students' development of the scientific critical thinking skills needed to be able to explain phenomena and design solutions to problems is the cornerstone of the NGSS. Recall from Chapter VI that *coming together* was the language Mrs. D and I used in our discussions to

describe the process of weaving the three dimensions. The findings demonstrated that Mrs. D noted the three dimensions coming together in various ways during the ATOD unit enactment as she described during ATOD Day 3. This lesson was highly scaffolded, with Mrs. D walking students through the CER framework. The following day, ATOD Day 4, Mrs. D identified the three dimensions coming together through students sharing out their own work of writing scientific explanations. On ATOD Day 5, Mrs. D described coming together as a process in which she identified only one dimension—first a practice, then a core idea—occurring in her teaching for the day. Although she identified two dimensions occurring on ATOD Day 5, she did not consider them working in concert. In many instances in the study, Mrs. D noted the three dimensions coming together as a process that took several days. As I noted in Chapter IV, there might be some in the science education community who believe the three dimensions must come together every day. The instances where she described the three dimensions coming together as a process challenges the reality that teachers and students should be able to experience or notice the three NGSS dimensions every day and in every lesson. I believe my findings show that creating opportunities to experience and notice the three NGSS dimensions coming together will sometimes take time for the teacher and students to accomplish.

I do believe, in some instances, it is realistic to assume teachers and students will experience the three dimensions working together in one day over one lesson. Nonetheless, I also contend that critics who believe that the three dimensions must occur *every* day in *every* lesson are not fully embracing the aim of the NGSS. The intent of the NGSS is to promote a deeper understanding of science through the weaving of the three NGSS dimensions. These abilities will take time to develop and teachers should create lessons that, over time, support students in developing this deeper understanding. Asking teachers to force the three dimensions into each

and every lesson of each day will be counter-productive to all the NGSS hope to attain. This is important because the science education professionals involved in creating support for science teachers should understand that weaving the three NGSS dimensions might take time. These professionals should encourage science teachers to create lessons that endeavor to develop students' higher level critical thinking skills through this weaving of the three dimensions so that students are able to explain phenomena and design solutions to problems, even if that means attaining that goal will take more than one day.

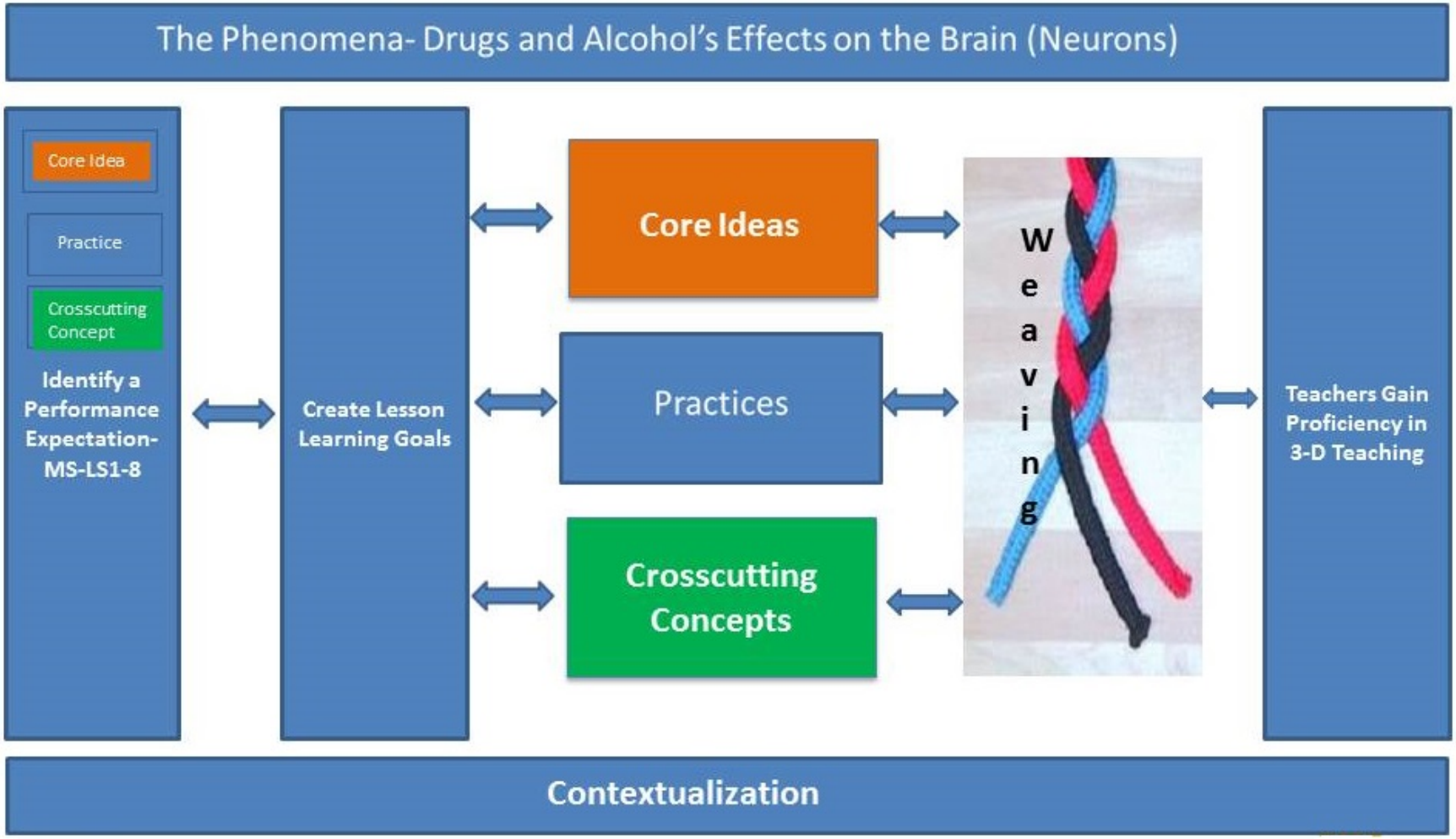
The findings that Mrs. D experienced coming together as a process that occurred over time align with Krajcik and colleagues (2014) who describe the process of teachers *constructing a storyline* and several smaller lesson level performance expectations over several lessons and chapters. In their article, they suggest that teachers should focus on a group of NGSS performance expectations and create a storyline and smaller lesson level performance expectations that break down the NGSS performance expectations into more manageable pieces. The storyline and the smaller lesson level performance expectations should support the development of the three dimensions *over time* with the final goal of helping students build proficiency described in the focal NGSS performance expectations and development of a deeper understanding and ability to explain phenomena or design solutions to problems. They suggest a 10-step process whereby science teachers would dissect the NGSS performance expectations and use them as guides to create smaller, lesson level performance expectations. Perhaps the storyline and the creation of lesson level performance expectations would be a good starting point for teachers to begin working on this complicated task of weaving the three NGSS dimensions.

The findings from my study suggest that perhaps science teachers may need to begin by creating shorter lesson level storylines. Mrs. D created her storyline around the phenomenon of the effects of drug and alcohol on the brain for her ATOD unit. Mrs. D focused on one performance expectation but utilized several different practices and two core ideas. The findings of this dissertation suggest that Mrs. D was attempting to make lesson level performance expectations through the creation of her learning goals (see Table 4-1 in Chapter IV). Perhaps with a deeper understanding of the dimensions and more practice in weaving the three NGSS dimensions, Mrs. D could have reached a moment in which she would have been able to create more elaborate storylines. I would posit that teachers may first need to create their own shorter lesson storylines with one, or a limited number of performance expectations. The shorter lesson level storylines may take one or several days to build up to the coming together of the three NGSS dimensions. However, these shorter lesson level storylines may help teachers to more fully understand, articulate, and identify instances of this process of coming together of the three dimensions in their planning and teaching. Through time and practice they too would be able to tell a more complete and complicated storyline that would include several lesson level performance expectations over the course of several lessons or chapters and that would incorporate several NGSS performance expectations. Teacher support needs to include more examples from the classroom in order for science teachers to better understand how to bring the three NGSS dimensions together as envisioned by NGSS and the *Framework*. In informal conversations with Mrs. D, she mentioned the need to see more concrete examples of lessons that brought together the three dimensions. The two professional development sessions were helpful but what she felt she really needed was more real-world examples.

What Does Implementing the NGSS Look Like?

Through the findings of this dissertation, I have begun to try to process and construct the process of implementing the NGSS as I understand them to be from analyzing the data. In Figure 7-1 I present my understanding of this process. Following Figure 7-1, I explain the process.

Figure 7-1 The Process of Implementing the NGSS



Although the process in Figure 7-1 is one dimensional and looks like a linear, right to left process, the double-sided arrows represent that implementing the NGSS and doing the weaving of the three dimensions—as I understand the process—is a very iterative process. As I explain below, each of the pieces support one another towards the goal of getting Mrs. D to develop proficiency in three dimensional teaching.

Mrs. D first began by identifying and proposing the science phenomenon that she wanted students to know and be able to explain: the effects of drugs and alcohol on the brain (neurons) and the subsequent physical and social effects of their use. That phenomenon ran consistently through her planning and teaching and that is why it runs the length of the process in Figure 7-1. The phenomenon in Figure 7-1 might be considered what Krajcik and colleagues (2014) call the storyline. Contextualization, the way Mrs. D incorporated current social and health issues to encourage students to develop critical thinking skills, further supported the phenomenon Mrs. D had chosen. Contextualization was a strategy that Mrs. D brought to bear throughout her planning and teaching and, consequently, it was a theme that ran throughout the findings of this dissertation.

Mrs. D then identified an NGSS performance expectation that aligned well with the phenomenon. In the first rectangle in Figure 7-1, Mrs. D chose the NGSS performance expectation MS-LS1-8. In alignment with the focal NGSS performance expectation, Mrs. D wanted students to be able to explain how neurons function and how, through the use of alcohol and drugs, normal neuron function would be affected and subsequently behavior and memory could be affected. After choosing the NGSS performance expectation, and using the phenomenon as her foundation, Mrs. D then set to planning and creating the various learning goals of the ATOD unit. As I presented in the findings chapters, Mrs. D chose various practices

and core ideas, and the crosscutting concept of cause and effect to create her learning goals. While Mrs. D taught the ATOD unit, she worked to identify instances during which the three dimensions were coming together both in her teaching and through her students' work. The findings indicate that as Mrs. D taught her ATOD unit she was also still planning and working through her learning goals and the three dimensions and the weaving of those three dimensions. This iterative process that Mrs. D displayed while planning and teaching seems to suggest that what is needed to implement the NGSS is very much a back and forth process.

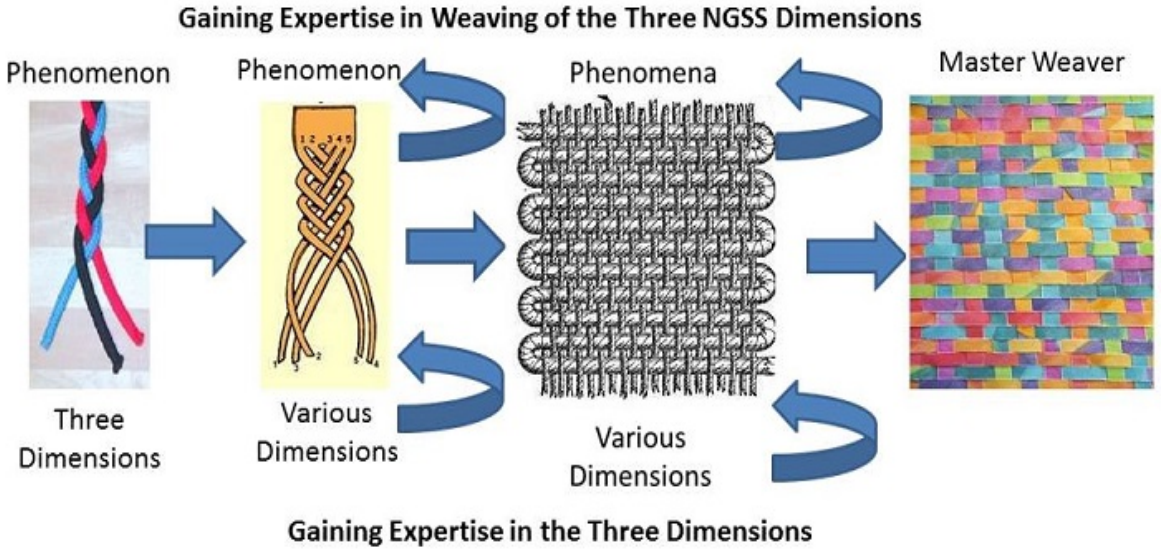
I propose the process described in Figure 7-1 might work as follows, beginning with the three dimensions in Figure 7-1 (core ideas, practices, crosscutting concepts). If we can help teachers to develop a better understanding of the three dimensions and their constituent parts, teachers will most likely develop and or improve their ability to do the work of weaving and identify instances of weaving in their practice. Conversely, if science teachers are able to develop a better understanding of what weaving is and what it looks like, they will gain a deeper understanding of the three dimensions and their constituent parts. Both steps of that process work to support one another. With a sharpened understanding of the three NGSS dimensions and the process of doing and identifying weaving, science teachers will be equipped to create better learning goals that support phenomena and/or create stronger storylines. The stronger storylines will support good decision making as they chose the performance expectations that best suit their students' needs. Conversely, as teachers become more familiar with the three dimensions and weaving, they will be better equipped to make decisions about which performance expectations can work together thereby creating better storylines and learning goals to fit the performance expectations.

As a science teacher becomes more familiar with the three NGSS dimensions and the process of weaving, she begins to incorporate more practices, core ideas, and crosscutting concepts and begins to move from novice to master weaver. The movement from novice to master weaver might look something like Figure 7-2. Reading from left to right, perhaps the science teacher begins by focusing on one phenomenon and only working within the confines of the three NGSS dimensions of one performance expectation. Quickly she realizes that she needs more dimensions to create lesson level learning goals that support students understanding and explaining the phenomenon and reaching proficiency in the performance expectation. Thus, the science teacher begins to incorporate more dimensions. Next, as she moves on and becomes more adept and comfortable weaving and more familiar with the three NGSS dimensions and their constituent parts, perhaps the science teacher begins to incorporate more phenomena based on more than one performance expectation and utilizes even more dimensions. As a master weaver, the final image in Figure 7-2, the science teacher has developed a deep understanding of the NGSS dimensions and their constituent parts and is able to utilize them and weave them beautifully to support multiple phenomena that integrate multiple performance expectations. In this dissertation, Mrs. D would have been operating at the second image as she utilized one phenomenon but various dimensions.

In this process of moving from a novice to master weaver, the science teachers gains proficiency in three dimensional teaching and is thereby able to align her practice with the NGSS vision of students' developing in their own three dimensional learning around phenomena. On paper this process sounds very straightforward, but this process of moving from novice to master weaver will take time and support. In the section that follows, I present some

suggestions about ways the science education community might think about how to best support teachers to do this complex work.

Figure 7-2 Novice to Master Weaver of the NGSS



Studies have speculated about (Krajcik et al, 2014; Osborne, 2014; Reiser, 2013; & Wilson, 2013), but not yet directly explored, the kind of work teachers will need to do in order to make this three dimensional weaving happen in their planning and teaching. That is not a criticism of the work that has been done to date on understanding teachers and the NGSS; I am merely pointing to a gap that needs filling. We know science content knowledge by teachers is very important (Anderson et al., 2001; Shulman, 1986); we know novice and some expert science teachers "have limited knowledge of the history and philosophy of science" and therefore struggle to support student learning of science processes (Gallaher, 1991, p.132). Teachers themselves often feel less than confident in their science content knowledge (Czerniak & Lumpe, 1996). We know some teachers also struggle to implement various practices (Svoboda &Passmore, 2011; McNeill & Krajcik, 2008). Because the crosscutting concepts are

new to standards, I have not found any studies focused on teachers' knowledge of the crosscutting concepts. The findings of this dissertation suggest more support might be necessary to help teachers understand the significance of the crosscutting concepts and identify them in their practice.

Therefore, we know some teachers struggle with the three dimensions separately. However, since the NGSS have only been in existence a relatively short time, we do not have a lot of research on what implementation of the three dimensions looks like in practice. At present, I know of no other research within the science education research community that has presented an in-depth teacher perspective on what it is actually like trying to implement the NGSS into a teacher's own practice without any highly structured support. My study represents a first step toward filling this gap by providing some much needed information about some of the experiences one teacher had while attempting to plan and teach with the various components of the NGSS.

The examples that do exist focus on teaching with the NGSS (NSTA.org, 2016). Investigating how Mrs. D was talking about planning and teaching provided a dual perspective into her decision making and sensemaking. I was able to get a more complete picture of what was challenging for Mrs. D as she tried to make sense of and make decisions about the NGSS both as she planned and taught with the NGSS. Looking only at the teaching aspect would have provided only part of the story of Mrs. D's decision making process and how complex this process of weaving really is. Westerman (1991), commenting on the importance of research on teachers' decision making, aptly stated, "This type of research [on teachers' decision making] led to the realization that teaching is a complex and cognitively demanding activity" (p. 292). Indeed, this study has shown that the work called for by the NGSS is going to be complex and

cognitively demanding. This study has also shown that the challenging work being asked for by NGSS is also attainable and support will be needed for science teachers to do the work well, as envisioned by the NGSS. The findings in Chapter VI present several instances in which Mrs. D was doing the work of weaving, but it was complicated work.

The NGSS are asking teachers to do something pedagogically with the three dimensions that is quite new, complex, and highly demanding. As I detailed earlier, teachers will need to have a solid foundation of knowledge around all of the NGSS dimensions and their constituent parts. As Reiser (2013) cautioned, it is not enough that teachers know the eight NGSS practices, teachers must also understand how they work together. I fully agree with that statement and I believe that in order to understand how they work together, teachers must also have a deep understanding of each practice (e.g. modeling and its constituent parts). I would also extend Reiser's comment to include the idea that it is not enough that teachers know the eight practices and how they work together, teachers must also know the seven crosscutting concepts and the core ideas related to their subject matter, and teachers must understand how they *all* work together. This task is going to require teachers to fundamentally shift their planning and teaching focus from isolated components to highly integrated components. Even for the most highly motivated and qualified teachers, like Mrs. D, this is not going to be an easy task to accomplish.

To be fair, the NGSS has done some of the heavy lifting in creating the performance expectations that outline what students should be able to know and do to attain proficiency around various science ideas at the end of each grade level. However, it is one thing to tell teachers what students should know and be able to do at the end of each grade level (through the NGSS performance expectations) but quite another story to actually put this weaving of the NGSS dimensions into practice. The bulk of the heavy lifting is now being placed on science

teachers to create lessons that actually weave the NGSS dimensions in a way that require students to then demonstrate their proficiency in the NGSS performance expectations. This is not going to be an easy task for teachers. Cognitively, we are asking teachers to make a huge shift in thinking about how they themselves have learned, how they have been taught, and how they have been teaching. As explained in the literature review, previous science standards, such as the NSES that were replaced by the NGSS, have treated science practice and core ideas as separate; this has been the case in most science classes for a very long time. Now we are asking teachers to purposefully and thoughtfully weave core ideas, practices, *and* crosscutting concepts into their lessons. Furthermore, the crosscutting concepts, although implicitly important to science, have not been prominent components in the standards prior to the NGSS.

The findings of this dissertation offer some ideas about ways in which we can support teachers as they begin to tackle the NGSS and to do this work of weaving the three NGSS dimensions into their own practice. Teachers will need support to develop a deeper understanding the three NGSS dimensions and their constituent parts and support to develop the skills necessary to weave the three dimensions into their curriculum. Additionally, teachers will need support to be able to identify when this weaving occurs both in their own teaching as well as be able to identify when their students demonstrate this competence. Although Mrs. D was confident in her ability to identify a phenomenon and utilize contextualization strategies, teachers, especially novice teachers will most likely need support to identify phenomena that is of interest to students and strategies for engaging students with the phenomena. So, how can the science education community make the NGSS more attainable for teachers?

How Can the Science Education Community Support Teachers Through the Process Described in Figure 7-1?

I would argue that if we want teachers to present science in a three dimensional way, we must also teach teachers in a three dimensional way. Loucks-Horsley and colleagues (1998) suggested a similar strategy in their book *Designing Professional Development for Teachers of Science and Mathematics* when presenting teachers with new science or math curriculum they noted it was beneficial for teachers to experience learning the curriculum in ways that were similar to how their students would eventually experience the curriculum. That would mean professional development sessions presented in terms of all three NGSS dimensions so that teachers would experience learning science similar to how the students would learn it (Mundry & Loucks-Horsley, 1999). For example, regardless of the teacher's comfort with the science core ideas, they would benefit from learning the science core ideas, in concert with the practices and crosscutting concepts. The NGSS should be presented to teachers via three dimensional teaching, and in alignment with the vision of the NGSS and the *Framework*. However, it is not enough that science education experts simply create professional development sessions to present to science teachers. Just as students must be actively involved in their leaning, teachers must be actively involved in the process of learning to work with the NGSS.

Science teachers are an integral part of the success of standards implementation; not only should science teachers be actively involved in their learning about the NGSS, but they should be actively providing input on how professional development should be structured. This input should be recognized and valued. Kleiger and Yakobovitch (2012) also understood and commented on the importance of teachers working collaboratively to understand and implement new science standards; they understood the importance of teacher input in developing

professional development sessions as possible ways to improve standards' implementation. In addition, professional development should provide teachers with multiple opportunities to practice what they have learned and ample time to reflect on that experience and their learning (Allen & Penuel, 2015; Wilson, 2013). The design of this study, as an in-depth case study, provided many opportunities for Mrs. D to work through her sensemaking process as she practiced utilizing various components of the NGSS as well as provided various opportunities to reflect during our debriefs. This experience of reflection and sensemaking might have been more productive had she also had the added factor of more peer collaboration or a social component as Weick (1995) includes in his seven proposed characteristics of sensemaking. Other researchers have also found these social interactions among peers as well as other experts in their fields to be extremely valuable to teachers taking on and making sense of new education reform (Coburn, 2001; Spillane, 1999).

Working collaboratively with peers might be one way to help teachers develop the skills needed to implement the NGSS. The findings of this dissertation suggest that Mrs. D's and my working together, as peers, was helpful to Mrs. D. When I asked her about whether her experience participating in the study had been a positive one, she stated, "Big time! The positives, well, you coming out here has definitely pushed me to be a better teacher in this last month" (Interview, May 21, 2014). This idea of me being physically present in the classroom in California to collaborate with Mrs. D as she worked to integrate the NGSS into her ATOD unit also touches upon the notion of situated learning and the context in which teachers learn. Bertrand and Marsh (2015) and Spillane (2009), all suggest that the context of school is an important place for teachers to makes sense of and learn about their practice. Their ideas about the importance of context suggests that locating these learning opportunities for science teachers

to work with one another to understand the NGSS in the context of their own schools and classrooms provides positive learning spaces. As the science education community works to create the spaces for science teachers to learn about the NGSS we should also think about where the most productive learning spaces might be. Learning spaces within the teachers' own schools and classrooms with their peers might be the best place to start.

In reflecting on our time together, Mrs. D also stated that it was extremely helpful to discuss the lessons and the various NGSS dimensions she wanted to use as she planned the ATOD unit. Mrs. D stated, "I think it's good for me [to be a part of this study and planning] (Interview, December 13, 2012) and "Look how much you've inspired me (Interview, February 26, 2013). This opportunity to learn was inspiring for me as well, since I was able to work with such an experienced, passionate and dedicated teacher. Our discussions about her experience using the NGSS helped bring the challenges of using the NGSS to the fore and I believe helped her work through some of the struggles. In essence, we were learning together and this was a powerful experience for both of us as we worked to make sense of what it meant for a teacher to weave the NGSS into her planning and teaching. Mrs. D's comments above would seem to suggest that perhaps more opportunities to work with peers would have, at the very least, provided some positive support as she tackled this complicated task. That is, opportunities to do peer planning, teaching, and observations, receiving and providing peer-to-peer feedback would be beneficial and could help teachers work through implementing and making sense of the NGSS.

Perhaps teacher led professional development, where teachers come together to share lessons and share moments of noticing and simply debrief about how to make those NGSS dimension connections stronger or more visible, would be equally as constructive for other

teachers. This call for peer collaboration by teachers echoes other studies on teachers and reform, and the kinds of professional development support that might be beneficial for science teachers taking on the NGSS. My study supports the findings of other studies that call for more peer and collaborative support to understand standards reform and policy enactment. The study by Allen and Penuel (2015) details a case study of three teachers' sensemaking around professional development focused on the NGSS. They found that teachers who were able work collaboratively to make sense of the new reform, and had support from their local school administrators were able to more fully participate in the process of sensemaking. They concluded that, "Teachers need opportunities to engage in collaborative and sustained sensemaking to see, understand, and work through [various] incongruities" (Allen and Penuel, 2015, p. 147). In other words, teachers need to be actively involved in their learning. They further suggest, "Successful implementation of new standards will require focused attention to teachers' sensemaking and the development of supports that help teachers make sense of ambiguous situations and manage uncertainty" (Allen and Penuel, 2015, p. 147). The findings of this dissertation suggest that it was constructive for Mrs. D to verbalize those instances where she believed she saw this weaving coming together as well to describe the process of the three NGSS dimensions coming together over time. I believe the debriefs really helped remind Mrs. D and helped her notice that she was always working towards students being able to explain the phenomenon and then towards having proficiency in the focal NGSS performance expectation. Coburn (2001) looked at teachers' collective sensemaking—making sense of the world through interactions and conversations with fellow practitioners within their community of practice—around reading policy. She found that collective sensemaking helped teachers not only increase

the resources and expertise available to teachers but also helped them grapple with and ultimately integrate new policy ideas into their classrooms (Coburn, 2001).

As noted above collaborative work is an important practice to help teachers make sense of complex education reform such as the NGSS. The collaborative work in this study was somewhat limited. I purposefully took a less active role in the planning and teaching because I wanted to focus on Mrs. D experience without my researcher input. However, as I noted previously, I would argue that the instances during her planning interviews and debriefs when Mrs. D was able to share her thinking about the NGSS still had that positive social aspect of the sensemaking process. These social exchanges seemed to make her experience in the study more fulfilling; as she noted, "It's good for me," and "It's inspiring". Perhaps her sensemaking process would have been more comprehensive had it included more opportunities for collective sensemaking, such as those described and encouraged in the studies by Allen and Penuel (2015) and Coburn's (2001).

Similar experiences could be created by providing teachers with the time, opportunities, and resources (professional development) to meet and discuss their planning and teaching with one another as well as observing classroom activities of other science teachers implementing the NGSS. Teachers need time and professional development opportunities to develop their sensemaking around policy issues (Allen & Penuel, 2015; Coburn, 2001; Coburn, 2005) like the NGSS. The professional development activities should provide teachers with material resources, and especially time and space to discuss and share out with other teachers as they strive to attain the goal of three dimensional learning as supported by the NGSS and the *Framework*. The consequences of not supporting teachers is aptly described by Spillane (1999) who cautions, "Absent a teaching population with both some threshold level of individual capacity to

appreciate the core reform ideas and access a rich array of social and material resources to support their learning, external reform initiatives alone are unlikely to bring about substantial changes in the core of practice" (p. 171). For the NGSS vision to be successful we must provide the time, materials and social resources for teachers to be successful.

Finding Three- A Need to Look Beyond the Science Domain; Health and Contextualization Approaches to Engaging Students

Finally, a most interesting and unanticipated, yet equally significant, finding of this study was that Mrs. D utilized health core ideas as a way to contextualize the science core ideas in an attempt to present both in a way that was engaging to the students. To contextualize the science phenomenon of how drugs and alcohol affect the brain and subsequently behavior and memory, Mrs. D presented various real-world instances and social media related to relevant health issues. What Mrs. D was doing in the classroom was to use relevant health issues and contextualization as a pedagogical strategy that allowed students to better engage with the science ideas. Although health is typically a subject taught separate from the sciences, Mrs. D was very thoughtful about what and how she presented the science and health ideas so that they were not only relevant and engaging to students but also touched upon the science ideas deemed important by NGSS. Below, I explicate this connection between health, science, and contextualization.

Health in Science Through Contextualization

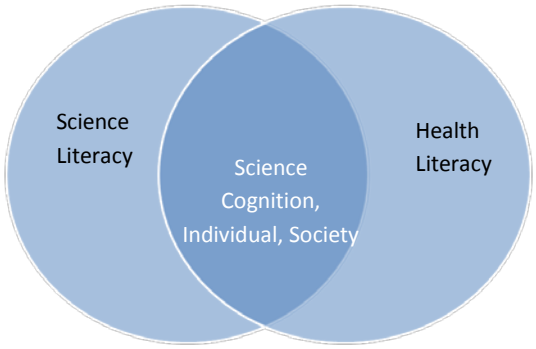
I, like other science education scholars use the World Health Organization's (WHO) definition of health literacy as a way to support the call for more health related issues in science education (Faria et al, 2014; Schulz and Nakamoto, 2012; Dillon, 2012). The World Health Organization defines health literacy as "the cognitive and social skills which determine the

motivation and ability of individuals to gain access to, understand, and use information in ways which promote and maintain good health" (WHO, 2015). In Chapter 2, the literature review, I presented this definition of scientific literacy from Science for All Americans (SFAA):

> One who was aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; was familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (SFAA, 1990, Introduction, Recommendations, second paragraph).

Using these two definitions—health literacy and science literacy—one can locate a compelling intersection of science and health literacy at this cognitive, social, and individual level as shown in Figure 7-2. In the section below, I will describe in more detail how health and science education researchers describe this important link between the two literacies as a way to promote student learning in both domains.

Figure 7-VII-3 The intersection of health and science literacy as a way to meet the expectations of the NGSS and make the science interesting and relevant to students' lives.



The meaningful intersection of science and health literacy occurs at the cognition of science knowledge and the scientific ways of thinking that can support the empowerment of individuals to make informed discussions that promote and maintain good health both on an

individual and societal level (See Figure 7-2). Many prominent scholars in the field of science education agree that both health and environmental issues hold an important place in science education and in supporting students to become scientifically literate (Bybee, 2012; Zeyer, 2012; 2008; Dillon, 2012; Bricker et al, 2014). These same scholars make the case that a concerted effort should be made to include health and environmental issues in the sciences as a way to make the science relevant to students' lives. Using the strategy of contextualization is one way to include health issues in science in a way that is relevant to students' lives.

In Chapter VI, I defined contextualization as the way in which Mrs. D utilized the various NGSS dimensions in concert with current social and health issues to support students' development of critical thinking skills to be able to explain phenomena related to the effects of drugs and alcohol on the brain (neurons). Current health and social issues involved ideas that Mrs. D believed were relevant and engaging and helped her students develop ethically and morally around science and health issues related to the effects of drug and alcohol use on the brain. Through contextualization Mrs. D aimed to demonstrate to her students that science and society were interdependent and could directly impact their lives. I drew my definition from Sadler (2009) and Zeidler and colleagues' (2005) ideas of the use of socio-scientific issues in the science classrooms. In my opinion combining both definitions helped more accurately reflect how Mrs. D approached contextualization as a way to promote her students' science, ethical and moral development in her ATOD unit and to show that science and society are interdependent.

The fact that Mrs. D purposefully chose to integrate the NGSS into her ATOD unit demonstrates her ability to broaden her views beyond the traditional domain of biology. Specifically, the findings in Chapter VI aimed to present specific instances during which I noted that Mrs. D was using the strategy of contextualization. I posit that the findings from this

dissertation show that Mrs. D was able to bring together health and science ideas in a way that was relevant to students' lives through utilizing the strategy of contextualization. The instances of contextualization and the instances in which Mrs. D was specifically talking about the connections between science and health that are presented in this dissertation are exemplars of this intersection of science cognition, individual, and society I describe in Figure 7-2.

As Rivet and Krajcik (2008) suggest, contextualization attempts to support students' understanding of challenging science ideas through leveraging students' experiences and prior knowledge. In their study of contextualizing instruction for middle school science students, they purposefully created curriculum materials that fostered contextualization through project-based instruction around the driving question, "Why do I need to wear a helmet when I ride a bike?" (Rivet and Krajcik, 2008, p. 83). Rivet and Krajcik's (2008) study focused on students' use of contextualizing features in the unit to foster learning outcomes; the results of the study were positive in both motivating students and supporting their learning.

In the case of Mrs. D, her contextualization strategy was more organic and related to specific current event issues that students were experiencing at the time the ATOD unit was being implemented. Similar to Zeidler and colleagues' (2005) work on socio-scientific issues in the classroom, I would argue that Mrs. D was attempting to not only foster student learning about the effects of drugs and alcohol on the brain but she was simultaneously attempting to "tap into students' personal philosophies and belief systems" (p. 371) through her ATOD unit. Mrs. D used an example of a famous young person having to cancel concerts and recover from a respiratory illness, possibly due to smoking tobacco or marijuana, to demonstrate the possible negative effects of drug and alcohol use both from a scientific, health, and social perspective. She made a powerful statement about the devastating effects of drugs on communities of color

and the statement was made even more powerful when she stated, “our communities” and included herself as a member of the students’ community.

Mrs. D felt that her adolescent students likely didn’t understand the repercussions of drug and alcohol use and were likely being challenged by peers to try alcohol and other drugs like marijuana. As presented in the literature review, as youths’ perceptions of the dangers of marijuana have gone down, use has gone up (NIH, 1998; NIH, 2012; NIH, IOM, 2013). I would posit that through contextualization, Mrs. D was challenging students’ personal philosophies and belief systems around marijuana by presenting the scientific view of what happens to your brain when you use drugs and alcohol. Likewise, because of Mrs. D’s science and public health background, she also understood the health and social consequences of drug and alcohol use. As discussed in Chapter I, early drug use exposes adolescents to a myriad of future physical and mental health issues (National Research Council-Institutes of Medicine report, 2013). Mrs. D’s hope was that if students had the science knowledge about how drugs and alcohol affect the brain, they would be more likely to make better and more informed life decisions.

Ultimately, what might be the gold standard of contextualization is students’ ability to contextualize the core ideas for themselves as one indication that students are engaging with and grasping the science concepts. I presented one instance in Chapter 5 when Rudy moved to contextualize the science core ideas of the function of the cerebral cortex into a social context that showed he was thinking about how a disruption in the cerebral cortex because of the brain’s exposure to drugs might disrupt a young person’s ability to make good discussions. This instance of a student contextualizing the science core ideas seems to complement Sadler and colleagues (2007) ideas about students’ engagement in socio-scientific inquiry to develop socio-scientific reasoning skills. In their study they looked at students’ ability to use socio-scientific reasoning as

a result of participating in a curriculum that fostered socio-scientific inquiry ("the integration of science concepts and processes with social constructs and practices," p. 371-372). They suggest that the use of socio-scientific inquiry has the "potential to foster citizenship education" whereby students are prepared to actively participate in "modern democracies" (p. 372). Similarly, Mrs. D wanted her students to gain a deeper understanding of the science phenomenon of the effects of drugs and alcohol on the brain so that they would be better informed, or educated, from an individual health and social point of view to understand "the realistic perception and consequence of what drug use does" (Interview, May 9, 2014). In that way, I argue, she was fostering citizen education in her classroom.

Unfortunately, because the focus of the study was not on student work, my video recordings of the classroom focused on Mrs. D's teaching and not on student responses. I was able to pick up some student exchanges but it is highly likely that I missed opportunities to demonstrate that other students were capable of contextualizing the science. Future studies might look at how students develop the ability to contextualize science ideas as a result of their teacher's ability to contextualize. Future studies might also look at student performance when teachers attempt to contextualize the science ideas for them and whether that helps students to develop a deeper understanding of the science and engineering being presented. Likewise, it would be important to study students' experiences when a teacher attempts to contextualize the science core ideas. The focus of this study was around Mrs. D and I noted the areas in which I thought Mrs. D was contextualizing the core ideas; student input or experiences with contextualization were beyond the scope of this study and would need to be addressed in a future study.

The passion with which Mrs. D thought about the importance of utilizing health to help students understand the science core ideas cannot be overstated. As a science community, we should not limit these kinds of connections between students' lived experiences and the science that helps students understand those experiences. The challenge will be in figuring out how to support teachers to develop the skills to contextualize. That challenge is beyond the scope of this study but future studies would ideally study how various teachers utilize contextualization in their classrooms. Perhaps strategies could be developed from those teachers that could be utilized to help other teachers develop their own strategies to contextualize.

Conclusion and Implications for Future Studies

The amalgam of core ideas and pedagogical knowledge that will be needed by teachers in order to implement the NGSS, as envisioned by the NGSS and *Framework* committees, will require much thought and support for and by teachers. One cannot forget or diminish the fact that the NGSS are asking teachers to do a very new, complex, and complicated task. Teachers are going to need time and support to acquire the necessary expertise to make sense of and utilize the NGSS in their teaching and planning as envisioned by NGSS.

As discussed throughout this chapter, there are several components and constituent parts that make up the NGSS that teachers will need support to master: the three main components—disciplinary core ideas, crosscutting concepts, scientific practices —and their components (e.g. analyzing and interpreting data, writing scientific explanations, and modeling) as well as the constituent parts of those components. Modelling is a science and engineering practice that has various constituent parts that can be employed in the classroom (e.g. to help students to develop questions to be studied, to develop hypotheses to be tested, and to revise and refine their models to support a deeper development of understanding). Pedagogically speaking, teachers will need

support to skillfully weave the three dimensions together in a way that supports student learning of the science. As I suggest in Figure 7-1, the process of developing expertise to utilize the NGSS successfully is an alternating, back-and-forth process. As science teachers become more familiar with the three NGSS dimensions and their constituent parts, their ability to weave and identify instances of weaving will improve. Conversely, as science teachers become master weavers, they will develop a deeper understanding of the three NGSS dimensions.

The challenge is in supporting teachers to do the complex work that the NGSS are asking them to do. A suggestion for the kind of support that might be beneficial to teachers is peer-led professional development in which teachers come together to discuss instances where they experience or notice three dimensional teaching and learning occurring. Having time to tease apart those instances and discuss with peers the successes and the struggles it took to attain those moments seemed to have been particularly helpful to Mrs. D and might form the bases for future professional development sessions related to three dimensional teaching and learning. Finally, Mrs. D possessed a powerful knowledge of her students and their communities that allowed her to contextualize the science and health core ideas in a way that engaged her students. This theme ran consistently throughout Mrs. D's planning and teaching of the ATOD unit and is depicted in Figure 7-1. The potential of contextualization cannot be overstated, it provided much of the foundation for the ATOD unit and it was the driving force that motivated Mrs. D to teach the ATOD unit. I would argue that Mrs. D was quite successful at utilizing the NGSS for the first time precisely because she was able to find ways to contextualize the science through the health issue of alcohol and drugs' effects on the brain and subsequent effects on behavior and memory as well as the possible negative social implications.

What is involved to support in-service science teachers taking up the NGSS?

The findings from this study suggest that professional development around teacher uptake of the NGSS should tap into the prior knowledge of the science teacher. For Mrs. D, her expertise was in public health and in contextualizing the knowledge she possessed about her students. Mrs. D utilized this knowledge to create a health unit that she felt confident in teaching in this new way. Similar to science education that advocates that science teachers tap into students' prior knowledge around the science ideas, the architects of NGSS professional development sessions should also work to tap into the science teachers' prior knowledge. Science teachers' prior knowledge is a starting point from which to support teachers as they work to make sense of the NGSS and work to create their own lessons that weave the NGSS dimensions within areas they feel they have expertise.

However, it is not enough that the architects of NGSS professional development create opportunities to tap into science teachers' own experiences and knowledge. The architects must learn to work *with* the science teachers as they work with their own expertise and develop mastery of the NGSS. As this study showed, it was a powerful learning experience for both Mrs. D and me as we moved *together* through this process of making sense of and learning about the implementation of NGSS dimensions within a science classroom. It was also important that much of the learning and exchanges occurred within the context of Mrs. D's classroom. This brings to mind the theories of sensemaking and situated learning that have been discussed previously in this dissertation. Both theories value the ideas of the construction of the individual identity as the learner is learning. Likewise, for teachers, the construction of their individual identity comes from the prior knowledge and expertise they bring to their practice. This is important because that identity will ultimately help each teacher develop their own

understanding of the NGSS. Both theories also value the need for social interaction to support learning. For teachers this would manifest itself by creating professional development opportunities that encourage science teachers to work collaboratively as they develop an understanding of the NGSS. Finally, both theories value the identification and importance of a learning environment. Similarly having professional development sessions within the learning environment of the classroom and within the school setting will support teacher learning of the NGSS. These theoretical ideas will be important to recognize as the field moves forward to support teachers' successful implementation of the NGSS.

Scaling-up to support the vision of teacher-led and more individualized professional development sessions for large populations of science teachers to develop expertise to utilize the NGSS will likely be challenging. Master science teachers could be trained in the use of the NGSS. They could then then go back to their schools to help other science teachers to tap into and develop their own expertise. To encourage continued growth in expertise around the NGSS, teachers would then work together at their schools. Teachers could share lessons, observe one another, and provide feedback. One of the challenges Mrs. D encountered was a lack of concrete examples of the NGSS in use in the science classroom. Providing opportunities for teachers to share and co-create lessons and then observe those lessons in action would create powerful learning opportunities and provide concrete examples of the NGSS in use that other teachers could tweak to fit their own expertise and experience, and could customize to their own student populations. This development of expertise in the NGSS, which is both ongoing and retrospective Weick (1995), will need to be ongoing and it will take time. The field must provide time for science teachers to reflect on their teaching so that their sensemaking includes moments

in which they can be retrospective about their learning, which in turn will support the development of their expertise in the NGSS.

Future Research

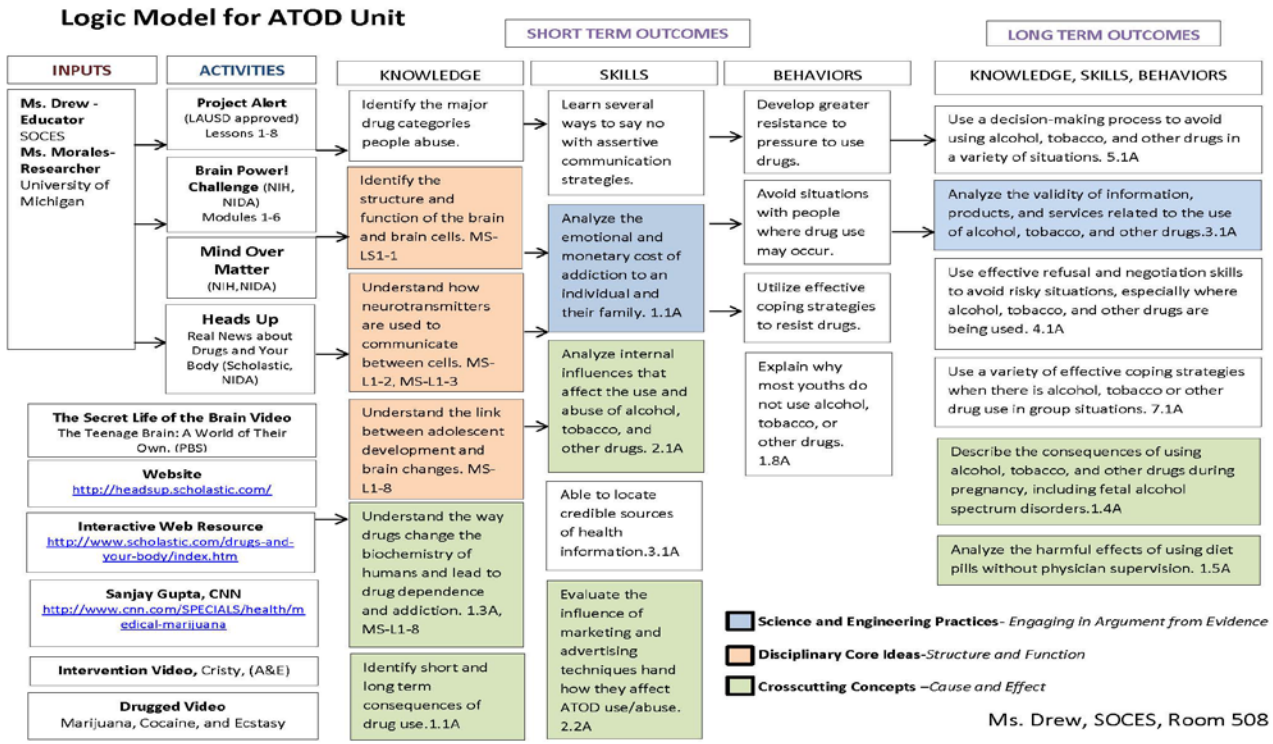
Future studies could investigate the process by which master teachers are trained and then go out to the classroom to support the development of other science teachers around the NGSS. The research could study, over time and through the lens of the theories of sensemaking and situated learning, the development of expertise by both the master teacher and the teacher who is developing expertise in implementing the NGSS. While I did use the theories of situated learning and sensemaking to help me make sense of Mrs. D's experience, I did not specifically study Mrs. D's experience through the lens of the theories of sensemaking and situated learning. Similarly, this study did not look at how Mrs. D developed her understanding of the NGSS dimensions or weaving over time. Future studies could look at how teachers might move from novice to master weavers (Figure 7-2) through those theories. Research could simultaneously investigate the development of teacher understanding of the three NGSS dimensions and their constituent parts, and the alternating process of developing expertise in weaving and expertise in the NGSS dimensions and their constituent parts.

The literature on the NGSS is beginning to grow as more states and districts are working to understand how to integrate the NGSS into their frameworks. This dissertation is distinct and adds to this important body of literature on the NGSS because no other studies to date have looked in-depth at one teacher's experience utilizing the NGSS in her own practice. The present study, reporting on the experience of one seasoned science teacher and uncovering many interesting facets related to implementing the NGSS was, of course, limited in its scope and generalizability. However, this study is an important contribution to the science education

communities understanding of the kinds of challenges science teachers will likely face as they attempt to implement the NGSS. I contend that more in-depth case studies like the present study are needed and that future case studies should include more teachers of various teaching experience, in order to more fully understand the kinds of support teachers will need to successfully implement the NGSS as envisioned by the NGSS and *Framework*. It is through these more detailed case-study examples that we get a more genuine picture of teachers enacting reform. Self-reports and surveys, while an essential part of our research, are limited in that they only give us a very small glimpse into teachers' thoughts and beliefs. The NGSS are relatively new, and there is much work yet to be done; this study was only a first step towards some answers to the important question: "How can the science education community support teachers to do the challenging work asked for in the NGSS"? I hope this study has piqued the interest of those within the science education community to continue the work of supporting and working alongside science teachers to ensure success in utilizing this new, complex, and challenging, science education reform.

APPENDICES

Appendix A. ATOD Logic Model



Appendix B. ATOD Unit Plan

WEEK 1					
DATE	**LESSON DESCRIPTION PERIOD 2,4**	**NGSS Learning Goal**	**NGSS/ Practice Used**	**CA Health Standard**	**Three Dimensions- Coming Together**
Wednesday April 30 Per. 2, 4 *114 min*	**ATOD DAY ONE** **PROJECT ALERT: Lesson 1 Introduction to Project Alert** Ground Rules, Individual KWL on DRUGS (ATOD) Groups for Reasons List, Compare Marijuana and Alcohol **Homework:** Drugs Foldable page 299		8-1, 8-4, 8-2, 8-5	1.1A 1.7A 2.1A	No Introduction to ATOD
Friday May 2 Per. 2, 4 *114 min.*	**ATOD DAY TWO** **Accessing Valid Health Information** Evaluate google search results together on Promethean board **Source Quality Pyramid Activity** Classroom brainstorm master checklist for evaluating resources **Homework:** Bring an article about drugs and the body to class. Page 197 (1-6)	**1. Students will gather, read, and evaluate online or print data that describes how marijuana consumption affects behavior due to the manner by which it was processed in the brain.**	8-2, 8-4, 8-5		Not Yet 1 Dimension: Practice
Week 2					
Wednesday May 7 Per. 2,4	**ATOD DAY THREE** Short video clip intro. the curriculum **PROJECT ALERT: Lesson 2 Consequences of Cigarettes and Marijuana**	**2. Students will analyze and interpret data about drug effects (short-long**	8-2, 8-4, 8-5 8-4, 8-5	1.3A	Yes: Three Dimensions Coming Together

114 min.	Review Reliability and Validity Use master list on Marijuana article and on article brought in for homework **Claim, Evidence, Reasoning Lesson** Use Mr. G Spaghetti Story to identify claim, evidence and reasoning Use CER on Marijuana article from NIDA Read article out loud with students taking turns. Students will underline/highlight key findings. Teacher will demonstrate how to pick out a claim, evidence, and how to write a reasoning statement that explains the logic. **Homework:** Finish CER assignment using the marijuana article and own article found on one drug and its effects on the body	**term) that describes how drug consumption affects behavior and memory.**			
Friday **May 9** Per. 2,4 *114 min.*	**ATOD DAY FOUR** Pot the Party Crasher video clip used to practice CER *First Time, After a While, After a Long Time* charts for cigarettes and marijuana in health log Students will use the article they brought in to provide their own results Homework: Finish CER for their own article TedEd video on Brain Homework: Neuron and Brain Diagram to Color and Label		8-4, 8-5	1.3A	Yes: Three Dimensions Coming Together
Week 3					
Wednesday **May 14** Per. 2,4 *114 min.*	**ATOD DAY FIVE** **Drug Groups Defined** **An Introduction to the Brain and Nervous System** Basic Brain Anatomy and Nervous System Complete CER homework in class		8-2		Not Yet 1 Dimension: Disciplinary core idea

	Intro. to neurotransmission Homework: Neurotransmission Worksheet				
Friday **May 16** Per. 2,4 *114 min.*	**ATOD DAY SIX** **Drug Groups Card Sort** Basic Brain Anatomy Reviewed Neuron components, Neurotransmitters and Neurotransmission Neurotransmission videos		8-2, 8-4 8-5, 8-6		Not Yet 2 Dimensions: DCI and Practice
Week 4					
Wednesday **May 21** Per. 2,4 *114 min.*	**ATOD DAY SEVEN** **PROJECT ALERT: Lesson 5 Social Pressures to Use Drugs** Lindsey's Choice Video Clip Ways to Say No Discussed in Pairs and then Whole Group Reward Center Neurotransmission Step by Step Groups Formed by Choice **Homework:** Brain and Body Connection Worksheet		8-2, 8-4, 8-5, 8-6		Not Yet DCI and CCC
Friday **May 23** Per. 2,4 *114 min.*	**ATOD DAY EIGHT** **Group Time to work on Projects**	**3. Students will create models to describe the structure and function of neurotransmission (transmitting signals that travel along the nerve cells). The signals are then processed in the brain, resulting in immediate behaviors and memories.**			Yes Three Dimensions Coming Together
Week 5					

Wednesday **May 28** Per. 2, 4 *114 min.*	**ATOD DAY NINE** Drug Group Project Presentations **PROJECT ALERT: Lesson 6 Resisting Internal and External Pressures to Use Drugs** Pot or Not? Video Refusal Skills Review Clearing the Air Video – Smoking Cigarettes and Benefits of Quitting	**((4. Students will construct explanations and design solutions for drug addiction based on their knowledge of neurotransmission and how the drugs cause changes in behavior and memory.))**	8-2, 8-4, 8-5, 8-6		Yes Three Dimensions Coming Together
Friday **May 30** *Per. 2, 4* *114 min.*	**ATOD DAY TEN** **Drug Group Project Presentations** **Christy Video** **Discussion**	**5. Students will create models to describe the structure and function of neurotransmission (transmitting signals that travel along the nerve cells). The signals are then processed in the brain, resulting in immediate behaviors and memories.** **ADDED 6. Students will gather, read, and evaluate online or print data that describes how methamphetamine and alcohol consumption affects behavior due to the manner by which it was processed in the**	8-2, 8-4, 8-5, 8-6		Yes

		brain.			
Monday June 2	**Drug Group Project Presentations** **Christy Video** **Discussion**	**Same as above**			

ATOD UNIT MIDDLE SCHOOL HEALTH

**omitted Project Alert lessons 3, 4, 7, and 8 due to curriculum addition of Brain Power curriculum (NIH)*
**omitted Brain Power NIH curriculum activities – used worksheets for definitions and homework*

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