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EDUCATORS’ UNDERSTANDING OF SCIENTIFIC SENSEMAKING AND LITERACY: A CULTURAL-HISTORICAL ACTIVITY THEORY ANALYSIS

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ABSTRACT

The purpose of this qualitative study was to describe a community of middle school science educators' understandings of scientific sensemaking and literacy during their participation in professional development. Six teachers from Marksboro Middle School initiated and participated in a semester-long book study of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). Three of these science teachers also participated in an interdisciplinary workshop series on sensemaking and literacy across the curriculum with three additional school colleagues from other disciplines conducted by a regional science professional developer and the author, a literacy education scholar. Two professional developers also participated in this study.

This study explored two research questions: (1) How were middle school teachers' and professional development providers' understandings of scientific sensemaking and literacy demonstrated during their participation in professional development? (2) How were these understandings mediated by the *Ambitious Science Teaching* book discussion activity system within which this work was situated?

Central to this investigation was use of Cultural Historical Activity Theory (CHAT) as both a theoretical and analytical framework. CHAT provided a way to capture the complexity of teachers' activity and how their understandings were mediated by systemic elements. These elements included social and historical factors of both individuals and educational institutions. This framework was also supported by the use of qualitative research methods and Actor-Network Theory (ANT).

Educators described their understanding of scientific sensemaking and literacy in similar ways. Descriptions of each included cognitive and social processes of grappling with

information, however, what counted as information differed. Sensemaking was generally discussed as a process focused on a scientific phenomenon. Literacy was generally regarded as reading print-based and multi-modal texts. Throughout their work together, teachers also considered students' equitable engagement in classroom discourse as a feature of sensemaking-oriented instruction.

Through their involvement in the activity system, educators demonstrated further understanding of sensemaking as a discrete activity as well as an extended process in which students engage in while learning through science instructional units called storylines. Through their collaborative activity, educators also demonstrated understanding of literacy as incorporating a variety of communicative modes, with student talk serving as the primary vehicle for students' sensemaking. Literacy was also understood as a set of tools students' draw upon when engaging in sensemaking. Teachers actions during book discussions demonstrated that considering how to support students' literacy was a taken for granted component of planning for students' sensemaking.

Teachers' demonstrations of these understandings were mediated through the community's use of the pedagogical suggestions provided by *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018), consideration of performance expectations included in their state standards, and incorporation of resources beyond the focal text. It was bounded and challenged by institutional factors such as time constraints for instruction and the influence of statewide assessments.

The findings of this study build on previous research in science education and literacy education and support Hinchman and O'Brien's (2019) call for literacy scholars to consider a hybridized view of disciplinary literacy. By considering scientific sensemaking and literacy as a dialectic, this study positions literacy as an inherent component of science teaching, rather than as a separate goal for educators to address. It has implications for literacy practitioners working in science spaces and for both science education and literacy education scholars researching sensemaking and disciplinary literacies.

EDUCATORS’ UNDERSTANDING OF SCIENTIFIC SENSEMAKING AND LITERACY: A CULTURAL-HISTORICAL ACTIVITY THEORY ANALYSIS

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DISSERTATION

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DEDICATION

I dedicate this work to the “Lit Lab Lifers.” May your deeds and brilliance dazzle the world and make trails for those who follow.

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CHAPTER 1: INTRODUCTION

Purpose of the Study

The purpose of this qualitative study was to describe a community of educators' understandings of scientific sensemaking and literacy during their participation in professional development. The community described in this study consisted of six Marksboro Middle School science teachers and the other teachers and professional development providers, including myself, with whom they interacted during professional development one spring. The science teachers initiated a teacher-led book study of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) to facilitate their efforts to develop curricular units tied to new state standards. Three teachers from the book study group attended an additional workshop series on scientific sensemaking and literacy at Marksboro Middle School co-led by a regional professional development provider and me. Cultural Historical Activity Theory (CHAT) was used as a theoretical lens and analysis tool to explore how the community of practice, and available teaching resources, as well as explicit and implicit institutional and cultural factors mediated educators' insights. Analysis was also supported by qualitative research methods and Actor-Network Theory (ANT). More specific research questions were:

1. How were middle school teachers and professional development providers understandings of scientific sensemaking and literacy demonstrated during their participation in professional development?
2. How were these understandings mediated by the *Ambitious Science Teaching* book discussion activity system within which this work was situated?

This study documents science teachers' willingness to enthusiastically engage in conversations around new standards and pedagogical recommendations in order to enhance their science instruction. It also illustrates how teachers' descriptions of scientific sensemaking and literacy were mediated by their interactions with one another as well as with colleagues from other disciplines, by the district's curricular decisions, by the New York State Science Learning Standards (NYSSLS, New York State Education Department, 2016), and by professional resources such as *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018). Larger social structures such as race, class, gender, and ability likely also indirectly mediated teachers' activity; however, they were not commonly addressed in teachers' discussions.

Rationale

The National Research Council (NRC) published the *Framework for K-12 Science Education* in 2012 (National Research Council, 2012). This framework served as the foundation upon which the Next Generation Science Standards were based (NGSS Lead States, 2013). The stated goal of the *Framework* is for "*all* students [to] have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; [to be] careful consumers of scientific and technological information related to their everyday lives, [to be] able to continue to learn about science outside school; and [to] have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology (National Research Council, 2012, p.ES-1).

The *Framework* assumes that teaching science includes apprenticing students into scientific sensemaking (Schwarz, Passmore, Berland, & Reiser, 2017). Scientific sensemaking refers to students' approximation of scientists' knowledge-building processes. The development of scientific knowledge depends upon physical or symbolic observation and interaction with material objects and involves the use of social discourse in two concerted processes – construction and critique to describe and progressively clarify emerging ideas (Ford, 2012, Knorr-Cetina, 1999; Latour & Woolgar, 1978; Longino, 2002;). In the scientific community, ideas are developed through individuals' interactions with networks of participants, institutions, and materials (Latour, 1990, 1999; Latour & Woolgar, 1986). These interactions form an "ensemble of activity" (Lehrer and Schauble, 2006, p 158). Incorporated into the ensemble are specialized ways of understanding, communicating, and representing scientific phenomena (Bazerman, 1988; Latour, 1990). The *Framework* approximates these knowledge construction processes through the inclusion of scientific and engineering practices.

Prior to the publication of the *Framework,* science classroom activity nationwide had not been dominated by students' active engagement in scientific practices. The 2012 National Survey of Science and Mathematics Education (NSSME) indicated that while 60% of science teachers have students conduct labs or other hands on activities, interact with data and representations of data, and support claims with evidence, the percentage dropped sharply when asked if these practices are used on a weekly basis (Banilower et al., 2013). In analyzing video recordings of science lessons, Roth et al. (2006) found that 8th grade lab activities were more likely to involve students in observational activity, rather than in model construction or in controlled experiments. Weiss, Pasley, Smith, Banilower, and Heck (2003) observed science teachers' classroom practice and found that middle school science lessons demonstrated a lack of time, structure, and questioning strategies to support students' scientific sensemaking. The 2018 NSSME+ (+ indicates inclusion of computers science for the first time) indicated that middle school science teachers' use of some instructional strategies described above had shifted in the intervening years. A higher percentage of teachers reported asking students to engage in small group work on a weekly basis as well as on a daily basis (Banilower et al., 2013; Banilower et al., 2019). A smaller percentage of teachers reported providing teacher explanations and facilitating whole class discussions on a weekly basis as well as on a daily basis (Banilower et al., 2013; Banilower et al., 2019).

A potentially prominent feature of instruction intended to develop scientific sensemaking is that it invokes literacy (Buck-Bracey, 2017). Norris and Phillips (2003) argued that scientific literacy is a set of reasoning skills predicated upon foundational literacy. Here, foundational literacy was used to describe skills such as decoding and encoding words, understanding vocabulary, and developing fluency in reading and writing. While these skills are certainly cognitive pillars of literacy, it is possible that a social constructivist conceptualization of literacy may better encapsulate the variety of ways in which literacy can be invoked during scientific sensemaking. Through this lens, literacy is a social process that shapes and is shaped by communities (Gee, 2012; Street, 1984;). Communities of scientists have come to share specialized literacies, or ways of communicating and representing scientific phenomena (Bazerman, 1988; Gee, 2012; Latour, 1990; Lemke, 2004). Literacy may be seen not as an individual possession, but as an outcome of a group working towards the resolution of a socio-scientific conundrum (Roth & Lee, 2002). If classroom activity systems are to mimic those of scientists, literacy should be invoked by tasks designed to elicit scientific sensemaking (Mawyer & Johnson, 2017).

Attention to literacy in content-area classrooms such as science is not a new initiative. Efforts to position science teachers as literacy teachers date back over 100 years (Moore, Readence, & Rickelman, 1983). Yet, in 2019, only 46% of middle school science teachers indicated that their instruction included literacy skill development on a weekly basis (Banilower, 2019). Studies conducted across several decades have discussed how content-area teachers eschewed efforts to incorporate literacy into their teaching as they did not see it as part of their discipline or that the literacy methods presented to them did not align with their understanding of teaching in their disciplines (Moore, Readence & Rickelman, 1983; O'Brien, Stewart, & Moje, 1995, Siebert & Draper, 2008).

Yet the *Framework* presents an unclear image of the role of literacy in scientific sensemaking. The *Framework* contains no explicit definition of literacy in support of sensemaking, science literacy or scientific literacy; moreover, the *Framework*'s index indicates that science literacy is conceptualized as consisting of communicating information, reading science text, and the use of scientific terminology and language and is located within multiple scientific and engineering practices (National Research Council, 2012, p. 376).

This description positions science literacy as a thread tightly woven within and between each of the *Framework's* practice strands, however, its features and connections to the practice strands may not be apparent to the casual reader due to the lack of explicit attention to defining or conceptualizing the term in the main body of the document. The NRC released a draft of their *Framework* for public comment in 2010 (National Research Council, 2012, p. 331). The draft included six practices central to the development of science knowledge and understanding. While the stated goal of the *Framework* was to design a comprehensive framework that would increase the scientific literacy of high school graduates, public response indicated that the framework did not adequately address connections between the practices and literacy and math skills as conceptualized by the Common Core State Standards. Thus, two additional practices were added before the *Framework's* final publication: mathematics and computational thinking, and obtaining, evaluating, and communicating information (National Research Council, 2012, p. 339).

As teachers develop science instruction that aligns to the NRC *Framework*, the sociocultural role of literacy in science classrooms may become more pronounced. The 2018 NSSME+ indicated slight shifts in the ways that middle school science teachers incorporated literacy as compared to the 2012 iteration. A higher percentage of middle school science teachers reported that they provided literacy skill instruction on a weekly basis than reported doing so in 2012 (Banilower et al., 2013; Banilower et al., 2019). Similarly, a higher percentage of teachers reported in 2018 that they asked students to write reflections on a weekly basis as well as on a daily basis (Banilower et al., 2013; Banilower et al., 2019). However, a smaller percentage reported asking students to read from science textbooks on a weekly basis as well as on a daily basis in 2018 than in 2012 (Banilower et al., 2013; Banilower et al., 2019). When science is taught as a participatory knowledge building activity rather than as a subject to learn about, students may be likely to see science as closely aligned with their experiences in the world (National Academies of Sciences, Engineering and Medicine, 2015). Yet laboratories and classrooms represent distinct activity systems, impacted by varying cultural and historical influences. What works in one system may not work in another. Teachers are immersed in classroom activity systems. Thus, they are lynchpins for scholars working to understand and developing possibilities for sensemaking and literacy in K-12 science teaching.

CHAT is a theoretical and analytical tool that positions the local community of middle school science teachers as the unit of analysis. As a theoretical lens, CHAT conceptualizes learning as highly contextualized and expansive in nature (Engeström, 1999). It positions literacy as potentially serving several roles within the system – a tool/resource, a shared goal, or an outcome of an activity focused on achieving another goal (Roth & Lee, 2007). Subjects, the people involved in the activity, are seen as influencing the system as well as being influenced by it. As an analytical structure, a CHAT activity system analysis explores the community's goal-directed activity including the ways in which it is mediated by tools, the community's division of labor, and contextual rules, defined in part by historical and cultural practices. Tensions are seen as important moments to focus on within a CHAT analysis. Tensions occur when multiple systemic elements seem tied up in tension with one another (Engeström, 1999, 2008). CHAT helps to explain how the tensions and inconsistencies between available resources, policies such as standards and district initiatives, and educators' beliefs about literacy, science, and teaching impact the activity system in this study.

This Study

This study explored educators' understanding of scientific sensemaking and literacy. Participants included nine Marksboro Middle School teachers and two representatives from a regional professional development agency and me. The middle school teachers taught a variety of subjects. Four taught science, one science and ELA, two ELA, one Music and one was a special education teacher working across subjects. The professional development agency representatives included a science professional developer and the head of the professional development team. The four science teachers, the ELA and science teacher, and the special education teacher engaged in a book study on *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) led by one of the participants. Three of the science teachers also participated in a literacy workshop series with the two ELA teachers and the music teacher, led by the science professional developer and me. The head of the agency's professional development team participated in an initial interview but was not able to attend subsequent meetings.

As is described in more detail in chapter three, qualitative data analyzed using CHAT included semi-structured interviews, observations of book discussions, workshops, and professional development planning meetings, and artifact collections, as well as frequent personal memoranda that I composed to delineate my evolving understandings and biases regarding literacy, sensemaking, and my role within the activity system. While there were several activity systems operating within this study, that of the book study group of teachers was selected as the focal system for analysis.

This study is significant because it responds to Hinchman and O'Brien's (2019) call for literacy scholars to consider a hybridized view of disciplinary literacy. These literacy scholars critiqued an infusion approach to disciplinary literacy in which literacy professionals advocate for the incorporation of literacy in disciplinary teaching without deep consideration of the epistemic practices of each discipline. Rather, they propose a hybrid approach which would respect and incorporate literacies inherent in a discipline's epistemic practices as well as literacies inherent to the school and everyday discourses in which students participate. The *Framework* (NRC, 2012) and associated science standards explicitly attended to scientific practices and sensemaking as ways for students to engage in science's epistemic practices. Thus now, as teachers are beginning to translate these documents into classroom instruction is a good time to investigate how they are considering sensemaking and literacy. In this study's activity system of middle school teachers engaged in a book study, teachers held multiple understandings of both sensemaking and literacy and drew upon them throughout their discussions. Yet often, their teaching practices related to literacy were glossed over as taken-for-granted components of science activities. Additionally, while science scholars have discussed equity as an integral consideration in sensemaking-oriented instruction (Rodriguez, 2015; Morales-Doyle, 2017) and literacy scholars have described an equity-informed critical literacy stance to be a component of disciplinary literacy (Moje, 2015), explicit considerations of equity were limited within this study's focal activity system. By working with a group of science teachers who are among the first in their area engage in this work, this study has implications for science and literacy practitioners and scholars.

Definition of Key Terms

Scientific Sensemaking

In introducing the purpose of the NGSS practice standards strand, Schwarz, Passmore, & Reiser (2017) define sensemaking as:

> The conceptual process in which a learner actively engages with the natural or designed world; wonders about it, and develops, tests, and refines ideas with peers and the teacher. Sense-making is the proactive engagement in understanding the world by generating, using, and extending scientific knowledge within communities. In other words, sense-making is about actively trying to figure out the way the world works (for scientific questions) and exploring how to create or alter things to achieve design goals (for engineering questions) (p 6).

For the purposes of this study, scientific sensemaking was defined as the array of cognitive and social processes students use to build meaning through interaction with texts, materials, and a peer community while engaging in the eight scientific practices outlined in the *Framework*.

Scientific Practices

The *Framework* outlines eight scientific practices noted as essential to student learning (National Research Council, 2012). These practices are:

1. Asking Questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information.

These practices are not isolated actions; rather, they often overlap and/or are conducted cyclically (Schwarz, Passmore, & Reiser, 2017, Moje, 2015).

Storyline

Teachers took up the word “storyline” to refer to their developing units of instruction. According to the Next Generation Storylines webpage,

> a storyline is a coherent sequence of lessons in which each step is driven by students’ questions that arise from their interactions with phenomena. A student’s goal should always be to explain a phenomenon or solve a problem. At each step, students make progress on the classroom’s questions through science and engineering practices, to figure out a piece of a science idea. … Together, what students figure out helps explain the unit’s phenomena or solve the problems they have identified. A storyline provides a coherent path toward building disciplinary core ideas and crosscutting concepts, piece by piece, anchored in students’ own questions. … In a storyline, students should be involved in co-constructing the question we are working on and should see the activity as helping make progress on that question. In a storyline, the coherence is from the students’

perspective, not just the teacher's (Edwards et al., n.d.).

Literacy

For the purpose of this study, I adopted Frankel, Becker, Rowe, & Pearson's definition of literacy. Frankel et al. (2016) define literacy as, "The process of using reading, writing, and oral language to extract, construct, integrate, and critique meaning through interaction and involvement with multimodal texts in the context of socially situated practices" (p. 7). Multiplicity is inherent in this definition – multiplicity of practices, of texts, of purposes, and of contexts. Academic disciplines such as the sciences represent several of the myriad contexts in which these socially situated practices may be carried out, as the disciplines are delineated by their varying epistemological stances, discourses, and inquiry practices (Goldman et al., 2016).

Texts and Representations

In this study, participants used these words in seemingly interchangeable, which is noted as a common practice by Wilson and Chavez (2014). However, many literacy scholars, such as Wilson and Chavez (2014), delineate between texts as "communication in any mode or combination of modes" and representations as pertaining to signs "that stand for a referent or that communicate aspects of their referents" (p. 5). It is unclear in the data which constructs' definition may best capture participants' intents, as there are numerous instances where the two words are used to refer to the same thing by the same participant in the same utterance. Thus, while a distinction between these terms may hold importance in the literature, I have chosen to use the terms interchangeably so as not to misrepresent participants' intents.

Collaborative Professional Development

One way to support teachers' continued development is through collaborative professional development. Glathorn (1987) defined cooperative professional development as "a process by which small teams of teachers work together, using a variety of methods and structures, for their own professional growth" (31). In this study, both the teacher-led book study discussions and the workshop series were considered to be collaborative professional development.

Overview of Chapters

This introductory chapter was intended to provide an overview of this study. I introduced my research questions, a brief rationale, and key definitions central to understanding the study. In the next chapter, I will further develop this rationale through a literature review related to scientific sensemaking, and literacy.

The second chapter also includes a review of literature on collaborative professional development as rationale for the study's setting. It concludes with a description of CHAT as a theoretical and analytical tool for examining teachers' understanding of scientific sensemaking and literacy in a collaborative professional development context.

Chapter Three outlines the methodology used in this study. It presents a description of the middle school and professional development agency, participants from both organizations, as well as data collection and analysis methods. This chapter also includes a description of my researcher-participant role in the study and how I worked to maintain trustworthiness when operating in and between those roles.

Chapter Four presents an analysis of the *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) book study activity system. It includes analysis of the systems' objects, activity, and mediating elements. It concludes with an analysis of individuals' developing understanding of scientific sensemaking and literacy as an outcome of the activity.

Chapter Five presents a discussion of themes established in Chapter Four in order to address the research questions. It also includes implications for literacy and science education scholars.

CHAPTER TWO: RELATED LITERATURE

This chapter shows how this study builds upon relevant science and literacy education research. First, I review literature that describes scientific sensemaking and literacy. Then I review research on professional development, including consideration of Communities of Practice (Lave & Wenger, 1992). I conclude by describing Cultural Historical Activity Theory (CHAT) as a useful theoretical and analytical tool for analyzing educators' understandings of scientific sensemaking and literacy demonstrated through their participation in professional development as well as how Actor Network Theory (ANT) can support a CHAT analysis.

Scientific Sensemaking

In its simplest sense, sensemaking is the process of figuring something out. Newman, Morrison & Torzas (1993) used the phrase scientific sensemaking to refer to the "endeavor to construct and articulate explanations of observed phenomena based on the coordination of theory and data" (p. 2). They argued that "fundamental changes" to science education would be necessary in order to promote students' development of scientific sensemaking (p. 1). References to sensemaking in science education research have increased exponentially, albeit with a variety of definitions, as I describe below (Odden & Russ, 2018).

The NRC's *Framework* (2012) describes scientific sensemaking as the goal of three-dimensional science learning. These dimensions include disciplinary core ideas, cross-cutting concepts, and scientific and engineering practices. While seemingly synonymous with methods or processes, the field of science education uses the term, practices, to highlight the interconnectedness of doing and learning something (Bybee, 2011; Michaels, Shouse & Schweingruber, 2008). In this manner, engaging in scientific practices is how the science community works to "build, test, refine, and use knowledge either to investigate questions or to solve problems (Schwarz, Passmore, & Reiser, 2017, p. 6). Numerous researchers have noted that it is through engaging with scientific practices that students demonstrate efforts to make sense of target phenomena (Ford, 2008; Koomen, Rodriguez, Hoffman, Peterson, & Oberhauser, 2018; Lee, Quinn, & Valdez, 2013; Schwarz, Passmore, & Reiser, 2017).

Some science education researchers have described scientific sensemaking as an individual cognitive action. Kapon (2017) and Rau (2018) did so when defining scientific sensemaking as the process of continually refining one's self-explanations. Kapon (2017) identified markers of improvement in self-explanations such as increased accuracy and depth of content knowledge, increased explanatory power of proposed mechanisms, and refined articulation of the contextual framing of the target phenomenon.

Yet Roth (2012) argued that while there are likely to be cognitive aspects to sense-making, one cannot directly observe the cognitive sensemaking of another. That which resides in the cognitive domain is measurable only through an individual's outward actions. The outward actions Roth (2012) discussed may be engagement with scientific practices, such as those identified by the *Framework* (NRC, 2012). To see someone's scientific sensemaking, they must outwardly demonstrate it, thereby necessitating a shift from a cognitive to social perspective of sensemaking.

Several science education researchers have described scientific sensemaking as a socially situated process. In their description of scientific sensemaking, Newman, Morrison, and Torzas (1993) indicated that it incorporated ways of "thinking and speaking that [are] learned in the context of interactions with other sense-makers" (p.8). Buck-Bracey (2016) also described sense-making as socially situated when describing the sensemaking processes of college students from non-dominant linguistic backgrounds. In their work to craft a unified definition of scientific sensemaking, Odden and Russ (2018) similarly described how three preservice teachers engaged in sensemaking through conversation.

The social and cultural context shapes students' actions and learning (Lee & Smagorinsky, 2000; Vygotsky, 1981, 1986) All actions students undertake while carrying out the aforementioned scientific practices are tied up in social activity and language. Students' initial explanations of a scientific phenomenon are likely to contain misconceptions and to appear to be messy rough drafts of ideas, rather than something resembling final form scientific knowledge (Campbell, Schwarz, & Windschitl, 2016). Students engage in scientific sensemaking when they shift from a reliance on everyday language and experience to scientific discourse structures such as vocabulary and syntax (Hakuta, Santos, & Fang, 2013). This shift is shaped by the resources available to the sensemaker(s). Resources may include things such as science and popular textual representations, existing models like the heliocentric model of the solar system, and available data in addition to one's interactions with the natural and engineered world through simulations, experiments, and observations.

Sensemaking also occurs through interaction with texts and peers. Berland and Reiser (2011) stated that one's revision of claims is in response to critique and interaction with new information. Manz (2015) described scientific practices such as argumentation as social tools students use to develop increasingly sophisticated scientific sensemaking repertoires. By adopting an oppositional voice through questioning and critiquing presented and self-constructed claims, students begin to align their thinking with the sensemaking practices recognized as scientifically sound by the scientific community (Ford, 2008). Ford (2008) and González-Howard and McNeill (2019) describe scientific argumentation not as a debate but as a shared effort to develop understanding through achieving consensus.

Odden and Russ (2018) offered a definition of sensemaking for the science community which incorporated both cognitive and social perspectives of the term. They proposed that sensemaking is

> a dynamic process of building an explanation in order to "figure something out" - to ascertain the mechanism underlying a phenomenon in order to resolve a gap or inconsistency in one's knowledge. One builds this explanation out of a mix of prior knowledge and formal knowledge by iteratively proposing and connecting up different ideas on the subject. One also simultaneously checks that those connections and ideas are coherent, both with one another and with other ideas in one's knowledge system (p. 191-192).

The cognitive dimension is seen here through the influence of one's prior knowledge and through the individual process of taking up new ideas. The social dimension is implied by the process of vetting evolving understanding with other people and sources of information.

***Framework*-aligned Standards**

The NRC *Framework* (2012) describes developing all students' scientific sensemaking as the goal of science instruction. It was drafted by NRC as a foundation on which to write new science standards, which became the NGSS. It drew upon a rich bed of science education research in order to comprehensively address concerns and shortcomings of current standards, such as an emphasis on students' learning discrete facts about science rather than learning how to engage in scientific endeavors (NRC, 2012, p.1).

The *Framework*, as well as standards aligned with it such as the NGSS (NGSS Lead States, 2013) and the New York State Science Learning Standards (NYSSLS, New York State Education Department, 2016), consider science to be three-dimensional. The first dimension consists of scientific and engineering practices. These are eight practices believed to encapsulate the ways in which scientific knowledge is constructed and to apprentice students into these ways. The eight practices are asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information (NRC, 2012, p. 42). The second dimension, crosscutting concepts, are overarching science ideas that "bridge disciplinary boundaries," meaning that they are valued in multiple domains of science (NRC, 2012, p. 83). The seven crosscutting concepts consist of patterns; cause and effect: mechanism and explanation; scale, proportion, and quantity; systems and system models; energy and matter: flows, cycles, and conservation; structure and function; and stability and change (NRC, 2012, p. 84). The third dimension consists of disciplinary core ideas from physical sciences, life sciences, earth and space sciences, and engineering, technology, and applications of science. For learning to be three dimensional, the *Framework* writers believe that students engage in all three dimensions in an integrated manner (NRC, 2012).

However, not all standards aligned with the *Framework*, are identical. While at first glance, the NGSS (NGSS Lead States, 2013) and the NYSSLS (New York State Education Department, 2016) appear similar, there are disconnects. Several of the standards are differently worded and constructed. While the NGSS has numerous appendices, such as appendices outlining several models for middle school content progressions and expounding on considerations of equity and diversity, the NYSSLS do not. Thus, teachers in states such as New York often draw upon aspects of both documents.

Storylines.

One of the ways science educators have operationalized planning instruction aligned to the *Framework* and associated standards is through the construction of storylines. Much like a traditional instructional unit, a storyline is a cohesive series of science lessons. While scholars and teachers in other disciplines may ascribe a different meaning to the term storyline, it is used by science education scholars, such as Brian Reiser, to focus instructional designers' and teachers' attention on how lessons flow together and help students progressively develop an explanation of a scientific phenomenon in response to a guiding question (German, 2017). A phenomenon refers to an observable occurrence through which students can develop explanations of through engaging in three-dimensional learning. According to the NGSS website, a central feature of a storyline is that it coherently connects the three dimensions of the standards by providing, "a coherent path toward building disciplinary core ideas and crosscutting concepts, piece by piece, anchored in students' own questions" (Edwards et al., n.d.). While such an explanation of storylines may sound broad, when science education scholars refer to storylines, they are often referring to a specific set of storylines created by Reiser and his research team and available to teachers via an open-source database. This collection of storylines has been vetted as fully realizing the intents of the NGSS.

However, other organizations, such as the National Science Teaching Association, have also ascribed the term storyline to their additional NGSS-aligned curricular collections.

Critiques of the *Framework* and standards.

Some science scholars have critiqued the *Framework's* (NRC, 2012) and NGSS's (NGSS Lead States, 2013) lack of inclusion of equity and diversity in the standards. While the *Framework* discussed the need for teachers to "understand the sensemaking practices of particular communities, the science related values that reside in them, and the historical relationships between communities and local institutions of education" (NRC, 2012, 284) and the NGSS (NGSS Lead States, 2013) incorporated an appendix on considerations of equity and diversity, Rodriguez (2015) argued that considerations engagement, equity, and diversity are largely absent from the documents. He noted that in an effort to appear politically neutral, that the committees who drafted both the *Framework* (NRC, 2012) and NGSS (NGSS Lead States, 2013) maintained a "discourse of politeness." Rodriguez (2015) indicated that the history of failure to address equity and diversity through education reform made it imperative for the new standards to adopt a "more direct and transformative approach" and advocated for equity and diversity to be considered a fourth dimension (1041).

Morales-Doyle, Price, and Chappell claim that "to center justice in science education requires explicitly considering critical questions about the relationships between scientific knowledge and oppression" (1351). They note that the NGSS's maintains a utilitarian perspective towards science, in which the benefits and applications of science are highlighted, and its harms are downplayed. This makes it challenging for science teachers to engage students in social justice science instruction, as to do so, a teacher must operate around the edges of the standards. They note that the NGSS asks teachers to focus on natural phenomena, despite the fact that focusing on socio-scientific issues with local social justice implications can be used to teach the same science ideas while also attending to matters of power and oppression (Morales-Doyle, Price, & Chappell, 2019). In a separate piece, Morales-Doyle (2017) describes how a justice-centered science approach, such as the one described above, can foster students' engagement in science learning by positioning students as producers of science knowledge and as science-informed changed agents. Such a focus "recognize[s] the agency of ordinary people to wield the power of science (alongside other ways of knowing) to intervene" in communities impacted by social justice science issues (Morales-Doyle, 2017) and clearly aligns with the *Framework's* goal to develop sensemaking oriented science instruction that includes all students.

Ambitious Science Teaching

Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018), the text selected by Marksboro science teachers for their book discussions, is a popular science education text which positions sensemaking as a central feature of ambitious teaching. The authors argue that, for teaching to be seen as "ambitious," teachers must attend to equity. To do so, they urge teachers to

> situate learning in familiar or everyday contexts, … [be] responsive to students' ideas, experiences, and questions, … make explicit to students how scientists generate and defend claims for knowing, and the norms for participation in disciplinary conversations, … [and] honor students' sensemaking repertoires (Windschitl, Thompson, & Braaten, 2018, pp.10-11).

The book is the result of twelve years of research and teaching collaboration between the authors. They identified a need for "professional [teaching] routines that were recognizable, principled, and improvable" in order to help preservice and novice teachers bring scientific inquiry to life in secondary classrooms (Windschitl, Thompson, & Braaten, 2018, p. vi).

Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018) is organized around four sets of teaching practices identified by Windschitl and Calabrese-Barton (2016) which support equity and rigor in science teaching: planning for student engagement with important science ideas, eliciting students' ideas and adapting instruction, supporting ongoing changes in student thinking, and supporting students' evidence-based explanations. To the authors of *Ambitious Science Teaching*, planning for engagement with big ideas encompasses teachers' identification of major science concepts to be learned, selection of an anchoring event and essential question to frame students' thinking, and sequencing of learning activities to support students as they seek to answer the essential question (Windschitl, Thompson, & Braaten, 2018, p. 20). Eliciting ideas consists of teachers' efforts to elicit initial thoughts, activate background knowledge, make student thinking available to the classroom community, and adapt instruction in response to students' misconceptions and understandings (Windschitl, Thompson, & Braaten, 2018, p.87). When teachers aim to support ongoing changes in students' thinking, Windschitl, Thompson, and Braaten (2018) recommend considering how and when to introduce new ideas, as well as how to engage students in learning through activity, and in opportunities to make sense as individuals, small groups, and through collective thinking as a whole class (p.153). Suggestions to support students' creation of evidence-based explanations include giving students a “gotta have it” checklist of important elements to include, pressing students to address seen and unseen components to create gapless explanations, and assessing understanding of science topics through students’ explanation.

Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018) uses these four types of activity as an organizational structure for introducing science teachers to recommended equity-minded ambitious teaching practices. For each type of activity, they provide a graphic representation of practices related to that activity type, a rationale and explanation of each practice, and classroom-based examples at elementary and secondary levels. Supports for students’ science talk and making student thinking visible through multimodal modeling and argumentation receive heavy billing throughout the text. Additional planning tools and videos of classroom examples are available through the text’s companion website (Lohwasser et al., n.d.).

Windschitl, Thompson, and Braaten (2018) also dedicate one chapter to supporting students’ sensemaking. Here they introduce sensemaking as the ways “students gain insight into some relationship between ideas, representations of those ideas, and experiences they have” (p. 173). They go on to describe sensemaking as “both about understanding an idea (such as mitosis in cells) and using that idea to explain events in the world (why out-of-control mitosis allows some cancers to spread more rapidly than others)” (p. 174). They argue that sensemaking involves students developing understanding of categorization and classification as a way to scientifically understand the world, of the role and development of scientific representations of real-world phenomena, and of the use of scientific ideas to explain everyday occurrences. In this chapter, sensemaking is situated as occurring during students' small group work. Presented supports for students' sensemaking include teachers' framing of an activity and use of planned differentiated questioning.

Summary

Scientific sensemaking refers to the ways in which people interact with scientific ideas in order to figure something out. Developing students' scientific sensemaking repertoires is a goal of the NRC's *Framework* (2012) and associated standards such as the NGSS (NGSS, Lead States, 2013) and the NYSSLS (New York State Education Department, 2016). Incorporating diverse sensemaking repertoires has been implicated as one of the ways teachers may attend to equity and diversity in science classrooms. However, some scholars have indicated that the *Framework* (NRC, 2012) and associated standards do not go far enough to support teachers' incorporation of justice-oriented pedagogies. *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018), the focal text of the book study group described in this study, is a practitioner text which attends to scientific sensemaking and an aspect of equity-oriented science instruction.

Literacy

Literacy is positioned by many scholars as a mediating process in social constructivist views of learning (Vygotsky, 1981; 1986). It facilitates interaction between individuals and their immediate and more distant cultural communities across both time and space. Literacy as a social process can be modeled as autonomous or as ideological (Street, 1984). In the autonomous model, literacy is a set of neutral, technical skills that facilitate one's interactions with texts and others. However, as literacy is always tied to other social "stuff" such as power relations and cultural contexts (Gee, 2012), it is neither neutral nor singular in nature. Rather, through the ideological model, literacy is seen as contextualized and embedded practice (Street, 1984). Worded differently, literacy's manifestations reflect the various ways a particular community engages with words (Heath, 1983). These ways include interaction with a variety of multi-semiotic representations including images, films, charts, diagrams, and models.

Orientations Toward Literacy in Science

Literacy's role in science is contested by both science education researchers and literacy education researchers. The field of science education has been theorizing scientific literacy for over 60 years (Holbrook & Rannikmae, 2012; National Academies of Sciences, Engineering, and Medicine (U.S.), Snow, & Dibner, 2016; Roth & Lee, 2002). Though several schools of thought have emerged, terminology used does not necessarily align with a generalizable meaning. Authors attempting to speak across all definitions of scientific literacy often create two camps, such as science literacy vs. scientific literacy (Holbrook & Rannikmae, 2012) or functional vs. derived scientific literacy (Norris & Phillips, 2003). Yet not even these binary camps remain stable in their usage across the field and do not fully represent the diverse conceptualizations of the term.

The field of literacy education has been enmeshed in debate about how to approach literacy in science– that of general strategies-based content-area literacy and discourse apprenticeship-based disciplinary literacy. Content-area literacy is frequently defined as "the ability to use reading and writing for the acquisition of new content in a given discipline. Such ability includes three principle cognitive components: general literacy skills, content-specific literacy skills (such as map reading in the social studies), and prior knowledge of content" (McKenna & Robinson, 1990, p. 184). These conceptualizations of literacy position it as separated from, but in the service of, academic disciplines.

Proponents of disciplinary literacy position literacy as emerging from disciplinary practices. Shanahan and Shanahan (2008) defined disciplinary literacy as “advanced literacy instruction embedded within content-area classes such as math, science, and social studies (p. 40), later adding that its emphasis is on “the knowledge and abilities possessed by those who create, communicate, and use knowledge within the disciplines” (Shanahan &Shanahan, 2012, p. 8). Moje’s (2008, 2015) conceptualization of disciplinary literacies stems from a more social and critical theoretical framework, highlighting the need for teachers and students to explore and critique the privileged discourses of each discipline, explaining the term as “a form of critical literacy because it builds an understanding of how knowledge is produced in the disciplines, rather than just building knowledge in the disciplines” (2015, p. 97).

Science education scholars, Tuckey and Anderson (2008), described three orientations toward literacy in science teaching: strategies, discourse, and content. They characterized a strategies orientation by one’s desire for students to gain agency in the use of scientific texts. Learning occurs through one’s comprehension of print and multimodal text. Teaching includes a focus on introducing and practicing a variety of reading and writing strategies. Tuckey and Anderson (2008) characterized a discourse orientation by one’s desire for students to gain agency within the scientific community through legitimate peripheral experience. Learning in this view is seen as one’s increased facility with the multi-semiotic discourses identifiable as scientific. Under this orientation, texts are a wide assortment of semiotic representations of cultural models and funds of knowledge. These range from traditional print texts, to oral discourses, to ways of being that might identify one as a scientist. Tuckey and Anderson (2008) characterized a content orientation by one’s desire for students to gain agency in the material world through command over content material or using scientific tools and practices within the real, or material, world. Learning in this last view occurs through sensemaking in response to experience with the material world. Under this orientation, experiences with the material world, data collected from direct experience, and representations and interpretations of data collected by others are seen as relevant texts in the sensemaking process.

Strategy orientations. Strategy orientations position general literacy skills as ways to access available text-based scientific knowledge. Here, literacy refers to a set of cognitive abilities, primarily the abilities to read and to write. Central to this belief is the bifurcation of literacy and science in that literacy is focused on texts and science is focused on meaning-making that extends beyond language (Lemke, 2004). Thus, comprehending texts and composing comprehensible science texts are only two of the goals of a science curriculum. As the definition of text moves beyond traditional print to include multi-modal and hybrid texts, the relationship between science and literacy grows; however, literacy skills are considered as generalized gateways to specialized knowledge, as prerequisites to scientific engagement rather than constituent elements of scientific engagement (Norris & Phillips, 2003).

Considering the incorporation of literacy strategies can have meaningful outcomes in science classrooms. In a study by Greenleaf et al. (2011), biology teachers engaged in professional development in order to apprentice students into science-specific metacognitive reading routines. The study's professional development aimed to assist teachers in integrating science and literacy teaching cohesively. Qualitative data regarding teachers' beliefs and practices as well as student survey data indicated that teachers receiving the professional development felt more capable of incorporating literacy (Greenleaf et al., 2011). Students whose teachers received the professional development outperformed their peers on the state-wide science assessment.

Across literacy and science education practitioner-focused journals, strategies orientations are prevalent. Jagger and Yore (2012) analyzed ten years of literacy-focused articles in three practitioner-oriented science journals. They found that the number of literacy focused articles declined as the age of the students represented increased. Out of the ten literacy categories Jagger and Yore (2012) established (argument and discussion, assessment, cross-curricular strategies, ELL vocabulary and special needs, multiple literacy strategies, questioning, reading, speaking listening and drama, technologies internet and media, and writing), reading strategies and multiple literacy strategies were a prevailing focus across journals. Additionally, 94% of the 402 included articles presented literacy strategy recommendations rather than empirical research findings (p. 568). As evidence in support of these strategies, authors were twice as likely to cite highly regarded literacy education journals than highly regarded science journals and most presented inadequate theoretical and empirical evidence in support of a presented strategy (Jagger & Yore, 2012).

In a similar study, Wright, Franks, Kuo, McTigue, and Serrano (2016) reviewed all articles discussing literacy in science classrooms presented in the *Journal of Adolescent and Adult Literacy* over an eleven-year span. Like Jagger and Yore (2012), they found that most strategies presented were focused on reading comprehension, more specifically pre-reading strategies intended to help students comprehend what they were about to read. These studies drew upon Schema Theory, Dual Coding Theory, and Social Constructivism as their theoretical grounding, though the connections to these theories were not often made explicit (Wright et al., 2016).

One type of strategies-oriented study exploring the literacy practices of science experts is an "expert reader study." An expert reader study is one in which the researcher identifies disciplinary experts and collects data regarding that individual's literacy practices through surveys, interviews and/or think-aloud protocols. A search for expert reader studies of scientists elicited few results: four studies that utilized a think-aloud approach (Bazerman, 1985; Chapman, 2015; Flury-Kashmanian, 2016; Shanahan, Shanahan, & Misischia, 2011;), and three studies that utilized interviews or surveys (Belefont-Miller & King, 2000; Brown, 1999; Jamali & Nicholas, 2010).

Across these studies, aspects of the reading behaviors of 145 identified individuals were explored. Yet, only 42, or 25%, of participating individuals were female, and none of these women were involved in a think-aloud study. In fact, determining the genders of individuals involved in think-aloud studies was not a straightforward process, as the authors did not specifically list the genders of their participants. In Chapman's (2015) and Flury-Kashmanian's (2016) studies, pseudonyms were given to participants; however, a number of these pseudonyms were gender-neutral (i.e.: Sam). Thus, I used authors' pronoun usage in findings sections to determine participants' genders. In the case of Shanahan, Shanahan, and Misischia (2011), even this fine-grained analysis left a degree of ambiguity. The authors clearly referred to the physical chemist using the pronoun *he.* Yet, throughout most of the piece, the authors referred to "one chemist" and "the other chemist," using the pronoun he to refer to one or the either, but not consistently across the article, leading the reader to assume both chemists are male. Clearly absent in the body of scientific expert reader studies are scientists who do not identify as or are not identified by the author as male.

Similarly, a very narrow band of what it means to be a scientist was represented in these studies. Across all included studies, 13 participants were not employed as faculty in a research-focused university. Out of the 15 participants, eight were full professors of physics at research universities. One was a full professor of engineering and four are engineers in the private sector. The remaining 2 participants were chemists. The survey and interview data corpus were also heavily skewed toward physicists but did include chemistry and mathematics professors as well. Absent from the corpus were the academic fields of biology (including medicine), earth sciences, and applied sciences. Additionally, absent were individuals beyond the academy who could be considered as scientists or scientific experts. Strikingly absent from this corpus of studies as well was mention of participants' race, ethnicity, nationality, or language background.

With very recent exceptions, the body of expert reader studies in science perpetuate problematic notions of who is and who is not considered a scientist. The resulting image is of a man, most likely a white man, who has a PhD in a physical science or engineering, who reads empirical research within his field. It may be unreasonable to assume that his reading practices are representative of what occurs across a variety of texts under a more inclusive portrayal of scientists.

While there is merit in establishing literacy as a set of strategies or tools to be used in service to science, the messages received by science educators may be incomplete. These messages may center on cognitive "recipe book" strategies for individuals to use in order to "unlock" the meaning of science texts and to improve students' reading in general across subject areas. In a study on mathematics teachers' beliefs regarding content-area literacy messages, Seibert and Draper (2008) found that mathematics teachers feel content-area literacy strategies do not align well with their understanding of the nature of mathematics and how to teach it. Such misalignments can make teaching literacy seem like additional work beyond teaching the content and process of a discipline, and as a result, they may be cast aside as teachers attempt to cover their course material in a manner they deem to be efficient and sufficient. The mouthpieces of these approaches, often literacy specialists or coaches, are disciplinary outsiders who may not understand the epistemologies of the disciplines (Seibert & Draper, 2008). As these approaches are developed by and advocated for by disciplinary outsiders, the approaches may be seen as attempts to position ELA instruction in the content-area classrooms – a move seen as problematic by ELA teachers and content-area teachers alike (Collin, 2015). These outsider strategies "challenge the dominance of subject area compartmentalization" and "threaten to blur subject area divisions" (O'Brien, Stewart, & Moje, 1995, p.449-450). Additionally, content-area literacy approaches have generally been based upon cognitive schools of thought focused on the learning of fixed content rather than on developing sensemaking processes, thereby disregarding the social nature of the disciplines as well as of learning (O'Brien, Stewart, & Moje, 1995).

Discourse orientations. Capital D Discourses are language communities defined by lower case d discourses, or the stable ways a certain group of people enact literacies over time (Gee, 2012). Membership in a Discourse is established by performance of accepted discourses which allow one to be recognized as a certain "'type' of person" (Gee, 2012, p. 148). In discourse orientations, literacy is "a discursive phenomenon that is situated culturally, historically, and spatially (and as such is often expressed in the plural form literacies)" (Rex et. al, 2010, p. 96). Reveles & Brown (2008) describe scientific literacy as "access to a socially accepted body of language, thinking, and acting" (p. 1020) or as "a product of students' academic identities as science learners manifest in the discourse practices of [the] classroom" (p. 1037). In acquiring this secondary discourse, individuals must disinvite aspects of their primary, or "lifeworld" discourse identities from scientific contexts in favor of adopting scientific discourse (Gee, 2004).

Work stemming from a discourse orientation includes studies that examine scientific language through systemic functional linguistics. This approach examines how words, syntax, and larger elements of discourse work within a given context. These linguistic forms include challenging grammatical constructions such as a high lexical density, reliance on nominalizations and abstractions, a highly specialized vocabulary, and an assertive, objective tone that positions an author as an authority on the subject at hand (Halliday, 1993; Schleppegrell, 2001; Fang, 2005). Fang (2005) asserts, "Learning science means learning to control the unique linguistic forms and structures that construct and communicate scientific principles, knowledge, and beliefs" (p. 337). Yet, science teachers may not have had previous explicit exposure to the systemic functional linguistics of their discipline (Patrick, 2009).

Another body of work characteristic of a Discourse orientation explores students' reading, writing, or discussing like scientists and can range from simplistic to complex notions of what it means to enact literacy like a scientist. In one practitioner-oriented article, reading in science class is justified by the rationale that scientists spend roughly half of their time reading and writing (Tenopir & King, 2004). A series of questions based on text type are then presented which are designed to orient a student to a science text in a similar fashion to how a scientist might read the genre (Mawyer & Johnson, 2017). However, it is unclear from this article whether there is empirical evidence that scientists actually use these questions when reading popular texts, textbooks, or primary scientific literature.

Discourse orientations toward literacy in science have also been critiqued. To argue that unique literacies evolve within disciplines, one must accept the assumption that disciplines are also discrete and do not overlap with one another (Collin, 2015). Teaching disciplinary literacies also legitimizes and reifies the dominant discourses within a discipline (Collin, 2015). Even though these discourses and practices may be legitimate and valuable ways of being worthy of school subject-area instruction, they may also marginalize groups of learners whose primary discourse communities are more distant from these practices than others (Gee, 2000). Those positioned as experts are deemed to be the most scientifically literate, and the aim of science education becomes depositing disciplinary insights into the minds of students without critiquing the established norms (Dos Santos, 2009). Additionally, this orientation may ask students to act like "little scientists" perhaps before they have mastered the subskills that would make such learning possible (Holbrooke & Rannikmae, 2007). Apprenticing students into a discipline may be viewed as establishing one narrow pathway for training within a discipline, rather than as providing a broad education upon which students can later decide the trajectories of their adult lives and professions (Brickhouse, 2001).

When disciplinary literacy is considered as apprenticeship in literacy practices used by disciplinary experts, one can question who gets positioned as a science expert. The expert reader studies previously described position research-oriented male professors as disciplinary experts, and the only indication of this gendered identity may be the use of an occasional pronoun (Bazerman, 1985; Latour & Woolgar, 1979; Shanahan, Shanahan, & Misischia, 2011, Tucker-Raymond, Gravel, Kohberger, & Browne, 2016). This alienation of diverse identities and everyday language practices from the enactment of disciplinary literacy in school may leave some students seeing disciplines as something "they" rather than "we" do, reifying their position at the margins of the discipline (Brown, 2005).

Some discourse-oriented research works to expand the definition of who counts as a scientific expert for students to emulate in K-12 science classrooms. An ethnographic study of working class and poor US-Mexico border communities revealed that women within the communities applied scientific literacy in their everyday actions and interactions (Licona, 2013). These women planted specific trees to prevent erosion around the homes they were building, conserved and recycled water in multiple ways, and had a working knowledge of how to use various herbs and plants to keep their families healthy. Licona (2013) proposed that these funds of knowledge and literacies could be incorporated into local science curricula in order to validate and build upon the knowledge and identities of local students.

Two recent studies have positioned a wider array of professionals as being science experts and recognize a wider array of discourse practices as constituting literacy. Early (2017) described a project that connected adolescent girls with an interest in science with female scientists with professional identities related to those interests. The scientists' professions included a zookeeper, a midwife, a forensic scientist, and a nutritionist, amongst others. The conversations between the adolescent and expert participants helped the young women to envision their futures as potential scientists. This study, however, did not explore the literacies involved in these careers. Tucker-Raymond's (2017) described the STEM literacy practices of makers. Makers are individuals who craft items either as a hobby or as a profession. Professional identities in this study included engineering educators, small business owners, community organizers, artists, and craftspeople. Some have scientist-aligned identities, such as an engineer, but others do not, such as a musician. What tied them together was the experimentation, design, and trial-and-error processes involved in making. The sample of 14 makers included five women. The author also noted the diverse ethnic backgrounds of participants, indicating that two women are Asian-Americans and that three males are of African diaspora decent. The array of texts discussed by makers displayed similar variety, including sketches, source code, and online forums and blogs.

Content orientations. Two conflicting ideas around the content of science complicate content-oriented conceptualizations of literacy. One view is that science content consists of working knowledge of basic facts, principles, and processes of the discipline or as the ability to think or act in scientific ways (Norris & Phillips, 2003). Most measurements of scientific literacy operate from a content-as-facts orientation (National Academies of Sciences, Engineering, and Medicine, Snow, & Dibner, 2016). An example of such an assessment is the selection of items from the biennial General Social Survey used by the National Science Board in developing their *Science and Engineering Indicators*. This assessment consists of a short battery of fact-based true/false statements and multiple-choice questions such as "The continents have been moving their location for millions of years and will continue to move" and "Does the Earth go around the Sun or does the Sun go around the Earth?" (National Science Board, 2016, pp.7-49). Additionally, educational standards such as the NGSS and American Association for the Achievement of Science (1995) *Benchmarks for Science Literacy* rely at least in part on claims regarding what counts as foundational content and procedural knowledge which all individuals should know (NGSS Lead States, 2013; American Association for the Advancement of Science, 1995).

Another measurement of science literacy is that of the knowledge consumers are assumed to have by mainstream media (Koelsche, 1965). Brossard & Shanahan (2006) systematically analyzed a sample of news pieces from the major newspapers included in the Lexis-Nexis database for the inclusion on any of 896 identified scientific terms. The frequencies at which these terms appeared were used to generate a list of the top 5% of commonly used scientific terms. From this list, a fill-in-the-blank assessment was created and piloted with a group of undergraduate students. The results from this pilot test correlated to the results of the GSS scientific knowledge measurement, thereby validating the notion that individuals possess a stable measurable amount of knowledge regarding scientific concepts and vocabulary (Brossard & Shanahan, 2006).

Limitations of this sort of content orientation include the ideas that the amount of scientific knowledge available is always increasing and that which knowledge is viewed as foundational is subjective and can be influenced by the beliefs of the institution or entity establishing the norms – be it a governmentally funded think tank or the consensus of popular media. Additionally, the growing amount of what factual knowledge is expected to be covered in classrooms may contribute to some teachers' beliefs that they do not have time to address other aspects of scientific literacy.

A content orientation can be conceptualized in a more agentive manner (Tuckey & Anderson, 2008). Learning science content involves the development of an understanding of how to make sense of the world through scientific practices. In this more agentive view, science instruction could incorporate both scientific literacy and embodied exploration/experience as important aspects of what it means to "do" science.

Moje's (2015) work represented a more agentive content orientation when she presented the four E's model for teaching disciplinary literacy. She suggested that teachers focus on four nested teaching practices when teaching the language of a discipline: engaging, eliciting/engineering, examining, and evaluating. The first E, engaging, requires teachers to create opportunities for students to engage in disciplinary practices. These everyday practices frame the context through which disciplinary insiders use language and literacy. Asking students to engage in scientific practices, however, is not sufficient. Students are not yet members of the discipline and require instruction and support in order to learn literacy strategies that can help them engage in the practices more productively. Moje (2015) argued that content-area literacy teaching strategies can be engineering tools for teachers to use to support students' acquisition of the disciplinary discourse. Through the third E, examining, she highlighted ways teachers can draw students' attention to technical and discipline-specific language constructions. Through the fourth E, evaluating, teachers can help students examine the usefulness and applicability of a discipline's literacies across a variety of everyday and academic contexts. Instruction involving the third and fourth E's will help students learn to make decisions about when, how, and for what reasons to evoke the language of the discipline.

Other scholars have also worked to identify scientific practices as common ground between science and literacy education efforts. Wilson-Lopez, Gregory, & Larson (2016) conducted an analysis of classroom activity in which a literacy researcher coded the data using reading practices such as predicting, inferring, and summarizing and an engineering researcher coded the same data using engineering processes such as generating ideas, problem definition, and modeling. The two coding schemes were then examined for overlap. Between a number of interdisciplinary code pairs, a large degree of overlap was identified. For example, 63.4% of what the literacy researcher coded as predicting had also been coded as generating ideas by the engineering researcher and 49.4% of what had been coded as summarizing was also coded as defining the problem (Wilson-Lopez, Gregory, & Larsen, 2016).

A content-as-facts and a content-as-practice orientation are evident in the NRC *Framework* and associated standards (NRC, 2012; NGSS Lead States, 2013) which incorporate the three dimensions: disciplinary core ideas, cross-cutting concepts, and scientific practices. The eight scientific practices in the *Framework* are nearly identical to the six disciplinary practices used by Moje (2015), with the addition of obtaining, evaluation, and communicating information, and mathematical computation (NRC, 2012). As literacy is not clearly defined within the framework or associated standards, both literacy and science scholars have worked to identify where literacy instruction fits within these practices, identifying anywhere between one and all eight practices (Capobianco, DeLisi, & Radloff, 2018; Faller, 2017; Hakuta, Santos, & Fang, 2013; Houseal, Gillis, Helmsing, & Hutchison, 2016; Lupo, Strong, Lewis, Walpole & McKenna, 2017; Wilson, Smith, & Householder, 2014; Wright & Gotwals, 2017; Zangori & Forbes, 2016). Because language use mediates engagement in each of the scientific practices, they may be a fruitful site for literacy instruction aligned to the standards.

Reconciling conceptions

Reconciling conceptions in science education. Science education scholars have worked to reconcile the differing definitions of scientific literacy and science literacy. Graber, Erdmann, and Schlieker (2001) placed previous definitions of scientific literacy on a continuum from meta-competence to subject-competence. Using this continuum, they created a generalized notion of scientific literacy as the intersection between what people know, what people value, and what people can do within science (Graber, Erdmann, & Schlieker, 2001, p. 209). Holbrook and Rannikmae (2012) used this model in order to reconcile two conceptualizations of scientific literacy. They stated that the term science literacy was often used to describe short-term goals regarding fundamental ideas and content, like the notion of literacy of science presented above. In opposition, they positioned the "requirement to be able to adapt to the challenges of a rapidly changing world" and the specialist skills necessary to fulfill that requirement (p. 278). Their conclusion was that an education in science literacy is one in which students develop

> an ability to creatively utilize appropriate evidence-based scientific knowledge and skills, particularly with relevance for everyday life and a career, in solving personally

challenging yet meaningful scientific problems as well as making responsible socio-scientific decisions, [which is] dependent upon the need to: develop collective interaction skills, personal development, and suitable communication approaches as well as the need to exhibit sound and persuasive reasoning in putting forward socio-scientific arguments" (Holbrook & Rannikmae, 2012, p. 286).

Norris and Phillips (2003) consolidated twelve conceptualizations of scientific literacy into a unified construct. Their work hinged upon a division between functional literacy (the ability to read and write) and derived literacy (knowledgeability within a domain). The resulting conceptualization asserted that "the notion of scientific literacy must hold that science is a result of cumulative discourse that trades on the fixities of text and on what is taken for granted by that text" (Norris & Phillips, 2003, p. 232). Thus, they positioned literacy as the communicative vehicle for scientific theory and ideas to traverse time and space.

The National Academics of Sciences, Engineering, and Medicine's report on science literacy also works to reconcile these camps, albeit beyond K-12 education (National Academies of Sciences, Engineering, and Medicine, Snow, & Dibner, 2016). This report drew upon a variety of conceptualizations of scientific and health literacy in creating a three-tiered model of science literacy – as an aspect of the institution of science in society and the world, as a product of shared action by communities, and as a process undertaken by individuals. The report asserts that at the societal level, scientific literacy holds value for personal, economic, democratic, and cultural reasons and is constructed by institutional structures such as governments, schools, and the academy. Within communities, the report claims scientific literacy is more than a sum of the personal literacies of individuals. Like Roth, this report values a variety of orientations toward science as important in the enactment of community scientific literacy (Roth & Calabrese

Barton, 2009; Roth & Lee, 2007). The report also took a critical stance, stating that as some communities have been marginalized by societal structures, so too has their access to resources in order to enact community scientific literacy. At the individual level, this conceptualization of scientific literacy incorporated foundational literacy skills such as the ability to read and write and individual's actions and attitudes toward science. Noticeably reduced in the report's multi-tiered conceptualization of scientific literacy was the importance of an individual's understanding a defined scientific knowledge base. These tiers were said to operate in connected ways as individuals' enactment of scientific literacy was enhanced or constrained by community and societal factors and that communal and societal enactment of scientific literacy requires variety in individuals' enactment

Reconciling conceptions in literacy education. Literacy education scholars have worked to reconcile content-area and disciplinary perspectives toward literacy. Brozo, Moorman, Meyer, and Stewart (2014) drew upon social geography's construction of third space to advocate for the adoption of the "radical center," a third space between content-area literacy and disciplinary literacy in which multiple theoretical perspectives can be simultaneously accepted. Arguing from a pragmatic perspective, they noted, "strong adherence to a single theoretical perspective is luxury that real teachers with real students cannot afford" (354). They additionally argued that for efforts to incorporate literacy into the disciplines, it is paramount that literacy not be separated from the discipline. Dunkerly-Bean and Bean (2016) similarly argued for a unification of content area and disciplinary literacy, noting that disciplinary literacy "requires a comparison to content area literacy, but would not exist without it" (459). Collin (2015) argued that neither content-area approaches nor disciplinary approaches fully accounted for the role of literacy in K-12 content areas. He felt that content-area approaches imposed reconstructed views of literacy from an English Language Arts (ELA) perspective within the disciplines, thereby discounting the linguistic practices inherent to disciplines. Yet disciplinary approaches assumed academic disciplinary discourses as models for students to emulate, thereby discounting the influence and importance of everyday discourses. Hinchman and O'Brien (2019) also critiqued literacy professionals' efforts focused on infusing literacy into each discipline as occurring without consideration of the epistemic practices of knowledge construction inherent to each discipline. They argued for a hybrid approach, which would respect and incorporate disciplinary, school, and everyday discourses as aspects of literacy influencing learning within the disciplines.

Summary

Literacy has been conceptualized in a variety of ways by science scholars as well as literacy scholars. Within disciplinary spaces such as science, multiple orientations, such as Tuckey and Anderson's delineation of strategy, discourse, and content orientations exist. Considerations of equity are threaded across these orientations. When disciplinary literacy is conceptualized as incorporating the literacy practices of disciplinary experts, it may operate to perpetuate the dominance of particular groups, as can be seen through the identities of scientists included in expert reader studies. Some discussions of literacy in science describe it as a communally held item or tool and describe how access to science literacy has been unequally afforded to various communities. In both science and literacy, some work has been done to reconcile multiple conceptualizations. In this study, literacy is defined broadly in order to account for and value the multiple orientations towards and conceptualizations of literacy which could be held by middle school science teachers.

Communities of Practice in Collaborative Professional Development

Science teachers may perceive literacy messages as a mismatch to the discourse patterns and practices of the discipline (O'Brien, Stewart, & Moje, 1995). Science teachers are likely knowledgeable in science broadly and their undergraduate major more specifically, but they may not be experts, as the body of scientific knowledge expands every day. Most secondary teachers have taken one or two courses on literacy in their undergraduate and possibly graduate education programs (Snipes & Horwitz, 2008). Thus, they likely possess knowledge of some teaching methods that could be used to support literacy invoked in a science curriculum. Teachers also likely receive contradictory messages regarding how best to teach science and literacy from a variety of sources including local, state, and national standards and policies, practitioner journals, literacy coaches, and others. For example, the conceptualization of argumentation in the science classroom differs between the Common Core State Standards in English Language Arts and the NGSS (Lee, 2017). Thus, science teachers may be left to reconcile the discrepancies as they plan and implement their curricula. The result may be a science curriculum that fails to address a variety of ways in which attention to literacy might support students' science learning (Wexler, Mitchell, Clancy, & Silverman, 2017).

Collaborative Professional Development

One way that teachers develop their instructional practices and curricula is through participation in professional development. As part of the National Survey of Science and Mathematics Education (NSSME+), middle school science teachers were asked about their participation in professional development (Banilower et al., 2019). Banilower et al. (2019) found that 94% of middle school science teachers attended some sort of workshop in science content or science teaching during the three years preceding the survey. Additionally, 61% participated in some form of teacher study group regarding science teaching (Banilower et al., 2019). These opportunities were, by and large, characterized by collaboration among teachers within and across school district. Though the question was not asked in the 2018 NSSME+, only 5% of middle school science teachers had responded in the 2012 iteration of the survey that their professional development experiences had been a "waste of time" (Banilower et al., 2013). Thus, most middle school science teachers in this study reported that they benefited from these opportunities.

Not all professional development is equally effective. Some relies heavily on transmission models in which the professional developer delivers lectures on a given topic or instructional strategy. Such models often run the risk of positioning teachers as deficient and in need of development, rather than as resources for curriculum development (Webster-Wright, 2009). Additionally, "Too often, teachers encounter new ideas through single-session professional development sessions, often attended by teachers from many schools and districts, meaning the work is sometimes divorced from content" (Dobbs, Ippolito, & Charner-Laird, 2017, p. 125). Such "drive-by's" often lack the ability to help teachers contextualize recommendations in ways that are suitable to local settings (Wallace & Louden, 1992).

One recent research team developed an alternative professional development model for increasing content-area teachers' understanding and incorporation of literacy into various subject area courses (Dobbs, Ippolito & Charner-Laird, 2016, 2017; Ippolito, Dobbs, Charner-Laird, & Lawrence, 2016). Through their collaborations with several school districts, they identified several needs that needed to be addressed within their context. Their model recommended facilitating teachers' learning from one another rather than through lecturing about "best practices" that might not be suitable to classroom needs. They also recommended valuing participants' content expertise, encouraging them to tinker with strategies and possibilities, as "the best strategies [are] likely ones that [don't] exist yet" (Ippolito, Dobbs, Charner-Laird, & Lawrence, 2016, p. 36).

Communities of Practice

The preceding suggests the importance of addressing needs for change through collaborative professional development that is built within communities of practice. Communities of practice are sites for knowledge building and professional development, as "productive activity and understanding are not separate, or even separable, but dialectically related" (Lave & Wenger, 1991, p.102). Communities of practice are held together by a sense of mutuality in which all members are positioned as trusting partners working to take on a joint enterprise or shared activity (Wenger, 2000). The social learning that occurs within these groups is the result of an ongoing interaction between one's personal experience, both within and beyond the boundaries of the community, and one's understanding of the systems that surround them. The outcome of such learning is an evolution of social structures within the community and potentially within the larger social systems in which it is situated (Wenger, 2000). Adopting a communities of practice lens and structure positions all members as both learners and resources in the joint activity of knowledge building. Each member's participation is mediated by personal, situated, and professional circumstances which may enhance or inhibit their participation (Day & Gu, 2007).

A group of science teachers working within the same school may be seen as a community of practice. Friedrichsen and Barnett (2018) argued that such groups can be "critical linchpins" in furthering educational reform efforts. Similarly, in examining the enactment of reform efforts in two schools, Bridwell-Mitchell (2015) described how teacher communities of practices can enable micro-institutional change by working to generate shared knowledge in an institutional context ripe with ambiguity. Goals, practices, and histories are shared among colleagues in the same discipline in the same school. Interactions with members of the community shape how individual members and the community as a whole carries out their everyday tasks. Yet, depending on the nature of interactions, these kinds of communities of practice can also be confining spaces in which little growth occurs, such as when resources developed by other systems or communities are not available for uptake or exploration by group members. Experience alone does not lead to expertise (Day & Gu, 2007). To grow, a community must be able to identify gaps or areas in need of development and seek appropriate and useful knowledge sources. In essence, social learning in a community of practice occurs at the borders and boundaries between communities and systems while maintaining the core values and joint enterprise upon which the community was founded (Wenger, 2000).

Communities of practice can grow beyond their initial constraints through interaction with other communities and agents or objects who operate at the boundaries of the community (Wenger, 1998, 2000). As scientific practices and literacy in science classrooms can overlap (Wilson-Lopez, Gregory, & Larson, 2016), collaboration between teachers across these disciplines may represent a fruitful boundary encounter or crossing (Wenger, 2000).

Communities of Practice in Collaborative Professional Development

Professional development can be a structured opportunity to foster collaboration within and across communities of practice. Collaborative professional development incorporates individuals from what may be seen as multiple communities of practice (Szteinberg et al., 2014). It respects and relies upon teachers' and other collaborators' desires and abilities to positively impact student learning. Teachers possess practical knowledge that is action oriented, contextually bound, tacitly understood, and integrated across multiple discourses (vanDriel, Beijaard, & Verloop, 2001). Steeg and Lambson (2015) identified three vital qualities of collaborative professional development: teachers' care and responsibility for their own learning, individual learning supported and shaped by group interactions, and a coherent design that addresses connectedness between theory, professional development, and practice.

Collaborative professional development that incorporates individuals from differing perspectives and roles has the potential to impact teachers' beliefs and practices. Szteinberg et al. (2014) examined changes in chemistry teachers' views on assessment throughout a collaborative professional development experience that incorporated university researchers. As teachers worked in collaboration with university researchers, they began to see how assessment tools could help them to focus on the content of student learning rather than the correctness of answers. Szteinberg et al. (2014) concluded that focusing on the construction of instructional tools is one effective way to impact teachers' views regarding a focal aspect of pedagogy (Szteinberg et al., 2014). Van Garderen, Hanuscin, & Lee (2012) described a collaborative professional development model that incorporated experts in science education and special education to enhance K-6 teachers' ability to teach science to all students, including those with disabilities. Their model occurred in three phases, first developing teachers' conceptual scientific knowledge, then connecting this knowledge to practice by working with teachers to practice implementation, and by providing periodic follow-up support. Participants in such communities of practice have been able to draw upon major conceptualizations across both domains to create positive learning outcomes for a variety of students (Van Garderen, Hanuscin, & Lee, 2012).

Thus, a community of practice engaged in collaborative professional development can be a fruitful site for work exploring teachers' practice-based understanding of constructs such as scientific sensemaking and literacy. As communities of practice represent comfortable and collegial contexts, teachers are likely to discuss their teaching practices and the ideas that inform them. As the goal of a community of practice is to continue developing one's practice and support the development of others, teachers are likely to develop shared understanding through discussions of classroom examples, student work, and future planning.

Summary

Communities of Practice are groups of people who work closely with one another toward a shared goal. Teachers, such as middle school science teachers, may operate as a community of practice when they engage in collaborative professional development. In collaborative professional development, a group of teachers working together to collectively improve some aspect of their teaching. In this study, both the book study discussions and the workshop series are considered collaborative professional development offerings. As a theoretical lens, communities of practice has been previously used to examine teachers' professional development. In this study, it is used to bound the focal activity system as the group of middle school science teachers engaged in the book discussion professional development opportunity.

Cultural Historical Activity Theory

Cultural Historical Activity Theory (CHAT) is a useful framework for considering educators' professional development. As its name suggests, it is a theory of action, used both to describe actions as well as to inform expansive transformations (Engeström, 1999). It aims to de-center individual humans in socio-cultural research by examining interactions between humans, materials, and contextual cultures and constraints. Thus, it proposes the system as the unit of analysis, rather than an individual or an individual's actions in isolation.

CHAT has evolved in three waves. Drawing upon Marx, Vygotsky established social constructivism as activity mediated by the use of tools (Fenwick, Edwards, & Sawchuk, 2011). Explorations of this mediational relationship is referred to as first wave activity theory. Leont'ev (1979) ushered in second wave activity theory by regarding social, cultural, and historical dimensions of an activity system as well as an increased connection between and individual's thoughts and action and the possibility for collective subjects engaged in shared action (Roth & Lee, 2007, Fenwick, Edwards & Sawchuk, 2011). CHAT evolved as third wave activity theory as Engeström and others began to look at intersections among activity systems (Mills, 2016).

Communities of Practice and CHAT

Communities of Practice and CHAT are useful theories to use in conjunction with one another because each addresses the weaknesses of the other. In a community of practice, it is easy for shared practices to be normalized and their functions to be "blackboxed" meaning that they have become automatic and unquestioned (Latour, 2008). CHAT provides tools and a lens through which a researcher-participant team can question how and why such practices have come to be, how they hold together, how they might be challenged, and to use this information to inform future decision-making. Also, while an activity system may be viewed as extending across time, space, and contexts, a communities of practice perspective allows a researcher to establish clearer boundaries framing a study as? the interactions between participants bounded by the same context and shared activity.

Activity System Elements

CHAT scholars often use a triangle diagram similar to Engeström's (1999) to delineate the relationships between six central elements (Figure 1). Straight, double-pointed arrows within the model indicate mediating relationships, whereas "lightning-shaped" arrows indicate contradictions inherent to the system.

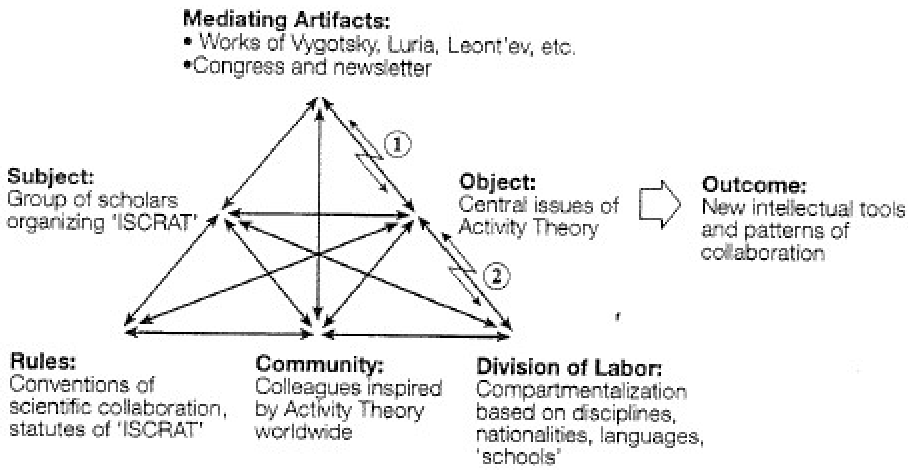


Figure 2.1. Activity system diagram (Engeström, 1999, p. 31)

To analyze such a system, one must understand what is meant by each of the six central elements. At the heart of an activity system is Vygotsky's model of tool mediation as seen through the penultimate triangle formed between subject, object, and tools. The object of the system is its central goal or purpose. Often misunderstood as a short-term concrete objective such as a lesson's learning outcome, Vygotsky's term in original Russian publications, *predmet*, refers to larger "units of actively, symbolically, and materially produced social concerns" (Fenwick, Edwards, & Sawchuk, 2011, p. 65), such as science learning operating as the object of science classrooms. This goal represents the intentionality of the system's subject. Subject refers to the human or humans working towards the system's object. While the singular form, subject, may be used for either a singular human or group of humans, the notion of a collective is inherent within the term, as an individual is not separable from the larger social collective. Using the subject-object relationship as a base, one can begin to explore mediation through the addition of the triangle's apex: tools. These tools, also called mediating artifacts, may refer to symbolic signs, as discussed by Vygotsky, or may consist of the material and physical tools used to conduct action within a system. Law and Hetherington (2003) provide a tripartite conceptualization of "stuff" consisting of bodies, materials, and texts. In an activity system, while bodies are likely to be positioned as subject or interactions between them as community, both materials and texts may be seen as mediating artifacts.

Elements forming the base of the larger triangle account for social, cultural, and historical mediators of activity as well as how these factors create tension within a system. Community refers to the social environment and culture within which an action is situated. In line with its Marxist roots, CHAT theorizes that communities have an established division of labor in which certain aspects of action are delegated to various members and completion of a task is predicated upon an element of cooperation. For example, members can play and shift between several roles within an activity system, including consumer, producer, and distributor (Engeström & Middleton, 1996). Additionally inherent to communities is the historical establishment of rules. These may be established and maintained through a variety of modes, ranging from unspoken social contracts shared by community members to codified policy documents, such as national and state educational standards. Implicit social rules may include things such as what is viewed as "good teaching" within a specific school context and how students should be expected to learn content material. It is also through these social elements where the influence of other activity systems may be most evident (Engeström, 1999).

The final element of an activity system is its outcome. As activity systems are in constant motion, their outcomes are ever-moving targets. Engeström (1987) described an activity system's cyclic evolution through time as *expansive* learning. Expansion occurs through the development of the internalization-externalization dialectic. Internalization refers to the improvement of elements within the system as the system grows over time. Early in the development of a system, internalization dominates. The system grows by tightening inward, increasing internalization, however, as it grows, it also begins to become more expansive, meaning that its growth can be seen through its influence on other aspects of society, first through the innovations of individuals, and later through transformations of entire systems (Engeström, 1999). Thus, expansion includes the simultaneous inward and outward growth of a system over time.

Dialectics and Contradictions

CHAT researchers also focus on contradictions or tensions that arise between or within activity system elements. Contradictions indicate challenged or stressed relationships where one element seems to be working against another. Through an exploration of contradictions one can expose the hidden workings behind the screen of the central subject-object relationship. When analyzing contradictions and tensions, certain discourse markers may prove fruitful. Engeström and Sannino (2011) described certain discourse markers as indicative of contradictions and tensions in an activity system. These include the use of hedging language such as “on the other hand” or “but,” oppositional language such as “no,” personal narratives, rhetorical questions, and expressions of helplessness. Yet contradictions are not always indicative of systemic failure.

Dialectics are contradictions composed of “nonidentical expressions of the same category which thereby comes to embody an inner contradiction” (Roth & Lee, 2007, p. 195). Dialectics exist as flip sides to the same coin. For example, if the object of a system is self-improvement, the system’s subject exists simultaneously as its object. In a dialectical entity, the two flip sides are unified through their interplay and reciprocal nature. Each expression exists because of and as a result of the other (Lee & Roth, 2007). Examples include individual|collective, praxis|praxeology, and coteaching|cogenerative dialoguing (Hwang & Roth, 2005; Roth & Lee, 2007; Tobin & Roth, 2005). Researchers use a line, rather than a hyphen or slash, to represent the inseparable relationship between a dialectic's constructs (Roth & Lee, 2007).

Dialectics can also manifest as tensions within a system as subjects work to navigate the multiplicity of roles carried out by a single entity, such as literacy. Literacy can serve as an object, as is the case in activity systems focused on literacy learning. It can be a tool, such as when an individual or group uses their literacy skills to access or communicate knowledge in textual resources. Additionally, literacy can be an outcome of a system focused on a different object. For example, in Roth's work with a community working to improve the health of a stream that flows through it, scientific literacy was an outcome of individuals from diverse epistemologies working jointly to build understanding (Roth & Lee, 2002; Roth & Calabrese Barton, 2004). Tension can arise between these roles and between subjects' (un)shared perspectives of these roles.

Roth and Lee (2002) described literacy as collective praxis. This conceptualization of literacy drew upon the individual|collective dialectic, in that while individuals engaged in literate practices, literacy was a collective outcome of shared activity in which participants operated in pursuit of a shared goal through adherence to contextual rules and the use of available tools (Roth & Lee, 2002).

As an example of how scientific literacy emerges through collective praxis, Roth and Lee (2002) provided an ethnography of a town working to make decisions regarding a river that flows through it. Members of the community represented a variety of identities and orientations to science through their participation in the decision-making process and included schoolchildren, environmental experts, questioning citizens, environmental experts, and Native

American tribal leaders. Under other orientations towards literacy, it is likely the environmental experts would be seen as those possessing greater scientific literacy, due to their educational backgrounds and professional titles. However, Roth and Lee (2002) saw literacy as dependent upon interactions between varied community members and upon the "right use of specialists, black boxes, simple models, interdisciplinary models, metaphors, standardized knowledge, and translations and transfer of knowledge" (p. 19). A thoughtful question during a public forum, data collected by students as part of their science class then used by town staff and environmental experts, and conversations while on a stream walk all worked to provide all participants with the widest array of perspectives possible and work together to make informed decisions regarding how to move forward. Roth and Lee (2002) expressed uncertainty over the applicability of literacy as collective praxes in K-12 science contexts. In their view, the science classroom would also be an activity system unto itself with students' science learning as its object. These scholars hypothesized that, in order to achieve this object, some level of attention to the individual applications of literacy would likely be necessary to support students' development of skills and tools they might use in other activity systems.

Actions and Operations

In a CHAT framework, an important distinction in terms exists between action and operation (Fenwick, Edwards, & Sawchuk, 2011). An action is an intentional move a subject or group of subjects makes in pursuit of an object. Yet activities consist of more than actions, more than what individuals actively decides to do to accomplish a goal. Subjects also conduct operations, which are unconscious or subconscious responses to systemic conditions (Lee, 2011). Un- and subconscious here may be misnomers, as operations may be intentional, but driven in response to conditions rather than in pursuit of the object. Operations contribute to activity systems in that they also occur in pursuit of a goal, but not in direct reference to the goal.

In addition to their two-sided coin analogy, Roth and Lee (2007) described the relationship between actions and operations as dialectic using an analogy to fibers and threads. Operations are fibers that make up an action's thread. The thread does not exist without the fibers and the fibers are meaningless to the system without their relationship to the thread. Barnard (2010) provided an example of operations within teachers' practice.

> "Operations are routine steps taken by a teacher in the course of any lesson – such as issuing instructions, giving feedback, making notes on the whiteboard, etc. These are carried out without much conscious though – although almost all operations are firstly learnt consciously before they are automatised (sic)" (p. 27).

For instance, teachers' actions may be seen through the intentional planning and delivery of lessons in pursuit of a content-area standard. Simultaneously, their operations may be seen through their organization of classroom furniture, classroom management, and grading practices that result from the classroom context rather than in direct response to the focal standard. While certainly some teachers deliberately consider these instructional elements in ways that would not be described as routine, for many observers of classroom activity systems they become "transparent" (Roth & Lee, 2007). Roth and Lee (2007) explain that transparent operations may be missed when describing mediational relationships within an activity system, as the operation may appear as an integrated part of a larger whole. They warn that lack of attention to transparent operations may result in a misrepresentation of the system. Rather, operations serve as fruitful entry point for fruitful exploration and analysis (Roth & Lee, 2007).

Yet, analyzing something that is transparent is tricky. Actor-Network Theory provides perspectives which may be useful when considering operations within a CHAT framework. ANT scholars work to deconstruct a taken for granted aspect of the current social world in order to see what has constructed it (Latour, 2008). ANT positions a socially constructed entity as a result of a series of sociomaterial interactions. ANT scholars trace how these interactions come to be, how they "hold together," and eventually, how they fall apart (Fenwick, Edwards, & Sawchuck, 2011). ANT scholars believe that "an actor is made to act by many others," and that actions incorporate un- or sub-conscious components which can be disentangled through a consideration of how they have come to be (Latour, 2008, p.46).

ANT scholars explore five major sources of uncertainty when considering routine or taken for granted social constructions such as operations: the nature of groups, actions, actors, facts, and research (Latour, 2008, p.22). Considering these uncertainties opens up spaces to analyze taken for granted aspects of the social world, such as operations. The formation of a group has no clear initiation point. While one might be inclined to indicate that a group was formed when two individuals came together and bound a study to what happens after that point, ANT complicates the moment of initiation by exploring how – physically, cognitively, and socially – these two individuals arrived at a shared physical and social location, the series of delegations and translations involved in their coming together. Similarly, an action requires a stimulus. Actors, both human and material act in response to something or because of something. When doing so, their historical knowledge and experience is translated into the current action. An actor can extend their reach by delegating their action to another human or material actor. For example, the law can act upon drivers by delegating its role to a speed bump. While drivers may slow down for the speed bump either out of respect for the law or fear of damaging their car, the law has been followed as a result of the speed bump (Latour, 2008). ANT questions the authority of constructs perceived as a matter of fact. Knowledge is built through social interaction and is often open to dispute when new elements are introduced into the interaction. ANT also recognizes that research accounts are created using limited lenses. It is not possible to see the full network of interactions involved in how something came to be and how it is currently evolving. As one uses ANT to trace an entity's history, this development begins to feel like a reading of the picture book *Zoom!* (Banyai, 1998) where each illustration is but a small element in the subsequent illustration. Researchers are limited by what they can actually observe, what they adequately capture and analyze from what they've observed, and the lenses through which they have been "made" to see the world.

CHAT Studies in Science Education

Science education researchers have used CHAT to describe how elements of science teachers' practice shape inquiry activity systems for students. Patchen & Smithenry (2014) conducted a CHAT analysis to describe three participant structures in a high school honors chemistry classroom. They found that students participated in their inquiry-oriented science classroom as individuals, as groups, or as a class-wide collective. Over the course of a school year, the focal chemistry teacher in this study engaged students in each of these participant structures. Through examining the use of tools, Patchen & Smithenry (2014) drew connections between the participant structures. They also discovered that, even though a tool may be introduced through one participatory structure, it may be available for student or teacher use within other structures and may be transformed over time or across structures. These researchers concluded that teachers' diversification and integration of multiple participant structures facilitated students' development of agency in scientific inquiry.

van Eijck and Roth (2008) used CHAT to explore the representation of scientists in science textbooks. They determined that textbooks position the aims of scientific practice as separate from human activity, characterize scientists' actions as developing intangible tools from tangible objects, position a scientist's scientific activity as disconnected from the other activity systems the scientist may be a part of, and represent the community of scientists as including few outsiders and largely devoid of multi-directional division of labor. vanEijck and Roth (2008) concluded that, by and large, science as presented to students through textbooks is an activity that has already been completed by a small number of heroic men.

Prins, Bulte, and Pilot (2018) used CHAT to design curricular materials for a unit centering students' authentic modelling practices. They worked with six chemistry teachers using an activity-based instructional framework to re-design a unit's instructional activities. The CHAT-informed structure helped the design team to focus first on the overall structure of the teaching-learning dialectic before focusing on individual instructional materials and activities. The resulting activities supported students' enactment of authentic contextualized modelling.

CHAT Studies in Literacy Education

Literacy education researchers have used CHAT to explore young people's activities of reading, writing, and collaborative talk. Ivey and Johnston (2015) used CHAT to understand how four eighth-grade teachers' decision to alter their ELA instruction impacted the activity systems of the classroom as part of a four-year formative experiment. They explored two types of activity systems, teachers and classrooms as well as the interplay between them. As the teachers made changes to the classroom reading activity system, students' engagement with text changed. As student engagement shifted, teachers saw the need for continued tweaks to the teaching activity system (Ivey & Johnston, 2015). Jacobs (2016) conducted a CHAT activity system analysis to understand a high school student's instant messaging activity with 4 friends. Through instant messaging, the student was seen as a consumer, producer, and distributor of text in ways that allowed the student to meet the demands of a variety of contexts including academic and social contexts (Jacobs, 2016). Russell (1997) used CHAT to explore the connections between disciplinary and educational genres of writing, including how larger social structures could impact localized classroom activity. Lee (2003) used CHAT to analyze high school students' preparation for a literature-based class debate including how students' use of AAVE and Toulmin, Rieke, and Janik's (1984) argument structure mediated their argumentation. Gutiérrez, Banquedano-Lopez, Alvarez, and Chiu (1999) explored collaboration in an after-school computer club. As a tool, literacy mediated collaborative activities, allowing students to mobilize linguistic tools from a variety of languages to build relationships and create opportunities for all students to participate (Gutiérrez et al., 1999).

CHAT Studies in Educators' Professional Development

Educational professional development researchers have used CHAT as a lens to examine teachers' learning through participation in professional development and subsequent practice. Beatty (2012) examined the coevolution of a teacher's growth and subsequent development in their pedagogies regarding the incorporation of technology-enhanced formative assessment. This study positioned professional development as an activity system with a participating teacher as a subject and eventual teaching practices as the object. Beatty (2012) identified professional development methods and resources, expectations and norms of teaching, other participating teachers and professional development facilitators, and the roles participants and facilitators play in professional development as mediators of teacher learning. Additionally, the study positioned classrooms as activity systems where a teacher's action is oriented toward student knowledge as the object. While teachers' use of the assessment measurement was situated as an object in the professional development system, it was transformed into a tool in the classroom system. Thus, influences of the professional development system could be found in the classroom system through the subject and mediating tools (Beatty, 2012).

Feldman and Weiss (2010) explored the impact of collaborative action research on teachers' professional development through an ethnographic CHAT study of teachers involved in a collaborative action research project over two cycles. Teachers who completed one cycle of action research showed little to no change in their identities while teachers who completed both cycles demonstrated changes in their identities. A CHAT analysis was used to explore this differential. This analysis revealed that the confluence of differing objects and roles as well as the addition of small group meetings as a tool may have led to teachers' reported changes in teaching identities.

Summary

This chapter reviewed research on scientific sensemaking, literacy, professional development, and the use of CHAT to explore these constructs. It explained research that has explored sensemaking and literacy within science education, collaborative professional development as an environment for teacher learning, CHAT theory, and use of CHAT to describe science and literacy learning in activity systems.

Considering science educators' understandings of scientific sensemaking and literacy may serve as another avenue to reconcile varied orientations toward literacy in science within and across fields of study. Science education scholars' descriptions of scientific sensemaking seem to parallel literacy scholars' descriptions of literacy as meaning-making. Middle school science teachers are ideally situated informants, as they work to build students' scientific knowledge and learning skills in preparation for future high school science learning.

This study works to address gaps in the available research. Not much is known about teachers' understanding of scientific sensemaking as they work to implement standards aligned to the NRC's *Framework* (2012). Additionally, not much is known about the role of literacy in instruction designed to foster student sensemaking. A CHAT analysis of one community of educators engaged in professional development to incorporate scientific sensemaking into their teaching is likely to provide fruitful new insights about how teachers' understanding of these constructs is mediated by their context and resources. Using a CHAT lens allows for the exploration of tensions that arise as educators work to develop practices that support students' scientific sensemaking. The next chapter provides additional detail regarding the methods and CHAT analysis used in this study.

CHAPTER THREE: METHODOLOGY

This chapter describes the research design of this analysis, incorporating qualitative research methods, and a CHAT analysis supplemented by the use of ANT. This study explored the overlapping collective activity of teachers engaged in a book study group, a workshop series, and of the professional developers, including myself, planning and facilitating that workshop series. (Kemmis & McTaggart, 2005). In the following sections, I describe the context, including the school and participants, my role, a description of the activities in which participants engaged, data collection, and data analysis.

Qualitative methods were appropriate to use given the descriptive nature of this study (Bogdan & Biklen, 2007). Qualitative research methods encourage gathering data such as interviews, team meeting observations and transcripts, artifacts used by and created by participants to develop rich descriptions and insights (Bogdan & Biklen, 2007). A CHAT activity system analysis (Yamagata-Lynch, 2010) was used to explore the roles of activity system elements in developing professional development providers' and middle school teachers' understanding and use of literacy as a tool for scientific sensemaking.

Context

This study took place in New York State. While New York did not formally adopt the Next Generation Science Standards (NGSS), the New York Science Learning Standards, updated in 2016, align with both the NRC framework and the NGSS (NGSS Lead States, 2013; National Research Council, 2012; New York State Education Department, 2017). New York State charged publicly funded professional development agencies with initiating implementation of its new science standards across its regions ahead of the anticipated 2021 roll-out of assessments tied to these standards.

Within New York State, middle school was a good grade-level context for this study. Middle school science curricula covered a variety of scientific disciplines including both physical sciences and biology. Previous and current state standards do not delineate science content by grade level in middle schools. Rather, they present one set of standards for grades six through eight. This allows individual middle schools flexibility in how they choose to structure and sequence science courses. Teaming was also a more common practice at this level, with teachers often sharing and collaborating to address students' inclusion and development. Thus, teachers at the middle level were likely to be open to interdisciplinary conversations and collaboration focused on scientific sensemaking and literacy.

High school teachers were not selected as a target population for this workshop series or study. While science teachers at all levels in New York should have all be making efforts to align their curricula with the new standards, high school science teachers' activity was bound by the expectation that they prepare students for subject-specific Regents exams tied to graduation requirements taken at the end of each course. At the time of this study, these examinations were not yet aligned with the new standards and were not set to be so until 2021. Thus, high school science teachers likely felt a need to continue to teach as they had been to cover content to be tested. As high school science teachers' evaluation in New York is tied to student passing rates on applicable Regents exams, this would be reasonable. Many high school science teachers were waiting to see what exams tied to the new standards would look like before making potentially drastic changes to their pedagogies.

Elementary teachers were not selected as a target population for this workshop series either. While a state-wide assessment is currently given in fourth grade, this group was not as constrained by high-stakes state-wide science assessments as their high school counterparts because students' grade advancement was not tied to performance on this assessment. In addition, the regional professional development agency was already working extensively with elementary teachers to improve science through training and support tied to published curricular kits recently adopted by many of the component districts. While literacy was invoked by the sensemaking opportunities in these units, it was not feasible for the local professional development group to provide additional workshops for this level at this time.

At the time of the study, teachers across the state were working with regional professional development agencies to learn how to align their instruction with the new standards. One regional professional development agency was selected as a site for this study. The regional professional development agency served over a dozen component districts. It worked with science teachers in two ways. The agency served as the clearinghouse of science materials, often packaged in kits, used by elementary teachers throughout the region. While the agency had previously used kits designed in conjunction with local teachers aligned to previous standards, it was now providing *Smithsonian Science for the Classroom* curriculum kits (Smithsonian Science for the Classroom, n.d.). The agency also provided professional development for teachers of all subjects across all grades.

The regional professional development agency employed a number of professional developers across an array of disciplines including literacy and science. These individuals often attended state-level trainings where they developed knowledge of new standards and initiatives. They used this knowledge, as well as their professional knowledge of their disciplines, to provide regional workshops. At the time, the agency was working to provide more collaborative workshops through leadership teams where disciplinary teacher-leaders from the component school districts can learn from one another rather than merely with one another. District teaching teams were given assignments between sessions that encouraged collaboration among teachers within a school district for teacher learning and support. During the previous school year, the science leadership team focused on developing an understanding of the practices outlined in the standards as well as how they intersected and built off one another. Working in a state-funded regional professional development setting allowed me to engage with professional developers and teachers as they developed an understanding of scientific sensemaking and literacy and explored how to support teachers' implementation of new standards and pedagogy.

Marksboro's team of science teachers was recommended to me as a group of teachers doing exemplary work towards realizing the new standards by Grace, the head of the regional agency's professional development team. She described them as a team that was on the cutting edge of understanding and implementing the new standards.

Several Marksboro Middle School teachers were involved in the agency's science professional development offerings. At least one of the Marksboro participants had attended the science leadership professional development series during the previous year. Four Marksboro participants had also attended a summer workshop led by Rachel, a science professional developer at the agency. This week-long workshop had focused on the creation of storylines tied to the new standards. It used the first two chapters of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) as a framework and support for teachers' initial attempts to design a storyline. During the fall semester following that workshop, Marksboro Middle School science teachers had continued to consider how to build storylines into their science curriculum. Rachel and I provided a regional workshop on scientific sensemaking and literacy before Marksboro teachers were recruited for this study. Four of the Marksboro participants attended this workshop. During this workshop, I learned that Marksboro Middle School teachers would be conducting a teacher-led book study of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) to continue their exploration into how to best align their instruction with the expectations set forth in the new standards.

In collaboration with a science education professor, Grace spearheaded a lesson study conference which was held during the data collection period of this study. Mark Windschitl was a keynote speaker at this event. Five of the Marksboro participants also attended this event. Several participants explicitly connected aspects of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) to this event during subsequent book study discussions.

Thus, Marksboro Middle School was selected as the focal school setting for this study. It was a component district served by the professional development agency and in a suburban setting. It served as the only middle school within the district, with over 900 students attend (New York State Education Department, 2018). 74% of these students identified as white. 8% identified as Asian or Pacific Islander. An additional 8% identified as Black or African American, 5% as Multiracial, and 4% as Hispanic or Latino. Roughly 15% of Marksboro Middle School students received free or reduced priced lunch. This number was well below the state average. Fewer than ten students school-wide took the New York State English as a Second Language Achievement Test, indicating their status as English Language Learners. Roughly 60% of students scored at or above the proficient level on the state's most recently reported standardized grade-level ELA exam, and roughly 75% scored at or above the proficient level on the state's standardized grade-level mathematics exam. Roughly 90% of Marksboro's eighth graders scored at or above the proficient level on the state's standardized science exam. This exam is not given in grades five through seven. Even though it may appear that Marksboro's science achievement outpaced achievement in ELA and Mathematics, this was not the case. State data indicated a trend that in school districts with similar demographics to Marksboro, significantly more students scored at or above the proficient level on the science exam than on either the ELA or mathematics exam (New York State Education Department, 2018).

Participants

Eleven people participated in this study. Nine were teachers in Marksboro Middle School and two were professional developers at the regional professional development agency that served the Marksboro School District. Participants and their roles are listed in Table 3.1 and described in more detail below.

Marksboro Middle School

Name	**Role**	**Participated in**
Marie	Seventh-grade science teacher, department chair, book discussion facilitator	Book discussions, Workshops, Interviews
Elizabeth	Seventh-grade science teacher	Book discussions, Workshops, Interviews
Irene	Eighth-grade science teacher	Book discussions, Workshops
Mae	Eighth-grade science teacher	Book discussions
Ada	Sixth-grade science and ELA teacher	Book discussions
Frank	Special education teacher	Book discussions
Charlotte	Seventh-grade ELA teacher	Workshops, interview
Emily	Seventh-grade ELA teacher	Workshops
Joan	Music teacher	Workshops

Regional Professional Development Agency

Name	**Role**	**Participated in**
Rachel	Science Professional Developer, grades 4-12	Planning meetings, Workshops, Interviews
Grace	Professional Development Team Coordinator	Interview

Table 3.1. Participants and their contexts

Marksboro Middle School Study Participants

Nine middle school teachers from Marksboro Middle School participated in this study. I collected demographic data from the four participants who agreed to semi-structured interviews but not from those who had consented for data to be gathered only during book study meetings and workshops. However, all appeared to be white, which was typical of teachers in the region and of science teachers. Participatory data for each participant is found in Figure 3.1.

Marie facilitated the book study discussions. She was currently serving as the middle school science department chair and seventh-grade science teacher. She was a fifty-year-old white woman who had taught for over 26 years. Her teaching experience spanned three states, and included positions at the elementary, secondary, post-secondary, and professional development levels. She was certified in Biology, Chemistry, and General Science for grades 7-12 as well as in Childhood Education for grades 1-6. She held a doctoral degree in science education and was working on a Certificate of Advanced Studies in School Leadership. She participated in two semi-structured interviews, six book discussions, and three workshops.

Elizabeth was also a seventh-grade science teacher. She was a 39-year-old white woman. She had 14 years of teaching experience, mainly in an urban district. She had taught middle school science and high school Biology for the last five years at Marksboro in addition to serving as an instructional coach for one year in a previous district. Elizabeth held certifications in Biology and General Science for grades 7-12. Additionally, she held a National Board teaching certification in science. She had previously been a part of a study on inquiry science teaching led by a local professor. Elizabeth participated in seven book discussions (one via phone), three workshops, and two semi-structured interviews.

Joan was a fifth- and sixth-grade music teacher. She was a 50-year-old white woman. She had over 20 years of music teaching experience in K-12, post-secondary, and community settings. She held a New York State teaching certification in Music for grades K-12 and held certifications in specific music pedagogies. Joan was currently working towards a doctoral degree. She participated in three workshop sessions and two semi-structured interviews.

Charlotte was a seventh-grade ELA teacher. She was a 28-year-old white woman. She held teaching certification in English Language Arts for grades 7-12 and Special Education for grades 7-12. She had previously taught middle school ELA in an urban district in an alternative school setting as well as in a single-gendered setting. Charlotte participated in three workshops and one semi-structured interview. Due to a family emergency, she was not able to participate in a final semi-structured interview.

Five other teachers participated in the book discussions or workshops. Mae and Irene taught eighth-grade science. Mae had previous teaching experience in a nearby urban district. She attended seven book discussions. Irene was referred to by herself and other participants as the newest teacher in the group. During the course of this study, she also participated in science professional development and coaching through a state-sponsored program. Irene attended seven book discussions, serving as the facilitator during Marie’s absence. She also participated in three workshops. Ada taught sixth-grade science and ELA. During the course of this study, she also participated in two other book study groups with other colleagues. Frank worked as a sixth-grade special education teacher across disciplinary contexts. He attended three book discussions. Emily was a seventh-grade ELA teacher who had experience in a smaller, more rural high school in the region before coming to Marksboro. She attended three workshops. All five of these teachers appeared to be white. Frank identified as male, and the others all identified as female.

Professional Development Agency Participants

This group consisted of two professional development providers from the regional agency, Rachel and Grace. Rachel was a science professional developer at the regional agency focused on working with teachers in grades 4-12. While her position was initially intended to focus on the intermediate grades, her secondary counterpart had recently left the agency and

Rachel had picked up these responsibilities. As a retired teacher, Rachel was contracted to work part-time; however, often worked far more than 40 hours in a week. Rachel was a middle-aged white woman. She held certifications in Biology, Chemistry, Earth Science, and General Science for grades 7-12. She'd taught for over 30 years in two local school districts including courses within each of her certifications as well as in elective courses focused on topics such as biomedical technologies, environmental science, and global scientific issues. She also had previous work experience as an outdoor educator and had served on the board of trustees for an environmental sciences college. Rachel participated in two interviews, seven workshop planning meetings, and the three-part workshop series.

Grace was a peripheral participant in this study, as she oversaw professional development across disciplines within the agency. Grace was a 42-year-old white woman. She held New York State teaching certifications in Chemistry for grades 7-12, General Science for grades 7-12, and as a District Leader. Before taking the position as the coordinator of professional development at the regional agency, Grace had worked as a middle school science teacher in a local district and as a science center coordinator within the agency. She also had previous work experience as an engineer. While Grace had indicated interested in participating in the workshops, she was only able to attend a semi-structured interview. Despite her limited participation, this interview was kept in the data corpus because she is referred to by both the participating teachers and Rachel as a source of their developing knowledge. Thus, it was seen as important to include her perspectives on literacy and sensemaking, as they inform others' perspectives within the system.

Researcher's Role

I held two roles within the activities examined in this study. I was a member of the professional development planning and facilitation team and an observer of teachers' book study discussions. Like many of the other participants, I am a white woman. I was 34 years old at the time of data collection. I held New York State teaching certifications in Literacy, Biology, and General Science for grades 5-12 and Childhood Education for grades 1-6. I had previously taught for seven years as a high school literacy specialist. Thus, working in middle school science was beyond the realm of my previous teaching experience yet relevant to my areas of certification and college studies. As most participants in this study had more experience in science teaching, I worked to shape my role as that of a literacy educator who had some understanding of science, rather than as a science educator.

I was a participant of the professional development team. I had been invited by Grace to co-lead a workshop series for middle school teachers that built on the summer storylines workshops to further develop teachers' consideration of the new state standards and recommended teaching practices. This planning team had originally been conceived to also include science and literacy professional development providers from the agency. As the planned series was to focus on scientific sensemaking and literacy, it became clear that this would be a good site for my dissertation research. However, due to shifts in staff and their responsibilities within the agency, no literacy professional developer was available to participate on this planning team. Thus, I became the sole literacy professional developer on this team.

I worked with Rachel to plan and facilitate the workshop series. I took the lead role in identifying focal activities. Additionally, I provided Rachel research and professional resources to inform our planning and collaborated on the final workshop lesson plan for each session. I was cognizant that I was not well-acquainted with the complexities and intricacies of the regional and local contexts and relied on Rachel for this information. I also deferred to Rachel on matters of scientific accuracy and connections to science teaching.

Additionally, I observed the teachers' book study meetings. As opposed to my role on the professional development planning team, I conceptualized my stance here as an unobtrusive observer. I was able to maintain this stance for the majority of the time; however, there were two occasions where I entered the conversation. On March 25th, I indicated that I knew of and had access to a document to which two teachers were referring and I offered to bring it to the next book discussion meeting. On April 8th, I contributed to a conversation in which teachers were developing a modeling template. I contributed here in two ways, first by clarifying an aspect of the focal text, and second, by asking a question. The first contribution was trivial, in that I indicated that the authors had likely used their templates several times before publishing them. This was in response to one participant's distress that her template did not look as complete as the image in the book. The second contribution was more significant than the first, as I inserted a new idea into the conversation by asking what the developing model template would look like if a structure other than the one provided in this chapter of the book was used as the foundation for the teachers' developing model template. This interjection was intended to spark participants' memory of discussions they had had regarding previous chapters. After this interjection, one of the participants indicated that they recognized me as "one of [us] now."

While I worked to maintain my role as an observer during book study meetings, my knowledge of the science teachers' discussions influenced my work as a professional development provider. For example, when planning the second workshop, I was cognizant of the fact that the science teachers' discussions around the types of representations they planned to use with their students. Their discussions had centered on news stories from reputable new sources like *The New York Times* and videos made for middle school students. I decided to put texts in front of them that did not look like these for two reasons. First, I wanted the text to feel unfamiliar and challenging so that they would be able to consider how they work through challenging scientific texts as adults. Second, I wondered what their thoughts might be around how to prepare students for disciplinary texts which weren't written for a youth audience. This decision was also informed by conversations I'd had with Rachel in which she'd mentioned how she thought journal articles, or excerpts of journal articles, would be reasonable texts to include in sensemaking-oriented storylines.

Collaborative Professional Development

Two collaborative professional development experiences were included in this study: a science teachers' self-initiated book discussion group and a workshop series on literacy across the disciplines co-facilitated by Rachel and me. Three participants from the book discussion group, Marie, Irene, and Elizabeth, also attended the workshop series. The two opportunities were selected for study because they held potential to provide useful data regarding science teachers' understandings of scientific sensemaking and literacy. It was assumed that the book discussion group would likely provide ample data regarding understandings of scientific sensemaking, but that understandings of literacy may remain occluded in this setting. The workshop series was designed as an additional data collection tool in order to capture teachers' understandings of literacy as demonstrated in professional development activity.

Book Discussion Group

The book discussion group was formed as a professional learning community by Marksboro Middle School science teachers. The group received approval for this professional development opportunity through the district's professional development center, which meant that they received professional development credit hours and were paid for their attendance at each session. *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) was selected as a focal text because several science teachers had read the first two chapters in a regional professional development workshop facilitated by Rachel the previous summer. In her initial interview, Marie stated that the group believed that the book had the potential to "bring [the new standards] to life." The group met every other Monday for one hour immediately after school from January 28th to May 20th. Each week, the group discussed one or two chapters of *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018) in relation to their developing storylines and teaching practices. Research permissions were obtained to observe book discussions by the district in early February and consent was solicited from participants on February 11th. Thus, the first book discussion observed for this study was February 25th. The schedule of these discussions can be found in the data collection schedule found in Table 3.2.

Date	Event	Mar	El	Mae	I	A	F	Em	C	J	R	G
10/4	Coordination meeting (no data)											x
10/31	Regional PD Planning (no data)										x	
12/11	Interview										x	
12/13	Regional Professional development offering (Marie, Elizabeth, Mae and Irene present, but not yet study participants)										X	
12/18	Reflection meeting										X	
1/28	Regional Professional Development Planning										X	
2/11	Regional Professional Development Planning										X	
2/11	Book Study – Introduction of study, solicitation of consent	x	x	x	x	X						
	School district Workshop Planning										X	
2/25	Book Study – Eliciting students' ideas	x	x	x	x	x	x					
3/11	Book Study – Making thinking visible through models, Allowing students to show what they know	x	(by phone)	x	x	x	x					
3/25	Book Study- Supporting ongoing changes in thinking: introducing new ideas	x	x	x	x	x	x					
3/29	Interviews (individually)	X	x									
4/8	Book Study – Supporting ongoing changes in thinking: activity and sensemaking	x	x	x	x	x						
4/11	Workshop 1 – Engaging in practices as sensemaking	x	x		x			x	x	x	x	
4/17	School district workshop planning										x	
4/22	Book Study – Supporting ongoing changes in thinking: collective thinking, Making and justifying claims in a science community	x	x	x	x	X						
4/29	Interview								X			
5/1	Interview											X
5/6	Book Study – Drawing together evidence-based explanations		X	x	x	x						
5/7	Interview									X		
5/8	Workshop 2 – Practices while reading disciplinary texts as sensemaking	x	x		x			x	x	x	x	
5/15	School district workshop planning										X	
5/20	Book Study – Organizing with colleagues to improve teaching, Can we be ambitious every day?	x	x	x	x	x						

5/26	Workshop 3 – Argumentation as sensemaking	x	x		x			x	x	x	x	
6/7	Interview		X									
6/11	Interview	X										
6/13	Interview										X	
6/18	Interview									x		

Table 3.2: Data Collection Schedule

Workshop Series

The workshop series was originally conceptualized for this study as a regional professional development offering on scientific sensemaking and literacy for teams of middle school science teachers and their literacy colleagues. The aim of the intended professional development was to create an opportunity for shared learning that could improve teaching practice across component districts. The regional professional development agency's collaborative professional development model was built upon several assumptions. First was the idea that single-session, decontextualized professional development sessions do little to foster teachers' continual learning and improvement (Desimone, 2009; Yendol-Hoppey, Dana, & Hirsch, 2010). While this workshop series may have appeared to be a 3-part extension of a decontextualized "drive-by" model, it was intended to be one piece of a larger professional development scheme including the science leadership workshops that recur and connect across multiple school years, and grade-level band specific workshop series that are developed to support teachers' learning. The second assumption was that literacy and science teachers would approach the material from different perspectives and that drawing out the multiple perspectives would create positive learning outcomes. We also assumed that science and literacy teachers would draw upon each other's knowledge when collaborating to craft storylines and that this would benefit the developing storylines.

Rachel posted this intended workshop series on the agency's database of regional offerings on January 28th. By February 25th, only Marksboro Middle School teachers had registered. Under the guidelines of the regional agency, the regional offering was canceled. Rachel believed that the lack of registration did not indicate a lack of interest from teachers, but rather reflected other contextual constraints. All component school districts had declared multiple snow days and had a winter vacation during February. Grace indicated that many schools were converting a shared conference day into a make-up instructional day which was impacting other regional professional development offerings. Rachel wondered if some teachers were also feeling "professional development overload," as she knew that science teachers across the region had been attending multiple full-day, half-day, and after school professional development opportunities she facilitated.

To facilitate my ability to complete my research, Rachel offered to volunteer her time and collaborate with me to provide a workshop series on literacy across the curriculum in Marksboro tailored to Marksboro teachers. A Marksboro district administrator indicated that such a workshop should be open to all teachers, rather than only science teachers and their literacy peers. So, the focus of the workshop series was shifted to consider literacy and sensemaking across the district. Three science teachers from the book study group signed up as well as two ELA teachers and a music teacher. All teachers who signed up for the workshop series agreed to participate in this study. Four of these, science teachers Marie and Elizabeth, music teacher Joan, and ELA teacher Charlotte, consented to semi-structured interviews.

When the switch from a regional to a local workshop series, new meeting dates needed to be set. When the description of the offering was distributed school-wide, interested teachers were invited to indicate anonymously on a Doodle Poll which dates would work in their schedules.

Three Wednesdays were selected that best fit the schedules of the participants and would also work with Rachel's schedule. The final schedule of events is listed in Table 3.2.

The book study discussions and the workshop series ran concurrently during the spring semester of 2019. Book discussions were held on Mondays bi-weekly. At each meeting, teachers discussed one or two chapters of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). This group met twice before research permissions were obtained for this study. During the group's third meeting, I introduced the study and provided informed consent documents. Teachers were given two weeks to consider their participation in the study. All six teachers participating in book study discussions agreed to participate in this study. However, only two, who also attended the workshop series, consented to semi-structured interviews.

Workshop one. For the first workshop, Rachel and I used the first workshop to explore what literacy and sensemaking could look like in different disciplines. We adopted Moje's (2015) 4E's model as a useful framework for this task. I had shared this text with Rachel shortly after our initial interview because I believed she would appreciate its focus on disciplinary practices. When planning for the first workshop, Rachel noted that she liked that this framework was rooted in disciplinary practices and that the practices closely mirrored the scientific practices in the science standards. I liked that it incorporated attention to literacy strategies, including use of critical lenses. Rachel believed we should engage participants in a hands-on science activity in order to elucidate teachers' own sensemaking. I wanted to use a variety of texts in order to spark sensemaking conversations.

To connect our work across workshop sessions, and as a nod to science storylines, we focused all our examples on the phenomenon of getting sick. We developed a lesson plan for the first session that began with teachers asking questions in response to a bar chart representing the average number of sick days taken by members of various professions. We planned to introduce sensemaking and ground it in disciplinary practices. After considering their own disciplinary practices, teachers would participate in two science activities: a reading activity engineered to incorporate and support specific reading skills, and a hands-on simulation also engineered to incorporate multi-modal reading and writing. We selected a published summary of a research study on bacterial biofilms in preschools as the focal text for the reading activity. During the reading activity, cross-disciplinary pairs would work to fill out a chart, found in Appendix A. Cross-disciplinary pairs would then simulate wiping down surfaces using sandpaper and salt in order to describe how seemingly smooth surfaces may actually be porous, allowing some bacteria to stick to the surface after it had been wiped down. This simulation had been inspired by Tang, Tighe and Moje's (2014) chapter, which used a similar simulation. While their simulation focused on nanoparticles, I introduced it to Rachel as potentially working for our purpose as well. Rachel confirmed that this activity would accurately portray the scientific ideas we were presenting.

Workshop two. At the end of the first workshop, teachers selected the focus for the second. They wanted Rachel and I to focus on what sensemaking might look like across disciplines while reading. When planning the second literacy workshop, Rachel and I struggled to conceptualize an activity that would allow teachers across all three disciplines, science, ELA, and music, to experience and demonstrate what sensemaking could look like while reading in their disciplines. After discussing several ideas, Rachel and I decided that textmapping (Middlebrook, 2002) might be a useful strategy in that it could be used flexibly across disciplines to illustrate thought processes. Textmapping is a teaching strategy designed to help students navigate text features. While initially intended for non-fiction texts, the textmapping website also provides examples of how teachers might use the strategy with a variety of texts. When engaging in textmapping, teachers guide students to box in specific text features in a text that has been assembled into a scroll. Creating scrolls from texts allows students to see a text in its entirety, rather than a page at a time. During this workshop, teachers would describe how they progressed through specific lines and sections of their disciplinary texts using textmapping as a visual tool. We created a text set around infectious diseases representing each discipline. Science teachers would work with a scientific journal article and a multimodal excerpt on the immune system from a children's trade book. English teachers would work with an encyclopedia entry on malaria, Poe's (1842) *The Masque of the Red Death*, and a short poem. Joan worked with the score of "Guilio's Song" from Coregliano's (1999) *Symphony No.1*, eulogizing a cellist who died of AIDS. We selected only one text for Joan because it was significantly longer than any of the other texts.

Workshop three. At the end of the second workshop, teachers asked for the third workshop to focus on argumentation. For the final workshop, Rachel and I wanted teachers to be able to see connections in how literacy related to argumentation could operate across disciplines, as they'd ended the previous workshop considering the differences. We asked teachers to bring examples of argumentation assignments and supports from their classrooms and content areas. Rachel and I created an extensive supplemental collection with resources obtained from disciplinary sources, such as *Read Like a Historian Project* (Stanford History Education Group, n.d.) and *Arguing from Evidence in Middle School Science* (Osborne, Donovan, Henderson, MacPherson, & Wild, 2017), interdisciplinary sources such as EngageNY.org, and internet searches. Teachers would engage in an individual exploration of the resource collections by subject area, noting elements that they liked, disliked, or questioned. In cross-disciplinary partnerships, they would take a deeper dive in a specific content area other than their own, looking for structures, language, and supports which could be incorporated across disciplines to share with the group. In the final conversation, the group would discuss what they wanted to do, individually or collectively, moving forward.

Data Collection

I collected several different types of data from professional development planning participants and teacher participants. Yamagata-Lynch (2007) notes that a data collection that incorporates a variety of data types and sources is imperative for a CHAT analysis. I collected fieldnotes during professional development planning meetings, book discussions, and workshop sessions. Individual interviews were audiotaped. Audiotaping allowed me to accurately capture participants' responses. I collected artifacts in order to describe the design, delivery, and outcomes of the professional development workshops planned as well as local work done by the teaching team during book discussions, which included workshop plans and handouts Rachel and I created, teachers' collaborative work from each workshop, teaching artifacts and outside resources brought to book study discussions by teachers, and photographs of whiteboards and windows referred to in one teacher's interviews. Throughout data collection and analysis, I maintained a reflective journal where I kept memoranda regarding my own developing thinking. I believed that these forms of data would be a good representation of the activity system because they could capture multiple individual perspectives on scientific sensemaking and literacy as well as a description of shared activity.

Interview Transcripts

It is important for a CHAT study to capture the perspectives and beliefs of participants in their own words (Kaptelinin & Nardi, 1997). Interviews provided useful data for this study in that they provided individual participants an avenue to directly express their perspectives, beliefs, and understandings to the researcher. This can be helpful when analyzing an activity system as it can provide insight into individuals' perspectives, beliefs, and histories which may not be stated outwardly during collaborative activity. Conducting interviews at the beginning and the end of the data collection period allowed me to capture subtle changes in participants' descriptions of scientific sensemaking and literacy in their own words for those who were willing and able to engage in both interviews. The initial interviews focused on participants' educational and teaching background, descriptions of scientific sensemaking and literacy, and discussions of how one might provide instruction that supports students' development of scientific sensemaking and literacy. The final interviews also focused on participants' descriptions of scientific sensemaking and literacy and take-aways from an individual's participation in the book discussions and/or the workshop series. Participants were also asked during the final interview to reflect on how their understanding of literacy and sensemaking may have been shaped by their participation in the workshops, book discussions, or through other opportunities in which they were engaged. Final interview questions included references to activity system elements so that mediating effects I considered during data analysis could be triangulated using participants' own accounts. Specific interview questions can be found in Appendix B. Interviews were audio recorded using a tablet computer. Transcripts were written from audio recordings and both the transcripts and audio files were stored in a password protected digital data folder.

Six participants, Marie, Elizabeth, Rachel, Grace, Joan, and Charlotte, participated in semi-structured interviews (Bogdan & Biklen, 2007) near the beginning of their enrollment in the study. Four of these participants, Marie, Elizabeth, Rachel, and Joan, also participated in semi-structured interviews after the workshop series and book study had concluded. Grace did not participate in a final semi-structured interview as she did not attend the workshop series as she had originally intended. Charlotte had a family emergency which prevented her from participating in a final interview as well.

Fieldnotes

I gathered fieldnotes during book discussions, professional development planning meetings, workshop sessions and interviews. For this study, fieldnotes were used to translate group activity into analyzable data as well as to capture non-verbal data during interviews. Fieldnotes provide an inscription of a researcher's observations of what they saw, heard, and experienced in the field as perceived through their subjective lens (Emerson, Fretz, & Shaw, 2011). Fieldnotes can be a useful source of data for a CHAT analysis in that they describe participants' interactions with one another and can create a record of how ideas were developed between participants and over time. However, fieldnotes, by nature, cannot capture the entirety of an activity from an unbiased perspective. As I held a dual role as a participant and researcher during planning meetings and workshop sessions, my ability to capture activity in the moment was often limited.

During book discussions, I took extensive fieldnotes as the discussions were unfolding. As I was an observer rather than a participant during these sessions, I was able to capture much of what participants said as well as data regarding their actions, tone of voice, and body language as the activity was unfolding. As collecting fieldnotes in such a manner can limit a researcher's ability to accurately capture participants' speech word for word, I developed a system based upon the recommendations of Taylor, Bogdan, & Devault, (2016). One of their recommendations was to pay attention for key words or phrases during dialogue (Taylor, Bogdan, & Devault, 2016). I listened closely for words or phrases that would indicate that participants were discussing sensemaking or literacy in addition to their use of the actual constructs. For example, *figure out* and *grapple* were words that had emerged from my literature review as well as from participant interviews which could indicate teachers were discussing sensemaking. *Read*, *write*, and *talk* were words that might have indicated that participants were discussing literacy. I tried to focus on capturing participants' exact words when I heard one of these key phrases. I further delineated between exact quotations and my approximations of participants' speech, I used quotation marks within the document to indicate when I had captured exact statements. As recommended by Taylor, Bogdan, & Devault (2016), I also made every effort to add additional information and detail to my fieldnotes immediately upon leaving the data collection setting. The same day that each set of fieldnotes was gathered, I spent several hours afterward reviewing and adding additional information not captured during my time in the field.

During both professional development planning meetings and workshop sessions, I had to balance gathering fieldnotes with fulfilling my role as a participant within these settings. Before each professional development planning meeting, I drafted a meeting plan with space to capture notes about my conversations with Rachel on specific topics which I felt would be important for data analysis purposes. During the meeting, I filled in these structured notes and maintained additional notes regarding other topics that came up within conversation. After each meeting, I combined these sets of notes into a cohesive set of fieldnotes. I also took several hours on the same day as these meetings to flesh out these notes to the best of my ability. Following this process, I emailed Rachel a summary of our meeting for verification. She responded each time, indicating additional clarification regarding her take-aways from the meeting. These e-mails were used to further flesh-out fieldnotes. Lesson plans for workshop sessions also evolved as artifacts of these planning meetings. Lesson plans were co-authored by Rachel and me. This often included emails in which one of us would make a comment beginning with a phrase such as “I thought we said…” I used these clarifying statements to further confirm or clarify professional development planning meeting fieldnotes.

Workshop session fieldnotes began as a copy of the lesson plan for that session with additional space for in-process notes. I used this space to capture participant quotations that felt meaningful during the workshop and to capture my in-process thoughts while facilitating. When an activity or conversation centered on a text or artifact, I used a copy of that text or artifact as a place to capture notes, specifically around participants’ interactions with specific aspects of the text or artifact. Following a workshop session, I spent several hours combining these documents into a cohesive set of fieldnotes. Once I thought I had captured my full recollection of the session, I consulted artifacts of teachers’ engagement gathered during each session and used these to add additional detail to fieldnotes. Rachel also took notes regarding her perceptions of teachers’ engagement during workshop sessions. She orally shared these notes with me during the professional development planning meeting immediately following each workshop session, or in the case of the final workshop session, before we began her final interview. I took notes on what she shared with me and used this information to further confirm and clarify workshop session fieldnotes.

Artifact Collections

CHAT studies aim to describe mediational roles of an activity system’s elements. Artifacts can represent tools, rules, and/or the division of labor in a focal activity system. In these roles, they can mediate participants’ activity and the demonstrations of their understandings through activity. Artifacts can also represent historical data regarding subjects in that they can work to illuminate participants’ understandings that have already come to be before a collective activity is initiated. Thus, it was important to collect and examine artifacts in order to accurately describe teachers' understandings of scientific sensemaking and literacy as well as the mediating role some artifacts played withing in the activity system.

Across all settings in this study, participants used, created, and were represented in artifacts. Artifacts collected included research articles and professional literature used by or published by participants, state standards, digitally published storylines, representations of focal scientific phenomenon, teacher-created materials, and photographs of de-identified student work, and teaching aids. Rachel and I also created lesson plans, handouts, and activities for the workshop series. We communicated frequently via text message and email. I gathered these artifacts as data as well. Artifacts were gathered digitally, either in their original form or as a photograph. I have used the term collections to refer to the multiple document nature of several artifacts. For example, book notes were collected from two participants. These consisted of scans of their notes across fourteen chapters in *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). As each entire set of notes serves as one artifact capturing one individual's interactions with the text, the term collections felt more appropriate.

Data Analysis

A CHAT analysis was well suited for addressing this study's focus on teachers' understandings of scientific sensemaking and literacy and how these understandings were mediated their activity system. As its focal unit of analysis is the activity system, it allowed me to explore the mediational roles of resources and community collaboration in Marksboro Middle School science teachers' sensemaking during *Ambitious Science Teaching* book discussions about students' scientific sensemaking and literacy. In doing so, CHAT embraced, rather than reduced, the complexity of the context (Lee, 2011).

Data analysis began during the data collection period and was conducted more substantially after its conclusion. During the data collection period, analysis was conducted through my creation of reflective memos. In these documents, I noted my initial impressions of participants' descriptions of scientific sensemaking and literacy and posed questions to consider to further investigate my burgeoning understanding. I used Rachel as a sounding board to explore some of these questions during our planning meetings. Our conversations were then documented in planning session fieldnotes and became part of the data corpus.

Following the data collection period, data analysis occurred through three successive rounds. I used NVivo 12 Plus software (QSR International, 2018) to organize and code data. Before coding began, I first organized data by type (fieldnotes, interview transcripts, artifacts). Fieldnote and artifact types were further divided by the setting in which they were gathered (book discussion, workshop planning meeting, workshop session, personal communication). All data were dated in order to maintain their chronology because accounting for how an activity develops over time is an important aspect of a CHAT analysis (Kaptelenin & Nardi, 1997). All data were initially coded using participant pseudonyms to identify the sources of specific statements and artifacts. Participant identifiers allowed me to focus on an individual or on interactions involving an individual to describe how their understanding is influenced by elements of the activity system as well as how they influence others within the system. Data source codes also informed subsequent analyses by helping to corroborate themes across data sources.

Round One: Describing Sensemaking and Literacy

The first round of data analysis used a combination of a priori and inductive coding to preliminarily answer the first research question: How were middle school teachers' and professional development providers' understandings of scientific sensemaking and literacy demonstrated during their participation in professional development. During this round of data analysis, I used coding schemes related to the target constructs of the study as was done by Bingham (2015). I began by coding instances in which participants used the terms literacy or sensemaking. However, it appeared that participants were discussing aspects of sensemaking or literacy beyond their specific mentions of the terms. As discussed in chapter two, the literature regarding each of these constructs represents a variety of perspectives. To further code data that represented scientific sensemaking and literacy, I adopted broad definitions of each in order to capture what could be considered sensemaking or literacy across multiple perspectives. I defined it as cognitive and social processes students use to build meaning through interaction with texts, materials, and a peer community while engaging in the eight scientific practices outlined in the *Framework* (NRC, 2012). This definition was informed by Schwarz, Passmore and Reiser's (2017) as well as Odden and Russ's (2019) definitions in order to account for multiple perspectives regarding scientific sensemaking in the literature as well as to contextualize it within the *Framework* (NRC, 2012) and related standards. To further code for literacy, I used Frankel, Becker, Rowe, and Pearson's (2016) definition, "The process of using reading, writing, and oral language to extract, construct, integrate, and critique meaning through interaction and involvement with multimodal texts in the context of socially situated practices" (p. 7). In instances in which it seemed like data met the definitions of sensemaking and of literacy, I applied both codes.

I then used inductive coding (Strauss & Corbin, 2008) to explore how participants talked about each construct. For each construct, sub-codes were created by examining the corpus of data coded as that construct and establishing themes in the data. This process was reiterated until saturation was reached (Strauss & Corbin, 2008). Sub-codes related to scientific sensemaking included storyline, phenomenon, students' grappling, scientific practices, and teachers' planned supports. Each of these sub-codes was further subdivided. For example, the scientific practice sub-code was further subdivided into the practices listed in the Framework (NRC, 2012) and associated standards. Sub-codes related to literacy included read, write, talk, multimodal, vocabulary, academic language, named strategy. "Implied?" was used as an additional literacy code. Data coded as "implied?" represented something I had interpreted as potentially representing a participant's attention to literacy when coding using Frankel, Becker, Rowe and Pearson's (2016) definition; however, the participant had not called it out as such and it didn't seem to fit in any of the evolving themes. Initially, this code was used as a flag in order to go back and revisit whether the data met the selected definition of literacy as well as if it could be coded using evolving sub-codes. Upon closer review, much of the data coded as "implied?" was also coded as sensemaking and additionally coded as teachers' planned supports. I maintained this code as a way to continually question my perceptions around the question of if teachers were considering sensemaking, literacy, or both throughout data analysis. As recommended by Yamagata-Lynch (2010), this round of analysis also included a broader use of inductive coding, looking for any other themes that emerged from the data. These additional codes accounted for recurring topics or sentiments. Recurring topics and themes included codes such as assessment, equity, and time.

Round Two: CHAT Activity System Analysis

The second round of analysis consisted of a CHAT activity system analysis (Engeström, 2001; Leont'ev, 1978; Yamagata-Lynch, 2007, 2012) to help answer both research questions. To begin analysis, I needed to identify and define the activity system to be analyzed. I chose discussions of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) as the focal activity system for analysis for several reasons. Even though the study occurred in two organizations, Marksboro Middle School emerged as the dominant site. The majority of data were collected in Marksboro Middle School; the majority of participants were Marksboro Middle School teachers; and sensemaking and literacy workshops were designed specifically for them. I selected the book discussions as the focal activity system because it elicited the most data from Marksboro science teachers. Participating in the book discussion group was how Marksboro science teachers decided to address their individual and shared goals. Decisions Rachel and I made about shifting the workshop series to Marksboro arose from suggestions made by this group.

During this round of analysis, I used CHAT system elements as a coding scheme. Codes included goals, tools, rules, division of labor, additional communities, outcomes and tensions. Even though CHAT researchers use the term "object" to describe the shared purpose of an activity system, I used the code "goals" during this round of analysis because it aligned with the language teachers and I used during initial interviews and was also used throughout book discussions. Participants discussed their individual goals for participating in professional development as well as their perceptions of the purpose of science education and specifically of middle school science education. The system's object was determined through a thematic analysis of data coded as goals. I defined the tools code as resources participants accessed or created in an attempt to achieve their goal. Rules referred to codified and implicit bounds on the activity. Language markers such as "need to" and "can't" were useful in identifying when participants were referring to rules bounding their activity. I applied the division of labor code when participants discussed roles and responsibilities of individuals and groups, such as teachers of a specified discipline or grade. Additional communities was used to indicate when data implicated another community to which a participant belonged. This included geographic communities, affinity groups, and participation in additional professional development opportunities. I used the code outcomes to indicate teachers' reflections. These included reflections on classroom implementation of strategies and activities previously discussed during the book discussions, their reflections regarding their own learning in the final book discussion, and their mentions of plans for the future. Bingham (2015) separated coding for activity system elements and tensions into two separate rounds, however, I chose to code for tensions while also coding for activity system elements. This allowed me to handle instances when it was challenging to associate a data fragment with a singular activity system element. For example, statements teachers made about standards often seemed to implicate them both as rules that bounded what had to be taught and tools that helped them select and sequence learning activities within a storyline. I began this round of coding by focusing on data gathered during final interviews when participants were asked questions related to specific activity system elements. I then coded book discussion fieldnotes, and artifacts mentioned or stemming from these discussions. I concluded this round of coding by examining data from workshops that had been implicated by Marie, Elizabeth, or Irene during book discussions.

Following CHAT coding, my CHAT analysis examined the activity system as multi-planed. Rogoff (1995) outlined three planes of analysis useful in CHAT studies: individual, interpersonal, and community/institutional. She recommended focusing analysis on one plane at a time, while blurring the other two because of the ways in which the planes are interdependent. Considering all three at once would not allow a depth of understanding to be built in regard to any one plane, yet each plane cannot be understood in depth without a consideration of the other two. I first considered the individual plane while focusing on my first research question by analyzing how individual teachers were talking about literacy and sensemaking across settings and over time. For example, I examined data elicited from Elizabeth related to sensemaking beginning with the first observed book discussion and concluding with her final interview in chronological order regardless of data source. This helped me to describe her perspective. I did this for each book discussion participant.

I then shifted my focus to the interpersonal plane. Emerging themes based on individual's contributions to the discussion were vetted, clarified, and modified using discussion-based data. This occurred primarily through asking questions about what led a participant to say something or about what others did in response to an individual's contribution. I also examined data gathered during the workshop series to identify further support for emerging themes. Exploration of the second research question looking at how these understandings were mediated by the activity system occurred while considering the interpersonal plane. I examined individuals' final interviews to identify elements of the activity system they cited as important to their developing understanding.

I then explored the third plane: how community and institutional elements were discussed by participants. An important aspect of this analysis was the formation of a narrative timeline, which helped to establish the group's development regarding certain recurring topics over time. As participants were forthright in their discussions of activity stressors, the description of systemic influences occurred as a natural aspect of this round of analysis. I then returned to the individual plane to examine how individuals' understandings developed as a result of activity in the second and third planes.

This round of CHAT analysis also helped to account for my dual roles as a participant on the professional development planning team and as an observer of the book discussions. CHAT has been used in both descriptive and intervention studies (Postholm, 2015). Postholm (2015) noted that in intervention studies, researchers often introduce mediating artifacts or tools. These tools can be developed as a result of the researcher's analytical role within the system. As the researcher engages in data analysis throughout the study, they may develop resources in response to their evolving understanding of the context and activity occurring within the system. How these tools influence the flow of activity then becomes a focus of the researcher's continued analysis. This process is similar to the desired outcome of the professional development workshop series: to provide information and resources which foster continued growth and development of teachers' instructional practices. When analyzing the activity system, I needed to also examine how outcomes of my actions influenced others in the system and how my actions were influenced by my observations and interactions within the system.

Round Three: Using ANT to Revisit Sensemaking and Literacy

A third round of data analysis occurred after several attempts to write about the findings of this study in order to consider describe literacy as an operation within the activity system. As much of the data regarding literacy had been coded as "implied?" it was challenging to accurately account for how participants were considering literacy during their participation in the book discussion activity system. It appeared as though teachers' consideration of literacy during these discussions might consist of operations rather than object-oriented actions. For instance, teachers discussed creating templates for students' modeling. From student responses, they hoped to assess what sense students were making of a phenomenon and their developing command over scientific ideas. Yet, literacy was implicated in the creation of such templates when teachers discussed how many lines they might need to put into a text box to indicate how much writing they thought students would have to do in order to convey their thinking regarding certain elements of the model.

Since the CHAT literature did not offer an analytical method for considering operations within an activity system, I looked toward Actor-Network Theory (ANT) for analytical tools such as Latour's (2008) five sources of uncertainty which could prove useful. I gathered an additional artifact collection consisting of publicly available artifacts of participants' previous considerations of literacy within their disciplines. This consisted of Marie's research published in science education journals, Joan's research published in a music education journal, a book of interdisciplinary lessons co-authored by Joan, a curriculum map co-authored by Elizabeth, and an interdisciplinary instructional unit co-authored by Rachel. I examined each artifact for historic evidence of attention to literacy and compared this data with data coded as "implicit?" in the data corpus for each participant to infer a historic development of individuals' descriptions of literacy.

Memoranda

As gathering and analyzing qualitative data sources was framed by my own understanding and subjectivity, I wrote memoranda to capture my evolving thinking throughout the study. Reflective memoranda explored my perception of book study discussions, planning meetings and interviews including my asides and commentaries in response to the activity at hand. Reflective memoranda also explored how my understanding of sensemaking and literacy were developing throughout the study in response to my participation in other opportunities such as providing similar professional development in another school district and attending conferences for teachers and researchers. Analytic memoranda helped to identify initial and evolving themes across events and data sources and to develop appropriate coding schemes (Emerson, Fretz, & Shaw, 2011).

Trustworthiness

In qualitative research, trustworthiness is used as a rough equivalency to quantitative research's validity and reliability (Lincoln & Guba, 1985, Lincoln, 2002, Creswell, 2013). The use of a CHAT lens in naturalistic inquiry addresses criteria of trustworthiness through establishing credibility, transferability, dependability, and attention to subjectivity (Lincoln & Guba, 1985; 1989).

Credibility can be established through a researcher's prolonged engagement in the field as well as triangulation of data (Creswell, 2013). My data collection occurred throughout a seven-month time frame, including two interviews with multiple participants, six book discussion meetings, twelve professional development planning meetings, three workshops, 20 artifact collections, and twelve reflective memos. Themes were triangulated using data collected from multiple sources.

Transferability and dependability can be established through the use of thick description (Creswell, 2013). CHAT emphasizes the role of the community in learning and developing knowledge. Thus, when crafting findings, I worked to incorporate the multiple voices that made up this community. However, as participation across community members was not evenly distributed, some participants appear more in the data, and therefore in the findings, than others. Data gathered in small group meetings and interviews allowed me to record or approximate participants' own words so that wherever possible, findings can be supported through the words and voices of participants rather than solely through my subjective lens. While taking fieldnotes, I worked to capture participants' actual words as much as possible given that I was not able to audio- or video-record these sessions to fully capture participants' speech. As described above, I used a keyword system to more closely attend to participants' speech around sensemaking and literacy as well as a quotation mark system to indicate that I had captured participants' actual words and to separate these lines of data from others including my approximations. While my intent was to learn and encourage others to learn through my examined experiences within the activity system, it could be easy to overexpose participants in ways they do not find palatable. An ethical researcher must balance their loyalty to "truth" with their loyalty to participants (Ellis, 2007). As a "critical friend" (Costa & Kallick, 1993; Swaffield, 2005), and a "neighborly" researcher (Savage, 1988), I had a duty to form relationships with my participants based upon dignity, trust, and mutuality (Lincoln & Guba, 1989).

Trustworthiness is also established through a researcher's explicit attention to their subjectivities and biases (Peshkin, 1988, Lincoln & Guba, 1989, Lincoln, 2002). I came to this work as an assemblage of my previous and concurrent activities and identities. While I am aware of ways in which dominant discourses privilege me and disadvantage individuals with a variety of identities, I am also aware that my own lens shapes and delimits what I see.

I also began with a deep sense of respect for science teachers and a belief that they have capacity to build upon their knowledge of science content and pedagogy in ways that serve their students' learning needs and would be willing to discuss how supporting literacy could contribute to this. In my previous role as a high school literacy specialist in a high-performing, gap-closing, suburban school district, I worked with teachers across disciplines as the Common Core standards were developed and implemented and teacher evaluations became tied to students' performance on standardized exams. While the district had implemented its own literacy initiatives in the past, this was an influential moment in that now the state required all teachers to align their teaching to literacy standards as well as subject area standards and in that teachers would be held accountable for student success in unprecedented ways. Several of my former science colleagues expressed discontent regarding these shifts. After discussions with these teachers, I was not surprised by their discontent. The district had adopted close reading of extended passages as the expected way teachers across disciplines were asked to address literacy. I heard several science teachers lament that this did not represent “how we do things in science.” Meanwhile, however, I noticed that these same teachers often incorporated excellent literacy instruction, albeit beyond the narrow scope through which they were being evaluated. They frequently helped their students to navigate between a real-world phenomenon, and the material, graphic, and textual representations used to explain the phenomenon or build arguments based upon it. Just as my former colleagues shaped my understanding regarding connections between literacy and science, I believe collaboration in this study challenged and expanded my thinking regarding scientific sensemaking that has implications for the consideration of literacy in science education.

Summary

The purpose of this qualitative CHAT study (Yamagata-Lynch, 2007; 2010) was to describe a community of educators’ understandings of scientific sensemaking and literacy during their participation in collaborative professional development. The community of practice examined in this study consisted of six teachers engaged in discussions of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). This group’s discussions were considered as the focal activity system for this study’s CHAT analysis. Four of these teachers taught science, one taught science and ELA, and the sixth was a special education teacher. All six teachers worked at Marksboro Middle School, one suburban middle school in New York State.

Three of the teachers in the book discussion group also participated in school-based professional development workshops on literacy and sensemaking across the curriculum that I co-facilitated with another professional developer. Three additional Marksboro Middle School teachers participated in this workshop series. Two were ELA teachers and one was a music teacher. The professional development team was also interdisciplinary. Rachel was a science professional developer at a regional professional development agency serving Marksboro Middle School. She served as a disciplinary specialist on the professional development team. I served as a literacy specialist on the professional development team. Data were also gathered from Rachel's supervisor as she had intended to participate on the professional development team but was later unable to do so. This study used the development and enactment of this workshop series as a way to introduce literacy into the book discussion activity system.

This study used a CHAT activity system analysis to describe educators' understandings of how scientific sensemaking and literacy can be addressed in middle school science classroom instruction and how these understandings were maintained or modified through professional development. Data collection included gathering multiple sources of data including interviews, field observations, and artifacts to provide the rich contextualization inherent to a CHAT analysis. Data analysis occurred in three rounds. The first focused on thematic analysis regarding sensemaking and literacy. The second consisted of a multi-planed CHAT analysis of the book discussion activity system. The third drew upon ANT tools to conduct a deeper analysis of potential that teachers' understandings of literacy may be seen through operations rather than actions within the activity system.

In the next chapter, I present a description of educators' understanding of scientific sensemaking and literacy that emerged through and were mediated by the activity system. This begins with a summary of individual's descriptions of sensemaking and literacy gathered during initial interviews with science teachers, non-science teachers participating in the workshop series, and professional developers. The chapter then considers the study's second research question by presenting a description of the activity system, including its mediating elements, tensions, and outcomes. It concludes with an analysis of how teachers' understandings of sensemaking and literacy were demonstrated in the book discussion activity system.

CHAPTER FOUR:

DEMONSTRATING UNDERSTANDING THROUGH ACTIVITY

Marksboro Middle School science teachers' engagement in book discussions was motivated in part by a three-pronged change in their activity system. Teachers simultaneously responded to the mandate of new standards, shifting expectations around the content they taught, and to the introduction of new pedagogical recommendations. Rather than consider a transformation of their teaching to be too great a challenge, they collectively embraced the possibilities afforded by the moment and dug in.

This chapter explores science educators' descriptions of literacy and sensemaking and how these descriptions were mediated by their participation in the book discussion professional development activity system. I organized this chapter into three sections. First, I present educator's descriptions of sensemaking and literacy gathered during initial interviews. This provides insight into what understandings individual teachers brought to the activity system. Then, I present a description of the book discussion activity system. The book discussion group was selected as the focal activity system for this analysis because it provided the richest data demonstrating science teachers' understanding of scientific sensemaking. This activity system also provided insight regarding how literacy may operate in sensemaking-oriented instruction. The description of this activity system begins with a discussion of teachers' shared object and actions in pursuit of that object. I then describe how systemic elements mediated teachers' activity, the tensions which arose throughout activity, and conclude with the activity's outcomes. The majority of data presented in this section was obtained during book discussion meetings. Data from the literacy workshops and participants' final interviews contributed to the description of teachers' participation additional activity systems as well as to the description of the activity system's outcomes. I close this chapter with a section describing teachers' understandings of literacy as they were demonstrated within the book discussion activity system.

Descriptions of Sensemaking and Literacy

Six participants engaged in initial interviews in which they described sensemaking and literacy. This included the two seventh-grade science teachers who participated in book discussions and in workshops: Marie and Elizabeth. Descriptions of sensemaking and literacy obtained from study participants who were not members of the focal book discussion activity system are also included here. Joan and Charlotte were non-science teachers who participated in the workshop series. Rachel and Grace were professional developers with the regional professional development agency. These individuals' understandings serve as examples of the variety of perspectives book discussion participants interacted with beyond the focal activity system of middle school science teachers which may have impacted their understanding of sensemaking and literacy as demonstrated within the book discussion activity system.

Marie

Marie was a seventh-grade science teacher as well as the facilitator of the book discussion group. Marie believed that the purpose of science education was "to create scientifically literate people for our democracy." Her words implied a shared understanding about the state of the current US government and that decision-making informed by science is crucial to that democracy. She also hoped that students would develop "enough background that anything that they see on Facebook or Snapchat or whatever, they can know enough to be like, 'that doesn't really fit into the framework that I learned.'" Her views of the goal of science education were rooted within the current US cultural context.

Marie described sensemaking as both a cognitive and a social activity. In her initial interview, Marie described sensemaking as

> constructing knowledge. … My idea is sensemaking is another ... is a more friendly term for knowledge construction. … When I was in graduate school, knowledge construction, constructivism, was the framework. However, we knew it was a theory for learning, we didn't always know how that translated into a theory for teaching. [When I teach for sensemaking,] I think I spend more time, I hope, with them being able to grapple with the phenomenon, and just being thinkers even if they're not correct. And they're good at it. Yesterday I had a pedigree video, and then I paused it and I said, talk with your groups about what you think this answer is going to be. And they were right in it, talking and discussing.

For Marie, sensemaking was an old idea packaged in a new way. She had taught for 26 years across four states in public K-12 settings and university settings. To her, sensemaking was the same thing as constructivism. The shift was that it operates from the students' perspective rather than the teacher's, thereby positioning it as a theory of learning rather than a theory of teaching, as she had perceived constructivism. Marie also described student discourse, the act of orally sharing and discussing ideas, as a part of sensemaking.

During her initial interview, Marie had explained that while she had previously taught literacy strategies within her science classes, she felt that this had damaged her relationships with students. It had placed stressors on the amount of time she had to focus on developing their science learning. Marie's views on literacy had also been informed by a district initiative regarding literacy across the curriculum. She had engaged in a shared reading of *I Read It but I Don't Get It* (Tovani, 2004) and had participated in workshops where teachers of other disciplines shared literacy strategies as a means of disseminating best practices across disciplines. Marie reflected, “In general, those strategies did not work that well because a foreign language is a translation of a word. We are instructing knowledge. So, the rapid-fire hook was that stuff that does not translate well here.” Marie was referring specifically to a vocabulary learning strategy she had adopted from a Spanish teacher’s presentation. However, elsewhere she noted that content area literacy strategies such as concept maps, Frayer models, and word walls seem to “come back again and again” throughout her teaching career and that the messages to include more literacy in science have been “constant.” Marie’s doctoral program informed her views on literacy. She’d taken a K-6 literacy course where she felt “the bottom-line message was, ‘literacy is everywhere.’” Marie felt that such broad, inclusive orientations to literacy were not helpful because, “last I checked, kids need to know how to read.” Reading, to Marie, was the decoding and consumption of print text.

Marie had previously published research as a doctoral student and university researcher. Her published research includes reference to what may be considered literacy strategies by literacy education scholars. Across four articles and her dissertation, Marie discussed concept maps, using drawing as a support for writing, using writing to support conversation, and elementary students’ building conceptual understanding through conversation with peers. Gathering concept maps was mentioned across the works extensively as a pre- and post-assessment and used to note development of conceptual understanding or maintenance of a misconception. Concept maps are often presented as a literacy strategy or support to be used across content areas by literacy education scholars (e.g. Harvey, 1998; Fisher & Frey, 2008; Manzo, Manzo, & Thomas, 2005). However, Marie did not cite literacy scholars when referencing concept maps or other aspects of reading, writing, and classroom talk. Rather, she cited science education scholars in order to establish the validity of these measures as assessment of students' conceptual knowledge of science.

Marie engaged in professional development to refresh her teaching practice. She felt that embracing *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) would help her consider how to make meaningful instructional shifts. As the book discussion facilitator and science department chair, Marie also had goals regarding her colleagues' engagement in professional development. She wanted discussions to focus on strategies teachers could use in upcoming lessons rather than what they had used in previous lessons because, "'This is how I used it in my classroom' can become kind of a brag fest, and it's like, unless I'm in you classroom, I don't really know how you used it." By avoiding this type of talk, Marie was hoping for all book discussion participants to feel free to try new strategies without feeling judged by their peers.

Elizabeth

Elizabeth was a seventh-grade science teacher. She indicated that one goal of science education was to develop students' understanding of science to that they can "apply learning to other situations." Like Marie, Elizabeth used the word *grapple* to describe the action of sensemaking:

> It means that a student is given an opportunity to grapple with either an image or data or a concept and they're able to read about it and talk about it and write about it and develop their sense of what it means.

Elizabeth also initially described sensemaking as an individual action. However, unlike Marie, she depicted it as an action undertaken while an individual is interacting with a text. Elizabeth then described classroom activities she would consider sensemaking such as partner sharing, journaling, going up on the white boards on the windows in teams and now as a team coming together to do the sensemaking and then they all sit down together to compare and contrast each other's sensemaking to see what is similar and what is different.

> And that is usually what drives the class discussion and then you see, for me, I get to see where their misconceptions are when they're doing their sensemaking. … I make a point of saying to them, "When we're making sense of something, I'm not telling you if it's right or wrong." … So, you have to have that culture in the classroom that we're just trying to figure this out. We need all pieces of information we can gather so we can see what pieces we are missing or are fuzzy on that we need to know.

While journaling maintained Elizabeth's conception of sensemaking as individual activity, her other examples indicated a more social view. She concluded with a shift in pronoun use from *they* and *I* to *we*, indicating that achieving consensus was the end goal. For Elizabeth, sensemaking was first an individual's process of figuring out and then a social process of comparing ideas to arrive at consensus.

Elizabeth expressed that she felt comfortable with infusing literacy instruction into her teaching, describing how she often provided whole class direct instruction of literacy strategies on a regular basis. This comfort may have evolved from her previous experience as an instructional coach in an urban district in which instructional coaches are often tasked with supporting teachers' incorporation of literacy across all subject areas using models such as AVID (AVID / Closing the Gap in Education, n.d.) and cognitive coaching (Costa & Garmston, 2015). Elizabeth described literacy through the use of a toolbox metaphor. She then defined literacy as

> being able to connect a visual with a word and a meaning. … So, when you read a book or something online, to be able to take that and say, 'ok, what are my main ideas that I should understand?' because that is a hard skill for seventh graders to do. They can read

the words and spit it back at you, but then say, 'what is the big idea?' because some of the texts can be a bit complex and more of a challenge for the kids.

In this response, Elizabeth used "skill" to define literacy. She also positioned literacy as an interaction with print-based texts. Elizabeth also described one way she felt she was currently addressing literacy in her classroom. While she had used word walls in the past, Elizabeth stated during her initial interview that she was proud of her newly developed 'progression of learning wall' (Figure 4.1).

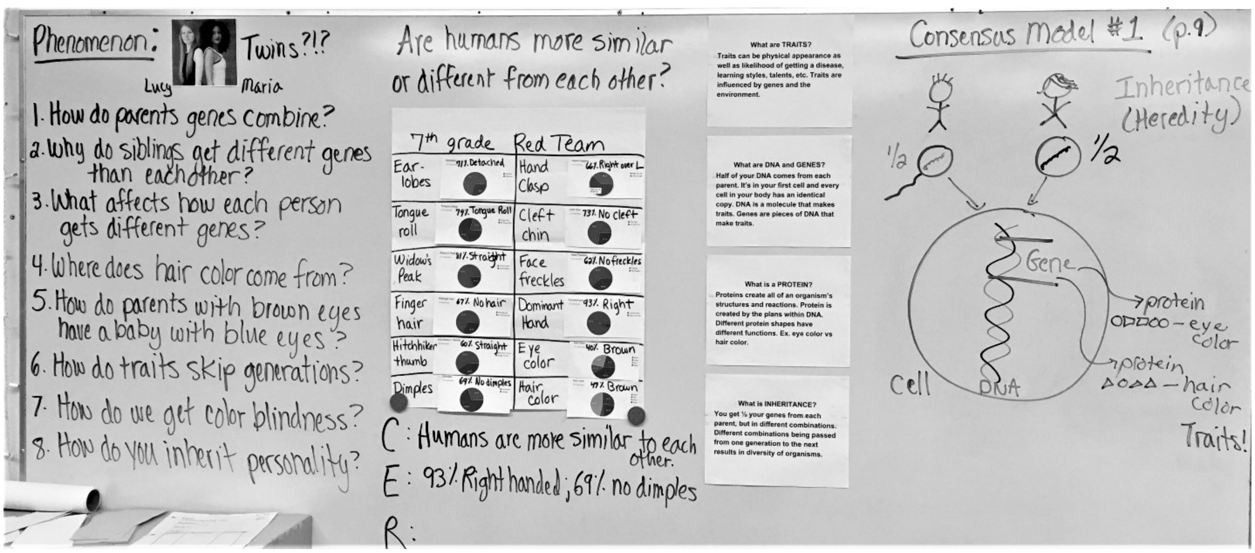


Figure 4.1. Elizabeth's progression of learning wall

She indicated that this wall supported students' vocabulary learning in more meaningful ways than her old word walls in that students "see how their thinking is changing, how it's becoming more specific, how there's vocabulary attached with their thoughts they had at the beginning during their initial sensemaking, because usually, they don't have the vocabulary to attach." She noted that she had watched a few students turn to the board in order to locate concepts and terms while engaging in whole group conversations and while writing about their learning throughout a storyline. Throughout the current academic year, she co-designed and implemented three standards-aligned storylines with Marie in addition to those discussed within the book study discussions.

Elizabeth had previously collaborated with other science teachers to create curriculum maps for middle school science in her previous school district. I reviewed the sixth- and eighth-grade maps available online. As was the case in Marie's research publications, these documents include reference to instructional strategies which literacy scholars might perceive as supporting literacy in science classrooms. These strategies include drawing diagrams, writing explanations, and reading textbooks. Concept maps, written lab reports, and oral presentations are listed as assessment strategies. A KLEW graphic organizer in included as an appendix to each grade level map. While citations are not provided for these strategies, KLEW has been presented by the National Science Teaching Association as a science-specific adaptation of a reading strategy (Hershberger, Zembal-Saul, & Starr, 2006). These documents do note that their creators accessed *Project 2061: Atlas of Science Literacy* (American Association for the Advancement of Science, 1995) as a resource for developing these curriculum maps. This source provides potential maps of science topics across grade levels. It does not present literacy supports in the way that literacy scholars conceptualize them.

Through professional development, Elizabeth was looking to gain confidence in her understanding of the new science standards and to "have enough tools in [her] toolbelt to help students transition from the old way of learning to the new way of learning." By this, she meant supporting students transition into learning through student-centered pedagogies rather than didactic teaching.

Joan

Joan was a fifth- and sixth-grade music teacher who attended the workshop series. She expressed that she had chosen to attend the series to engage with her colleagues across grades and disciplines with whom she does not frequently get the chance to interact. Joan also indicated that she elected to attend the workshops in order to "advocate for music as a discipline and as a way to be literate." attending, she had taught music for "a really long time" (over 20 years, though she didn't state a specific number). She felt unfamiliar with the new science standards, but she indicated that she felt part of their goal was to develop 21st century skills and require students to think more deeply than previous standards.

Joan described sensemaking in music as potentially being a visual, oral, or social activity in which students interacted with a piece of music.

> There would be sensemaking in listening to a piece of music and having an understanding of what you are hearing. Could be what timbres you're hearing, could be how parts are fitting together, could be harmonies, why is this piece dissonant, what choices did the composer make and why. It could also be looking at a piece of music and trying to make sense of what you are seeing on the written page, like how does this on the written page translate into actual sound, interpretation, like interpretive stuff. I work a lot with that, particularly in chorus, okay here's are choral target, what does all this mean? And, we have to fish through, okay that's the piano part, so I'm not going to look at that, this is, you know... So, making sense both orally and visually, and then there's working as an ensemble, so you get some kids, we play the recorder in here, they get locked in, they're playing along and it's not with the rest of the class but they're doing it, so, sense making in a sense of how do I fit in to this group.

Joan began by describing sensemaking as an individual act of listening. Her descriptions of the types of questions a listener might consider closely paralleled questions students are often asked to consider while reading, such as considering an author's purpose and craft. Joan added that musical sensemaking is also visual in that a musician interprets a visual symbol system and translates it to an auditory work of art. Joan closed by positioning sensemaking as a social act of "fitting in." Musicians in an ensemble need to develop a sense of the relationship between the individual parts and the greater whole.

Joan also saw music literacy as multifaceted. She said:

> Traditionally, we think of 'here's the notes on the page. How do I read this? How do I know that's a quarter note: it gets one beat. That's a half note: it's going to get two beats, and this is a G and this is an A.' But, there's also literacy in being able to improvise and being able to respond in what's going on around you and work within the harmonic structure or make choices that way. There's an oral literacy, being able to know what a perfect pitch sounds like and be able to sing it. So, there's all different kinds of literacy. I think for a while there, we got really focused on the music reading part of it, which I mean, I think it is important and I do a lot of that, but there's also many, many, many genres of music that are really done in the oral tradition and not written down at all, so that's a whole 'nother kind of literacy.

Joan felt that literacy looked "parallel" across different disciplines. The symbol systems and nuances of the disciplines shaped how literacy might be enacted, but commonalities could be seen between music and other disciplinary literacies.

Joan was currently enrolled in a doctoral program and had previously co-authored a book of interdisciplinary lessons for music teachers and non-music teachers with a music education professor. ELA was incorporated through the use of proverbs from various countries. A literacy resource, ReadWriteThink.org was cited regarding the incorporation of proverbs. Additional lessons were described which connect music and science. Science topics discussed include snowflakes and the water cycle, and endangered butterflies. Throughout the text, several picture books and non-fiction print and media sources are cited as additional resources teacher might use.

Charlotte

Charlotte was a seventh-grade ELA teacher who attended the workshop series. Charlotte considered attending the workshop series a way to better understand the connections between disciplines and to help students understand those connections. She thought that the goals of middle school science and ELA were similar in that both should help students "to think critically, to problem solve, to be a good reader, to be a good writer, and to form good habits … like questioning things and critical thinking."

Charlotte described sensemaking in ELA or science as:

> trying to figure [something] out on your own right. Or, with some resources, but like you really, you're looking at something, a text or any texts. You're looking at it and then you are making sense of it on your own, or with a group maybe. I guess with group means too. Yeah. Not, not being like totally teacher dependent, I guess. … I think anytime a kid reads, right, they're having to make sense of it. Or whenever they're analyzing a text, they're trying to make sense of it. When you're writing and trying to come up with your own ideas, I think you're making sense.

Charlotte's description of sensemaking implicates both individual and social processes. She considers reading to be an act of sensemaking. Her response includes frequent uses of the phrase, "I guess" indicating that this is not a word she feels familiar with and is working to build a meaning for it as she talks through it.

Charlotte's definition of literacy was very broad. "I think we can have literacy in anything. Like, it's not just reading a book. It's like the way in which you read anything, or look at or make sense of, or understand. … And your skills with how you're handling that material or the text." While she began with "anything," Charlotte concluded her definition of literacy by indicating that it occurred in response to a text. She later explained that "pictures can be text. Videos I think can be text. It doesn't have to be words."

Rachel

Rachel was a professional developer who co-facilitated the literacy workshop series. Rachel indicated that the purpose of science education was for students to have information they could use later "in an informed manner to make societal decisions, make personal decisions, make all sorts of decisions that are based in scientific reality rather than in popular press." This wording of a goal for science education was rooted in current events such as ongoing conversations regarding "fake news" in the media.

Rachel's description of sensemaking positioned it as something that would be occurring in science classes once teaching was aligned to the new standards. Rachel had worked as a science teacher for over thirty years. When also asked to define sensemaking in her initial interview, Rachel shifted into the future tense

> [Students] taking the ideas and they're starting to explain things, starting to bring their pieces of learning together, and they're starting to, starting to explain phenomena, because that's one of those things we're really starting to focus on is taking phenomena and using that as a guiding principle to explain concepts. So that sensemaking is going to be asking the questions and trying to find the evidence that is going to help them down the road explain the phenomena, explain the concepts that go along with that. … It's going to be really interesting because you're going to get kids that are trained now, and I

> say trained from kindergarten on to come up with alternative things, and as long as they can back it up with evidence they're going to be able to, you know, be able to do that.

Rachel described sensemaking as students' attempts to explain phenomena. Wrapped up in this description was a few scientific practices. She referred to asking questions and constructing explanations explicitly. She also alluded to argumentation when she discussed the validity of alternative thought processes if they are "backed up" with evidence. She also believed that as students became for facile scientific sensemakers, that science teachers would need to be open to the possibility of multiple "right answers." Though she spoke in the future tense, Rachel's understanding of sensemaking had been influenced by her experiences with high school students who she felt wanted her to give them the "right" answer, rather than think for themselves.

During her initial interview, Rachel described literacy as reading and interpreting disciplinary texts.

> There are so many parts to literacy because you can literally give kids three different versions of the same sort of information and how it's presented and how it's framed can give kids three different, three different, I don't want to say conclusions, but three different things to draw from that would give them, that would get them to different conclusions. So, I want them to get a little bit of literacy should be so important because they should be able to dig deeper a little bit. They may not be able to read an entire scientific journal, but they might be able to read the abstract. They might be able to read somebody's work, and somebody can summarize it and it could be, you know, in a science magazine that they're looking at and saying, "Oh! This is pretty important information. This is something I need to know, and I need to read about this.

In this description, Rachel focused on the fact that print texts can represent multiple perspectives. She then described literacy as the ways in which students extract information and draw conclusions from the text. She provided examples of texts she felt were useful in science classes – scientific journals written for disciplinary insiders and magazines written for a public audience.

Later in the interview, Rachel added that literacy also involved students' communication. Students were going to have to be able to communicate their work.

> Students, especially in the science and engineering practices part of [the science standards] they need to be able to construct and communicate their own, formulate their own ideas and evidence-based ideas. But communication is a big component of that which would be, you know, are they writing those? Are they presenting to a group?

Here, Rachel positioned literacy as wrapped up in the practice strands of the science standards. She alluded to a multiplicity of modes being seen as valid forms of communication in science.

In a previous collaboration with scientists at an environmental college, Rachel had been a co-author of an interdisciplinary environmental science unit published by the college. The introduction to this unit noted how nine of the ten lessons supported students' learning in response to the state's ELA standards at that time. Lesson descriptions of these nine lessons refer to reading and creating maps, conducting internet research, reading a variety of expository and argumentative texts, writing a position paper and journalistic piece, role-playing and debating. As actual lesson plans are not available online, it was not clear what instructional strategies unit developers used within each lesson. However, one lesson was available. In this lesson, students would be asked to read historical, expository, and argumentative texts, write a position paper using evidence from these articles to support their position. To support student reading, a series of guiding questions were provided.

Across her professional development offerings, Rachel's goal was to help teachers feel "competent with content knowledge" and to help them make the shift toward teaching aligned with the new standards. Her goal in co-facilitating this workshop series was for science teachers to find ways to meaningfully "infuse" literacy into their science teaching because "students are going to have to do research, and they're going to have to be able to read, comprehend, and make sense of [texts] to use those pieces to make their conclusions [about a scientific phenomenon]."

Grace

Grace was the head of the professional development team at the regional agency. While she attended neither book discussions nor workshops, Grace's interview has been maintained in the data corpus, as she was often referred to by other participants as someone who was influencing their thinking. Grace indicated that her goal at the agency was to provide "robust professional development" to support teachers as they align their instruction with the new standards. During the course of this study, Grace coordinated and presented at a lesson study conference attended by Rachel and the science teacher participants of this study. She oversaw Rachel's professional development activities, and the provision of and support surrounding elementary science kits. Thus, Grace's history, knowledge, and beliefs indirectly influenced the system. Grace described the purpose of middle school science as connecting and building upon previous learning to "build pretty complex explanations of real phenomena."

Grace defined sensemaking as a cognitive act of "figuring out." She described students efforts to "find patterns, find relationships in something, [and] to draw a broader explanation of something" as sensemaking because, "you're trying to pull different facets together to see if there is a connection to a broader explanation, and if so, can you figure out the why?" Grace saw sensemaking as the goal of the new science standards. She described attention to literacy as a shift she expected to see in science instruction if sensemaking was the goal.

> If we're doing science aligned to the new standards, kids ought to be engaged in figuring out something that's related to their daily lives or some phenomena that's meaningful and purposeful, and so then you can tie the reading and the writing and the discussion and it'll be more robust because kids are doing something that they can connect to. It's not some reading about all the planets like we used to do in elementary school when kids don't really understand the size of their town, right?

One important factor of sensemaking-oriented instruction mentioned here is that students can relate their learning to their lives. Grace rooted sensemaking in students lived experiences and saw reading, writing, and discussion as tools that can help students make, and subsequently draw upon, connections between learned science ideas and their worlds, rather than as an abstract concept detached for their realities.

Grace's definition of literacy was in flux at the time of her semi-structured interview. She indicated that a definition was hard to articulate "because I'm trying to make sense of what counts as literacy. Four years ago, I would not have said that speaking and listening counted as literacy." She described her previously narrow conception of literacy to be reflective of science education teachers.

> [Literacy] is a big tension because the field has a very narrow and superficial view of what counts as literacy. For example, if you do a reading on science, that counts as science. But, not only is that not a full picture of science, it's not a full picture of literacy. This is learning I've done in the last couple years to really understand the importance of discourse, speaking and listening, in literacy and not seeing literacy as just text-based,

> vocabulary-based. But that's a real struggle within the field because I still see a lot of practicing teachers that have that narrow view of literacy.

Grace felt that many science teachers hadn't considered oral discourse to be part of what counts as literacy. While her understanding had shifted, from Grace's perspective, the field had not yet made this shift. Grace went on to explain how she sees the new science standards as potentially opening up space for the acceptance of broader notions of literacy.

> When kids are trying to analyze data, whether it be graphs or observations or what have you, and they're trying to really argue from evidence to build an explanation, that's really deep literacy, but it hasn't been seen that way. So, I see the new standards as fully embedding literacy if you're teaching the science the way it's supposed to be taught. In the writing, we ought to be engaging kids in more notebook writing and in more ideas about letting them use writing as a tool for figuring their own ideas out – not writing as far as a formal lab report, just the more daily writing is really big, I think, in the new standards and underused so far.

Grace identified several of the practice strands of the new standards in explaining the role of literacy within the standards. Specifically mentioned here were analyzing data and arguing from evidence. However, Grace did not limit literacy to engagement in scientific practices. She also described literacy as a tool supporting students' sensemaking efforts through daily science notebook writing. She also intimated that just because something is in the standards does not mean that it is fully implemented across the field.

Grace referenced literacy researchers as being influential in her shifting understanding of literacy. During the time of the study, she and her literacy professional developers had been collaborating with a literacy professor to provide regional literacy professional development.

Grace specifically mentioned finding Frankel, Becker, Pearson and Rowe's (2016) definition of literacy helpful in coming to a "greater complex definition of literacy" after being introduced to it by the collaborating literacy professor. She also mentioned having read the briefs Nonie Lesaux and Emily Galloway (n.d.) had written for New York State regarding supporting English Language Learners.

Themes in Descriptions of Sensemaking

Several educators described sensemaking as a process that requires purpose-driven action. Rachel described former science reform efforts focused on inquiry as a situation as posing a problem and "doing stuff." In comparison, she described sensemaking instruction as more intentional, structuring "kids thinking about things in a purposeful manner." Similarly, both Marie and Elizabeth use the term "grappling" to describe how students are interacting with material while sensemaking. The word is more commonly used to describe hand to hand combat or similar physical struggles. Rachel and Grace cited scientific practices from the standards the ways in which students engage in sensemaking. Educators made references to three things students grapple with when sensemaking: phenomena, information, and representations.

Science educators indicated that students must grapple with a phenomenon – something the occurs in the natural or engineered world that can be explained scientifically. Grace indicated that these phenomena should be relevant to students' lives beyond school. Marie provides an example of such a phenomenon when she describes her students' interactions with dog pedigrees. In the Marksboro school district, many students owned dogs as pets and were familiar with the concept in an everyday sense. This everyday knowledge could provide resources for them to grapple with how to use their developing understanding of genetics to explain something about pedigrees.

In order to grapple with a phenomenon scientifically, students need additional information beyond their everyday understandings. Rachel used the term evidence when discussing this aspect of sensemaking. Elizabeth described the information students need in order to grapple with a phenomenon using a puzzle metaphor. In both educators' understanding, students' need to build sense by gathering, arranging, and evaluating gaps in the pieces of information or evidence they access while sensemaking.

Educators cited multimodal texts as some of the sources of information students might use when sensemaking. Marie described having used a video to spark students' discussion of pedigrees. Elizabeth indicated that students might gather information from an image or data set. Charlotte considered sensemaking to be the process students engage in when reading any text, broadly defined. Joan described how sensemaking might occur both orally and visually with a piece of music.

Sensemaking was also described as both an individual's cognitive process and a social process requiring groups of sensemakers. Both Marie and Elizabeth began their descriptions of sensemaking by discussing an individual and concluded by mentioning whole-class discussions. Charlotte similarly began her description by focusing on an individual and added that she thought it could also be something done by a group, but she expressed less clarity in how that might happen. Two educators discussed ties between individual and social sensemaking. Elizabeth considered individuals' sensemaking to be a precursor to sensemaking occurring in groups. In discussing the similarities, differences, and gaps between individuals' thinking, small groups, and ultimately the whole class, could come to a shared understanding. Joan connected the individual to the group when she considered how individual parts contribute to a musical piece to be sensemaking.

Sensemaking was considered a "big shift" in science standards that built upon theoretical frameworks with which teachers were already familiar. Three educators described sensemaking as stemming from social constructivism. Rachel, Joan, and Marie had all taught for more than twenty years. Marie described sensemaking as "a more friendly term for knowledge construction" and constructivism as a theoretical framework for learning. Joan connected sensemaking to the notion of "teaching for transfer" when she described sensemaking as "us[ing] your prior knowledge to inform what it is you are trying to figure out and connect it to other things." Both women referred back to their teacher preparation programs and made note that these experiences had occurred decades prior. While Rachel did not explicitly mention constructivism, she implicated it in describing the shift towards sensemaking as something that made sense based in her understanding developed through her life experience as a mom. "Small children are constantly asking questions. And this shift really focuses in on kids asking questions and piquing interest to get them to do the hard work of, I don't know, thinking about stuff."

Themes in Descriptions of Literacy

When asked to define literacy, several participants shared views that literacy was more than reading and writing. Joan noted a similar trend in music, that "traditionally, it's reading from the page, but I think reading is much more than that." She provided examples such as improvisation, understanding pitch and one's role in an ensemble as examples of literacy that went beyond "notes on the page. How do I read this? Often, the broadening of literacy was noted through the use of the term "text." Elizabeth described the view of a text as "words on a page" as a misrepresentation of literacy. She and Rachel noted that data and various representations of data also counted as texts. Joan noted that in music, some texts are heard rather than seen.

Charlotte defined a text as “anything,” adding later after prompting, “So, pictures can be text. Videos I think can be text. It doesn’t have to be words, I don’t think.”

Literacy was conceptualized as multi-modal communication. Marie stated that in her classroom, the primary way students develop these types of communication is through practice. “You can’t be in a classroom without practicing literacy, I would assume. They’re reading; they’re writing; they’re speaking; they’re drawing; they’re communicating. We’re always communicating back and forth.” She indicated that while at one time in her career, she incorporated lessons on communication, she’d since stopped. She felt it was not the most effective use of time. Grace also highlighted that students’ oral discourse could be considered literacy in the science classroom.

Literacy was also defined as a set of skills or tools used to access information. Elizabeth used both “toolbox” and “skill” to define literacy. She also positioned literacy as an interaction with a text. By using the word “visual,” she implied multimodality, but then positioned literacy within print-based texts through her example. Charlotte also uses the term skills as she defines literacy. “I think we can have literacy in anything. Like, it’s not just reading a book. It’s like the way in which you read anything, I guess, or look at or make sense of, or understand. So, it could be computer literacy. And your skills with how you’re handling that material I guess or the text.”

Connecting Scientific Sensemaking and Literacy?

Connecting sensemaking and literacy was a prominent theme for individuals who were not Marksboro science teachers. Charlotte’s definitions of sensemaking and literacy were both focused on interaction with text and were so broad that little could be noted to discern one construct from the other. Joan noted the importance of both visual and oral modes when considering sensemaking and literacy in music. Professional developers, Rachel and Grace, also connected literacy to the scientific practices included in the standards. When describing literacy, Grace used the phrase “analyze data” which comes from one of the standards’ scientific practices and then shares that she thinks that the new standards “fully embed literacy if you’re teaching the science the way it is supposed to be taught.” Rachel connected the notion of literacy as communication to the practice strands of the standards as well. Practice eight asks students to “obtain, communicate, and evaluate information” (NRC, 2012, 3-19). In her initial description of literacy, Rachel noted, “there are places where it is written that students are going to have to be able to communicate their work. That students, especially in the scientific and engineering practices part of it, they need to be able to construct and communicate their own, formulate their own ideas and evidence-based ideas.”

Fewer connections were noted in science teachers’ descriptions of sensemaking and literacy. Elizabeth implied that she saw value in teaching literacy strategies as part of her science curriculum, but she did not provide a reason behind this value. Marie noted that she felt such teaching distracted from the science learning in her classroom. She distanced literacy from science. Neither Marie nor Elizabeth make mention of connections between literacy and the science standards.

Describing the Book Discussion Activity System

The activity system described here is the Marksboro Middle School Science teachers book study group. The book discussion activity system was the observed activity session attended most consistently by science teachers. It was a professional development offering concerned with discussing implications of scientific sensemaking. As a volunteer gathering initiated by this community of educators, it represented a synergistic yet focused learning environment. All participants engaging in this discussion group focused on ideas that resonated for them from *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). Thus, Marie, Elizabeth, Irene, Ada, and Mae were primary subjects in this activity system.

The book discussion group met every other Monday from February through May for an hour each time. Teachers arrived at meetings having read one to two assigned chapters. All teachers brought their books to each meeting, most with marginal notes, highlighted sections, and flagged pages. Irene came with a separate binder of notes, which also included her thoughts in regards to the supplemental materials on the companion website. Sometimes, a teacher would bring their planning documents or student work examples in order to solicit peer feedback and connect the book discussions to their classroom teaching. During discussion, conversations would ebb and flow between sharing thoughts on specific quotes or ideas from the book and discussing previous or upcoming instruction. Even when discussing previous or upcoming instruction, discussions were tightly focused on the recommendations found in *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2019). Often, teachers' feedback on one another's planning included references to the text by pointing at examples, citing page numbers and strategies, or questioning someone's interpretation of what had been shared.

The descriptions provided in this section represent an analysis primarily of the fieldnotes gathered during these sessions as well as the artifacts teachers created or accessed during these sessions. Data from interviews, workshops, and workshop planning meetings have been used to triangulate findings. Because the five focal participants mentioned Rachel and Grace as well as their cross-disciplinary peers throughout discussions, data from the broader community of participants in this study also helps to account for the nested or multi-planed nature of activity systems.

While the broader community of teachers' initial descriptions of scientific sensemaking and literacy gathered during interviews indicated that they may see the two as distinct from one another, science teachers'demonstrations of their understandings during book discussions did not. While sensemaking was more prominent than literacy in these discussions, teachers' conversations often implicated both. Participants' demonstrations of their understanding of scientific sensemaking and literacy during book discussions were mediated by an intersecting web of activity system elements, rather than from discrete elements. Figure 4.2 summarizes the elements of the activity system as discussed by participants and presents them as interconnected. The arrow arcing from division of labor to rules is used to illustrate how teachers perceived the divisions of labor as rules governing their activity.

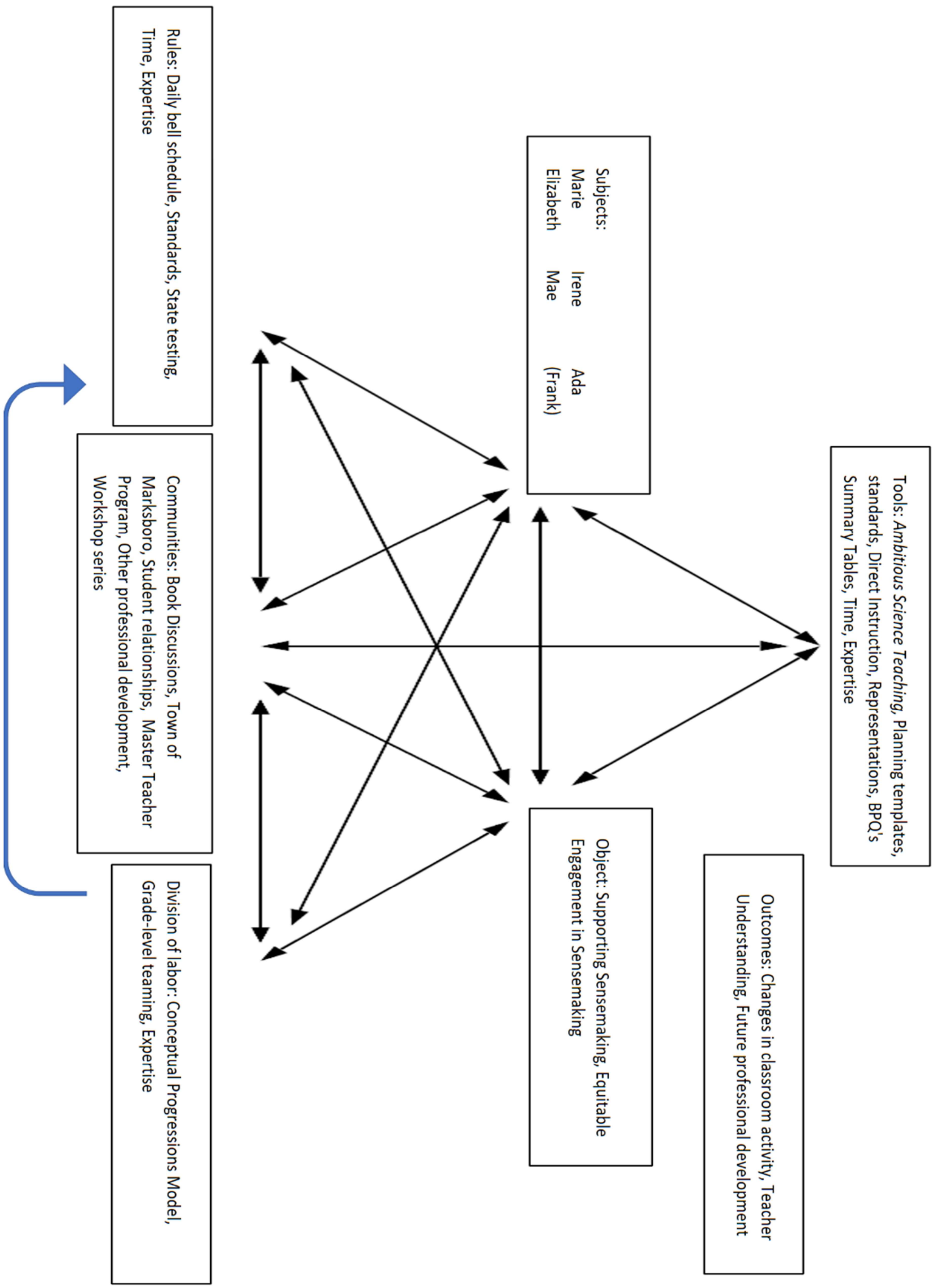


Figure 4.2. Book Discussion Activity System Diagram

To describe the system, I examine each systemic element. For each element, I address themes in subjects' talk that implicate that element. For each theme, I present an example excerpt from discussion. I conclude by describing participants' shifts detailed above as outcomes of the system, using the traditional CHAT triangle diagram. I have chosen to arrange analysis of teachers' talk by activity system elements implicated and then chronologically within each element. Across the seven observed discussions, teachers flowed flexibly between talking about important take-aways from *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018), planning storylines, and discussing contextual challenges. This meant that in each meeting's discussion, tools, rules, the division of labor, and a number of communities were implicated.

Object: How do we support students' sensemaking?

Supporting students' sensemaking was the primary object of the activity system. It drew upon a number of goals science teachers expressed for their participation in the activity system. Across book discussions, sensemaking was operationalized using a puzzle metaphor in which students obtained different pieces of information from multiple texts, representations, or activities, and then worked together to assemble the pieces into a cohesive explanation.

Five science teachers, including Ada who also taught ELA, engaged in the book discussion group as a means to align their science teaching to new standards and pedagogical approaches. Marie, a seventh-grade science teacher and the department chair, hoped to facilitate these discussions in such a way that teachers felt supported in their efforts, rather than judged in comparison to one another. Both she and Elizabeth, another seventh-grade science teacher, indicated that they engaged in this professional development as a way to align their teaching with the new standards. As the *Framework* (NRC, 2012) positions sensemaking as its goal and explains that it was not a goal of previous reform efforts, teaching for sensemaking is an inherent goal when attempting to align one's teaching to the new standards. Additionally, the group selected *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018) as their focal text. The authors use the term sensemaking when laying out their vision of what it means to teach ambitiously (p. 2). Thus, a focus on sensemaking is further implied by their text selection. Marie described the standards as what needed to happen and *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) as her "vision."

Even though I did not get a chance to interview Ada, Mae, and Irene, I assume that their goals for participation were similar to Marie's and Elizabeth's. These women also taught science, were also actively supporting one another's storyline planning during book discussions. Throughout the data collection period, they discussed changes they'd made to their own teaching and frequently tied these comments back to the new standards. On multiple occasions, Ada shared a sentiment about *Ambitious Science Teaching* similar to Marie's in that she called it her "science Bible." Frank's goals, however, may have differed, as his instructional role as a special education teacher differed significantly from the others in that he was not responsible for designing storylines. The supplemental pay and professional development hours provided by the school district for participating in book discussions was likely an additional motivating factor for all participants; however, this was not mentioned by any participant throughout data collection.

Equitable engagement in sensemaking. Not all of the teachers' goals for engaging in this activity, the book club discussion, were outwardly stated. Rather, they became clear through that they focused on while discussing *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). Largely, these goals related to teachers' creation of instructional storylines. One was to incorporate teaching practices that promoted students' equitable engagement in sensemaking, as this is a major focus of the focal text, *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018). "Equity" was the most frequent note Elizabeth marked in her copy of the book. In every discussion, teachers considered how specific supports and strategies might benefit specific students such as English language learners and "struggling students."

Equity was discussed through teachers' conversations regarding how to value and incorporate students' misconceptions during whole class discussions. On February 25th, Elizabeth sparked conversation around the importance of probing when students' first responses don't make sense.

> Elizabeth: What's hard for me is allowing all ideas, without saying this is right or wrong.
>
> Ada: But you want all those ideas. You need everything ranging from incorrect to correct.
>
> Mae: It's so hard to be unbiased toward it all.
>
> Ada: You've got to put your poker face on as a teacher doing this.
>
> Elizabeth: Sometimes [students] have ideas, and you're like 'Huh?!'
>
> Ada: That's when I go 'Tell me more."
>
> Marie: And sometimes they do make sense when they tell you more.
>
> Elizabeth: But then, you have to keep the conversation where you want it to be. You're there to facilitate it with purpose. It can't just go down rabbit holes. (Mae nods) Saying tell me more – this is when you can really tell if they get it or not, not just if their first statement makes sense."

Teachers struggled with their desire to follow Windschitl, Thompson, and Braaten's (2018) recommendation to incorporate all student ideas, regardless of their accuracy, into initial whole class conversations regarding a phenomenon while facilitating the conversation in such a way that helps students learn scientific concepts. Windschitl, Thompson and Braaten (2018) provide a taxonomy of teacher talk moves including probing, pressing, and revoicing, which teachers can draw upon when planning and facilitating science conversations (p.63). Much of the book study teachers' discussion of eliciting and incorporating students' misconceptions revolved around students' first interaction with a phenomenon. When Elizabeth stated that she could not "just go down rabbit holes," she was expressing that her instruction needed to provide students with meaningful information upon which to build their explanations. This, however, does not mean that she did not value the contributions students make to a conversation by sharing misconceptions. In her final interview, she indicated that it is through inclusive whole class conversations that she got access to students' misconceptions in order to use them to shape her evolving storyline in a way that would invite students to modify their thinking by introducing science concepts and data which challenge and confront their initial misconceptions.

Object-oriented Activity: Discussing Storylines and *Ambitious Science Teaching*

The bulk of teachers' talk during book discussions focused on applying ideas from *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) while incorporating material from published storylines and resources into their planning of science storylines. While Windschitl, Thompson and Braaten neither use the term storylines nor draw upon published storylines in their recommendations to teachers, Marksboro science teachers used the term storylines and several had had previous professional development experiences in which they had been introduced to publicly available storylines. Teachers' took up Windschitl and Calabrese-Barton's (2016) four practices for intellectual engagement and attention to equity presented in *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) and defined in Chapter Two: planning for engagement with big ideas, eliciting students' ideas, supporting ongoing changes in thinking, and drawing together evidence-based explanations. Additionally, they discussed assessment, a topic they felt was not adequately addressed by the authors. During each discussion, talk often drifted between these principles, rather than attending to each in a distinct manner, especially during conversations built upon later chapters. Throughout these discussions, teachers introduced ideas from other sources of information, such as recommendations and resources from other professional development opportunities.

Developing storylines using phenomena. Two pairs of teachers were co-planning and teaching phenomenon-focused storylines during this study and often discussed these storylines with their peers during book discussions. Storylines refer to curricular units in which students ask questions about a scientific phenomenon and teachers then present a series of activities designed to provide students bits of information to reason with in order to answer their own questions in a way that coherently connects disciplinary core ideas, cross-cutting concepts, and scientific and engineering practices (Edwards et al., n.d.). Unlike many science education scholars, Marksboro teachers believed themselves to be, at least in part, storyline creators. Seventh-grade teachers, Marie and Elizabeth, and eighth-grade teachers, Mae and Irene, offered their developing storylines as examples to further discussion throughout book discussion meetings. Marie and Elizabeth built a genetics storyline based upon the genetics and heredity lesson available from the National Science Teachers' Association website (2014) and began work on an ecology storyline based upon a *Daily Mail* article about a 50-year-old ecosphere linked on the Wonder of Science website (Wilkes, 2013 as cited by Anderson, n.d.). Mae and Irene modified the "Why don't antibiotics work like they used to?" storyline designed for high schoolers available on the Next Generation Science Storylines webpage (Affolter et al., 2014), as they could not find a published middle school storyline that addressed their focal performance expectations.

In none of this planning did the teachers replicate a published storyline. In each storyline, teacher used elements of published lessons and/or storylines to select the focal phenomenon and then curated their collection of activities and representations, drawing upon their previous teaching, resources from peers' previous teaching, and published resources available online. Elizabeth described the process of creating a storyline as

> …starting with that phenomenon. So, it should be a phenomenon that interests them, that they have some sort of background information on, but not something that is very obvious that they can explain everything about. And then your lessons should be created around the pieces that they need in order to explain that phenomenon at the end of the unit. And those pieces don't have to be directly related, so they have to be able to somehow gain that information and then hopefully apply it back to the phenomenon.

Teachers used the word, phenomenon, to describe the observable event used to initiate a storyline, such as the appearance of the twins discussed at the beginning of the genetics storyline. Occasionally, they also used an additional term "anchoring event" to refer to the initial representation of a phenomenon as Windschitl, Thompson, and Braaten (2018) did. Science teachers discussed the need for phenomena to be relatable to students' everyday lives. Irene and Elizabeth used their experience teaching previous storylines to further explain that the scientific explanations behind phenomena should not be immediately grasped by students, yet they should not be overly abstract. During the final book discussion meeting focusing on Windschitl, Thompson and Braaten's rhetorical question, "Can we be ambitious every day?, " (p. 257) Marie positioned finding a phenomenon as one of two central elements that make science teaching ambitious, "my thought is that the sensemaking chapter is the most important part. We should take the time for finding a phenomenon … Some things are worth us taking the time and they elevate all of our teaching."

Each storyline teachers created or modified followed a similar flow. Marksboro teachers presented students a video, and occasionally other representations, which illustrated the focal phenomenon. As a class, students created initial explanations of the phenomenon and then asked questions or offered information that might be needed to fully explain the phenomenon. Subsequently, teachers spent the bulk of a storyline presenting students with multiple representations and activities that illustrated aspects of the phenomenon or additional contexts through which to grapple with explaining the phenomenon. Partway through each storyline, a whole class discussion focused on making modifications to the class's initial model or explanation. Again, students would be asked what information was still needed to confirm the model or explanation. At the close of a storyline, the class would be asked to come to consensus on their current understanding of the model or explanation, again revising the evolving class explanation or model. Table 4.2 illustrates several of the activities and texts incorporated into these storylines as discussed with peers in book discussions. As much of teachers' planning occurred beyond the book discussion setting, this table is not an exhaustive list of the activities teachers planned and implemented.

Content Learning	Anchoring Event	Multiple contexts of Phenomenon	Students' Final product
Genetics, including asexual and sexual reproduction and environmental factors (7th Grade, Elizabeth and Marie)	Biracial Twins presented through images, video, and New York Post article	Variation in class traits (investigation and graphs) Dog Breeding (activity and video) Himalayan Rabbit markings and ice (reading passages) Obesity (reading passages) Sea star regeneration (reading passage) Planaria regeneration (investigation)	Explanation of how the twins could display different traits
Energy flow in ecosystems (7th grade, Elizabeth and Marie)	50-year-old ecosphere	Local and state deer population density (data, activity) Analysis of data on multiple organisms to explain trends in squirrel population (activity) Debate to explore student question regarding Venus fly trap as predator or producer (activity)	Visual model with explanatory captions explaining how energy recirculates in the ecosphere

		Student introduction of Carp as an additional example of population density	
Evolution/ Antibiotic Resistance (8th grade, Mae and Irene)	Girl keeps getting sicker despite antibiotics	Bacteria evolution simulation (activity) Peppered moth (reading passage) Tuskless Elephants (reading passage) Fungus Article (reading passage) Spiny Mouse Article (reading passage) Amoeba Sisters Videos on natural selection and genetic drift	Visual model with explanatory captions to explain how the girl was able to take antibiotics and not get better

Table 4.2. Storyline elements discussed during book discussions.

Eliciting student ideas. Teachers discussed the development of activities that elicited student thinking as interactions with a representation of the focal phenomenon scaffolded by teachers' planned questioning. Eliciting ideas in this manner at the onset of a storyline was the main focus of February 25th's book discussion. Teachers discussed the chapter in an applied manner as they tried to figure out how to introduce Marie and Elizabeth's genetics storyline given three representations of a set of twins who appeared to have different racial backgrounds: an image, a New York Post article, and a video. Though Elizabeth mentioned that the NSTA storyline she and Marie were using had a list of recommended questions, the group focused on developing a lesson by sequencing the introduction of the representations and planned teacher questions used to elicit students' initial ideas around what was happening and inferring how it might happen and what questions students' had. This information could then be used to sequence and structure the storyline in a way that could help students' answer their own questions and build upon their current understanding. Teacher questions developed included many variations of observational questions:

What do you think is happening?

What do you notice?

How are they different and similar?

What do you see and hear?

The group of science teachers decided upon using the similarities and differences question during Marie and Elizabeth's upcoming lessons, as it could be supported by a Venn Diagram to help students capture their ideas in writing.

Teachers' conversation then shifted towards developing inferential mechanistic questions. Irene reminded the group of *Ambitious Science Teaching*'s suggestion to follow up the WHAT conversation with the HOW (Windschitl, Thompson, & Braaten, 2018). Questions developed during this phase of the conversation were:

What is going on that you cannot directly observe?

How did the sisters get such different traits?

How can you explain your Venn Diagram?

How can you use your Venn Diagram to explain how these sisters get their traits?

What do you think right now?

How do unseen events influence what you see? What convinces you?

Using all your resources, what's our class understanding?

How do children get the traits they have?

Developing "HOW" questions was more challenging for teachers than developing "WHAT" questions. At one point, Marie expressed frustration over this challenge, noting "It's so hard to get to the perfect question. And then you're in the classroom." She implied that even after the group developed what they thought would be the "perfect" questions, inevitably, classroom practice would impact their delivery and success. Variables across and within classes might cause a teacher to deviate from their planned questions and may impact where the conversation with students might go.

This phase of the discussion also elicited a number of questions from participants regarding their own planning process in response to Windschitl, Thompson, and Braaten's (2018) recommendations. Some of these were procedural, such as "Is this when their thinking is made public?" "What probes can we use to go farther?" and "Now what?" In these questions, teachers were taking up some of the language of *Ambitious Science Teaching* as "probes" and "making thinking public" were phrases used throughout this chapter (Windschitl, Thompson, & Braaten, 2018). In addition to these questions, Elizabeth directly connected teachers' ideas or suggestions to the practices outlined by the chapter on three occasions.

As the discussion began to close, teachers took up the topic of discussion facilitation strategies. In this conversation, they were considering group size as a support for eliciting students' ideas. Marie wondered if her class should consider ideas in small groups or pairs. She then wondered if groups of eight would be useful. Ada indicated that she'd had a conversation about group size with her sixth graders, who felt smaller groups helped them to share their ideas more than larger groups. Irene offered "Four to five?" as an appropriate group size, and Mae wondered if the authors included a larger group as an intermediary between small group and whole group discussions: “Maybe it gives them a test audience?”

While discussing group sizes, teachers shared two strategies to support student talk. Marie mentioned that she has established “norms of discussion” with her class but did not provide detail around what these norms are or how students are reminded of them during discussion. Elizabeth shared that she has a handout titled “Conversation helpers” that she placed on each table during discussions. This handout contained sentence starters that give students options regarding how to enter a conversation in order to agree, disagree, question, or build upon others’ ideas.

Eliciting students’ initial ideas was revisited by the group on April 8th. This time, discussion of teacher facilitation strategies was more streamlined than their conversation in February, with only a few well considered student questions offered:

Marie: What do you see?

Irene: What pattern do you notice?

Irene: What will this tell us about antibiotic resistance?

Elizabeth: What missing puzzle pieces would you need in order to fully explain this to someone?

The three teachers rattled off this list of questions, building upon one another to create the same WHAT, HOW, THEN WHAT pattern they discussed of February 25th. Unlike the discussion of February 25th, the group did not work through additional possibilities or discuss how to formulate these questions. Rather, teachers’ planned questions seamlessly evolved from direct observations to inferences to questions to obtain additional information. Another difference between their previous discussion and this one was that this discussion continued with the sequencing of additional phenomenon to continue contributing to the storyline following this activity.

Supporting ongoing changes in student thinking. Teachers' discussion of supporting students' changing thinking involved designing interactive direct instruction, supporting sensemaking conversations with Back Pocket Questions (BPQ's), and using summary tables, as described below. These topics closely parallel the chapters into which Windschitl, Thompson, and Braaten (2018) separate supporting ongoing changes in student thinking. *Ambitious Science Teaching* presents more recommendations in each of these chapters than presented here. These represent the recommendations that resonated with the group and resulted in significant discussion (Windschitl, Thompson, & Braaten, 2018).

Designing interactive direct instruction. In discussing recommendations around teachers' introduction of new ideas, Windschitl, Thompson, and Braaten (2018) indicate a preference for the phrase *interactive direct instruction* rather than the more commonly used *direct instruction* (p.156). The use of interactive implies that students will have opportunities to engage with material throughout an instructional period, rather than passively consume presented information. Marksboro teachers discussed Windschitl, Thompson & Braaten's (2018) recommendations regarding the sequencing of direct instruction of conceptual vocabulary, activities supporting students' focus on central concepts during interactive direct instruction, and the importance of differentiating to support varied student strengths and needs as well as the authors' recommendations for teaching functional language and vocabulary on April 8th. By functional language, the authors mean "communicative acts (saying, writing, doing, being) that are used to transmit ideas in a social context" (Windschitl, Thompson, & Braaten, 2018, p.162). The April 8th discussion opened with Marie sharing this quote she had starred in her copy of

Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018).

> Even though we have made recommendations about a sequence for these instructional moves, we want to be clear that the research on learning is *not definitive* (original) about whether the teacher should introduce canonical ideas before any hands-on activity takes place, or the activity should precede the introduction of science ideas (Windschitl, Thompson, & Braaten, 157).

Elizabeth responded by providing a justification for both sequences,

> When [a concept] is dependent on a hard topic, when it is so abstract, they need something to connect to their knowledge base. (All group members nod their heads. Several affirmative "hmm hmm's" are heard.) But, if it's not abstract, we need to let them go. They need something to use to get the conversations going. Like when we did gravity, I know they have stuff, but when we did sound, that was interesting? They had some pieces, but as they started talking, it was obvious they were struggling. I don't know how you know that ahead of time.

Elizabeth reflected on two storylines she taught earlier in the year and expressed that knowing when to provide instruction before an activity and when to provide instruction after an activity is a challenge. Marie echoed this challenge and critiqued the book's advice.

> How do you know ahead of time if the struggle is too much? They did do this on page 158 with the teacher who made decisions about how to teach buoyancy. (She tracks her finger along the page) 'just enough information to reason with' (Windschitl, Thompson, & Braaten, 2018, p158), but that's dependent upon age.

Here, she was implying that students' reasoning or sensemaking skills develop as they age. What might be enough information for elementary students to explain why some things float and others sink may differ from the amount of information high school physics students might need to express a more sophisticated understanding. Marie seemed to be hoping for more explicit advice regarding how to know when to provide students additional information and when to let them grapple with what they had available.

Elizabeth described teaching “why you have two parents and the terminology that’s in the activity” through interactive direct instruction on the previous Thursday and was conducting an activity where students’ predicted the genetic variety of a litter of puppies using Punnett Squares that day (Monday). Irene described a similar activity in which students simulated sea star reproduction using colored chips to represent traits from each parent; however, the activity had not been preceded by direct instruction. She affirmed, “They end up knowing about dominant and recessive without having the vocab. The whole concept is built before the vocabulary.”

The teachers’ conversation returned to the timing of interactive direct instruction as the group began to focus on functional language, meaning “communicative acts (saying, writing, doing, being) that are used to transmit ideas in a social context” (Windschitl, Thompson, & Braaten, 2018, 162). Elizabeth and Mae mentioned teachers and students in their previous district had a handout which listed certain active verbs and their meanings. Both indicated that this handout had shaped their instruction, and Elizabeth mentioned that she was still in the habit of italicizing these words on all her materials to help students focus on them. Mae indicated that functional language needed to be taught before students engaged in activity. Ada warned her colleagues not to treat functional language as vocabulary, and Irene added a quote from the book: “If it is taught as vocabulary, students will not recognize the situations in which it is useful” (Windschitl, Thompson, & Braaten, 2018, 162). Mae then clarified her previous statement, indicating that functional language should be taught “just as they need to use it.” Ada supported this shift in understanding, citing an example from a previous district-wide professional development in which the presenter demonstrated how frontloading material could be disengaging for students. Ada's takeaway from that experience had been, "You can tell me anything you want, but until you tell me the relevance, I'm not paying attention."

Back pocket questions. Teachers discussed how supporting small group sensemaking conversations was more challenging than how they had been previously supporting group work. Much of their talk centered on the creation and use of BPQ's. Windschitl, Thompson and Braaten (2018) describe BPQ's as a written set of pre-determined teacher questions to support students' small group activity that teachers can keep handy when monitoring small group work. They are differentiated in order to support groups who are struggling to get started as well as groups who need more challenging questions to sustain their discussion and their thinking. BPQ's are intended to help groups of students focus on one or more aspects of a task or activity, rather than to generically check in on a group's progress.

Conversation on April 8th began with Marie recounting her use of the chapter's BPQ's earlier that day. She confessed that she had not planned the three types of questions offered by the book, but hoped they came up naturally through her intentional conversations with each group. She reflected, "To be that level of 'on' is challenging!" Irene added, "It's much easier to say, 'How are you guys doing over here?'" Frank provided a potential strategy of jotting questions down and dropping them on the table for students to discuss rather than engaging in that much conversation each day in order to "not go home and be a vegetable." Conversation shifted to other topics, but Marie kept trying to pull it back to BPQ's. When it did eventually circle back to BPQ's Irene provided an additional modification of the book's BPQ's- only draft 2 questions rather than three. She suggested writing a question to ask if groups were ahead and an additional question if groups were behind.

The final focal point of the discussion on April 8th was developing a lesson sequence within Mae and Irene's evolving storyline. This discussion began in generalities when Irene reiterated the importance of a storyline. "When we do this [incorporate sensemaking into lab debriefs] instead of teacher talk, and it's more student led, it will be so much more of a story. We can focus on how does it connect back to the anchoring event. How do we make it all part of the story?" Mae also chimed in, "It's kind of freeing that way." Irene and Mae were implying that shifting their lab debriefing discussions to focus on how the activity helps students think about the phenomenon, or anchoring event was different from what they had been doing previously; however they did not indicate what these discussions had previously entailed.

Summary tables. Teachers' discussion regarding how to track changes in student thinking revolved around the use of a summary table. Windschitl, Thompson, and Braaten (2018) describe summary tables as graphic organizers completed by groups of students throughout a storyline's progression to summarize key learning from each activity. Teachers discussed the creation of summary tables, variations of summary tables already used in their instruction, and finally, what purpose such idea trackers served within a storyline.

Teachers discussed the purpose of summary tables. Marie positioned it as a durable representation of learning. Mae initially thought it was an "idea catcher," but later described it as a tool for students to use when creating explanations or models at the end of a storyline. From here, their discussion briefly focused on creating explanations using a Claim Evidence Reasoning (CER) format. Ada expressed that the language used to scaffold these explanations was similar to language used in ELA classrooms. She appreciated the continuity. Marie told

Elizabeth that they could construct a CER activity on how genes and the environment affect traits, an activity they did later create and discuss in another book discussion meeting.

Members of the group held different ideas regarding when a summary table should be created. Marie planned to have her students construct a summary table at the end of her genetics storyline, recognizing that this was not aligned with the book's advice to embed the summary table throughout the storyline. However, she felt constructing it could serve as good review of learned material, and as she was well into the unit, couldn't embed it at this point. Mae considered pausing instruction after every four to five activities for students to reflect and summarize several activities at once. Elizabeth stated that she preferred to have these types of conversations embedded within activities and had been attempting through several methods to do it during every activity.

The group discussed several variations on the structure of a summary table. When discussing the construction of a table like the one offered in the book, Elizabeth noted that the last column of the table could be used to have students consider how an activity related to the storyline's phenomenon. She provided the example of "evolution," but Irene clarified that the storyline's central question (why don't antibiotics work like they used to?) might be a better option, as students weren't likely to know the meaning of "evolution" early in the unit. Elizabeth also suggested that this table could be stored as the last page of a teacher-created packet of a storyline's activities so that students could return to it quickly throughout the storyline. Ada liked this idea, as she'd watched her sixth-grade students try to sort through lots of papers to pull ideas from multiple activities during class discussions. In the high school storyline Mae and Irene were using to develop their antibiotic resistance unit, there was a similar type of document called an incremental model tracker in which students used images and words to track how different pieces of information learned through activities helped clarify certain pieces of the class's model of the phenomenon.

One large structural debate was over whose responsibility it was to add content to the summary table. Marie felt that a summary table would be a good tool for teachers to create before teaching a storyline so that they could see how the activities built the storyline. Throughout discussion, Elizabeth offered several times that the book suggested that summary tables should be made by students. Yet, Marie persisted in her view, as a teacher-created storyline seemed to fit the book's suggestion that students would benefit from a "durable representation" of their learning and could also serve as a copy of class notes. Eventually, Irene also supported a teacher-created summary table, indicating that it could be hung on the classroom walls in a way that represented the flow of a storyline. Elizabeth again stressed the book's suggestion that summary tables were created by students. She then offered her progression of learning wall as an analogous structure to a summary table co-constructed by students and the teacher. This wall contained images, vocabulary, and ideas gathered through activity and evolved throughout the unit. When students worked in small groups to explain or model something, Elizabeth selected key elements of student work to then include on the progression of learning wall.

Drawing together evidence-based explanations. While NRC *Framework* (2012) and the New York State Science Standards (New York State Education Department, 2016) outline modeling, argumentation, and explanation as separate scientific practices, teachers' discussions of these practices often overlapped. Models were seen as a multi-modal depiction of students' explanations of a phenomenon. Both written arguments and written explanations were described as following a Claim/Evidence/Reasoning (CER) format.

Discussion on May sixth focused on supporting students' creation of evidence-based explanations through multi-modal modeling and written argument. The group first tackled a model template for Elizabeth and Marie's upcoming ecology storyline. They then discussed how Mae and Irene might structure an upcoming argumentative activity where students would make a claim and support it with evidence and reasoning. How teachers should structure graphic organizers was a theme across both conversations.

Elizabeth discussed how she and Marie had spent an entire planning period trying to figure out how to model the energy flow of an ecosphere using a "before/during/after" structure. They had attempted to account for what's coming in and what was going out, but quickly discovered that because everything was interconnected, it wouldn't work cleanly. Elizabeth recounted,

> We don't know what we're looking for! Marie and I took a period and a half to create this (gestures to three column chart in Figure 4.3). We are trying to figure out the increments. The first one we did had all these images and arrows. We looked at it and we thought, 'We get this, but how do we get the kids there?' So, we thought we needed to separate the elements of the biosphere. So, I said, 'Let's do energy.' We have a beginning, middle, and end in this chart – what's coming in, what's happening, and what's going out. But this is a nonliving thing (points to Sun in her "in" column). So, then, Marie said let's do carbon-based things. So, I started doing that, but then I figured out I can't do the carbon-based living things without including the other non-living things. It became a mess!

At the heart of Elizabeth and Marie's struggle was a mismatch between the science content and the linguistic structure they were trying to use. In her descriptions of their co-planning, Elizabeth kept referring back to the book's "before/during/after" example and expressed that she and Marie were trying to follow what the book was suggesting despite the fact that their headings did not align with a before/during/after framing.

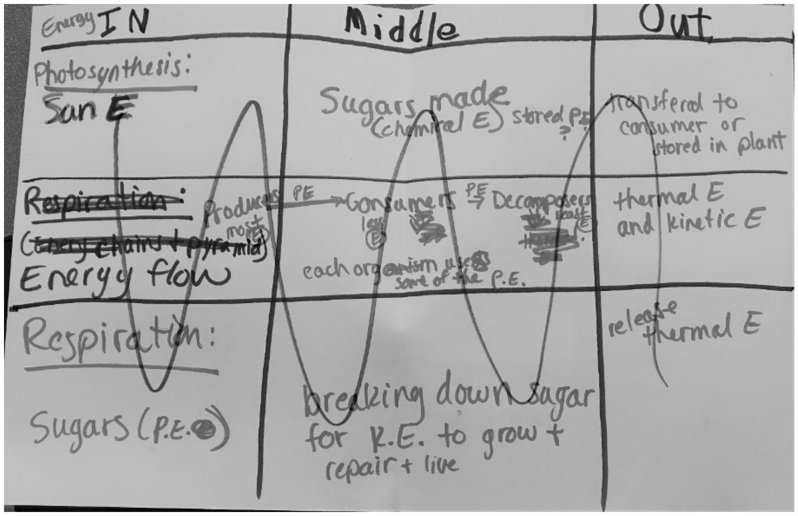


Figure 4.3. Elizabeth and Marie’s model draft

Mae offered the antibiotic resistance example from the storyline as an example that used a “cause and effect” structure rather than “before/during/after.” This sent Elizabeth back to the drawing board, scribbling on a blank sheet of paper. However, she continued to work in circles attempting to use the 3-column chart from the “before/during/after” example regarding an imploded tanker in *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018), albeit with In/Middle/Out headings. As she did so, Elizabeth began drawing an image of the biosphere and pointing to pieces of it as she expressed with exasperation, “We know there’s bacteria that’s cycling the nutrients down here (points to the soil). Because it’s a closed system, the only thing actually going in is energy.”

At this point, I inserted myself into the discussion. I could see that she was not making progress with the before/during/after format, was not understanding the intent of her peers’ advice to find a different structure, and was using an image to express her own understanding of the scientific process she wanted students to model. I asked, “What would happen if we didn’t use a chart? Is there a picture or diagram that might help us get somewhere?" Elizabeth started to redraw the ecosphere and the elements contained within. As she did, Mae began to chime in with ideas of template supports introduced in the modeling chapter: zoom-ins, sentence starters, and lines for sufficient writing.

Now that the model template was beginning to coalesce, the group dove into the content knowledge students would be expected to incorporate into the model. They discussed the standards addressed within the storyline. Elizabeth and Marie were planning to address two performance expectations in one storyline, a notable shift from the previous storylines discussed by this group. The group discussed vertical alignment – soil wouldn't be taught in depth until the eighth grade. They considered the background knowledge that students should have built throughout the year, given that this would be the final storyline of the year. At one point, Elizabeth expressed, "I'm stuck." Irene's advice harkened back to the "Big ideas" chapter, and likely to the professional development they'd engaged in the previous summer: "Take a step back. What do they absolutely have to know?" After stepping back, the group quickly arrived at a mock-up of a multi-modal model (Figure 4.4) which could capture students' understandings of relationships more clearly. This new mock-up indicated that the template students would use would contain a drawing of the ecosphere with "zoom-in's" to help students focus on three important aspects of the system: what's going on in the soil, how the plant is growing, and what happens when an animal is eating part of the plant. Lines were to be included in the boxes in order to provide guidance on how much writing was likely necessary to complete each section.

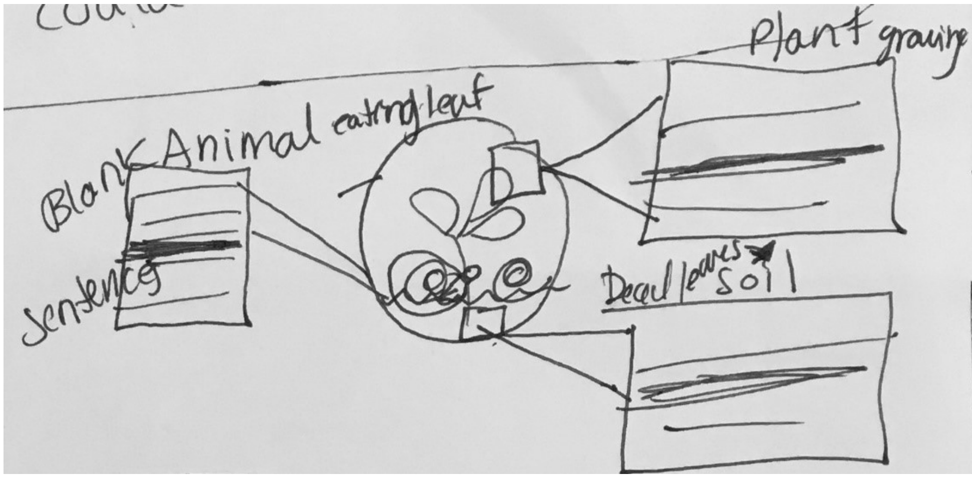


Figure 4.4. Elizabeth's multimodal model mock-up

After their modeling conversation on May 6th, discussion shifted toward how to structure a template for Mae and Irene's students to use when building a written explanation in their natural selection/antibiotic resistance storyline. This type of activity was called "a CER" by all members of the group, standing for "Claim, Evidence, Reasoning." Elizabeth shared a template she had constructed, used, and on which she'd elicited student feedback. While *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018) discuss claims, evidence, and reasoning as components of arguments, their advice on how to support it does not include an example that looked like Elizabeth's. She explained that Marie had used a different template, not creating separate boxes for evidence and reasoning. One template revision Elizabeth's students suggested making was to include the question they were making a claim about at the top of the page. Elizabeth explained, "I had it on the Smart Board. That's a bad idea." Irene and Mae worked through a series of questions to use in their template.

> Mae: So, the question they should be answering is why don't antibiotics work as well as they used to?
>
> Irene: Or should it be something that's at the lesson level? What happens when you don't take antibiotics as prescribed?

Mae: Or larger? Why do species change over time?

Irene: Oh! No! It should be "How do species' traits change?

Mae: How do they change over time? (pause) Use evidence from both activities to explain how they change over time. I want to compartmentalize my types of questions – overarching, lesson, etc. but I think I just need to forget about that. This is how these things tie together.

Mae first posed the overarching question they'd created for their storyline. The group settled on a prompt which students could answer using evidence collected from several activities which could help students address the overarching question throughout the developing storyline. Elizabeth explained how her students had three activities they could pull from when they completed her example. She described a student who had all of his materials in his lap, flipping back and forth between the activities. Irene then exclaimed, "Oh! This is where we use the summary table! It is seamless!" indicating that she saw a natural flow between the group's conversations regarding tracking ongoing changes in thinking and drawing together evidence-based explanations.

Assessing sensemaking. Throughout book discussions, teachers expressed concern regarding assessment. From their understanding, *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) did not adequately give them tools to consider how to construct assessments to measure individual students' science learning and sensemaking. Teachers' primary concern was that they didn't know what they were looking for when creating and grading student created models.

Windschitl, Thompson, and Braaten (2018) do take up assessment throughout the text. Primarily, their discussion of assessment is of formative assessment through conversations and exit tickets. When discussing the component practices involved in the core practice of drawing together evidence-based explanations, the authors present four principles for assessing understanding: assess what was taught, use authentic assessment tasks, make criteria for success clear to students, use combinations of lower- and higher-cognitive-demand items, and provide equitable opportunities for students to show what they know (Windschitl, Thompson, & Braaten, p. 231-234). Each of these principles provides general advice regarding how students might carry them out. Despite this coverage in the book, teachers expressed frustration. This may be in part because they did not discuss these pages until May but were trying to assess students' learning through their models throughout the spring. This may also have occurred because teachers were focused, in part, on how to assign grades to models, which represented a new type of assessment task for them.

Irene expressed frustration around assessment on March 11th, asking "When does it end? When is the model done enough to be considered a model? We need to develop rubrics, and we're not there yet." Irene felt that she did not know what she was supposed to assess in student models by introducing the standards as a tool which might address this concern. Throughout this conversation, the content knowledge to be assessed was not the focus of conversation. Though, teachers' understanding of the content knowledge may also be implicated by Irene's comment. Rather, teachers focused on assessing an important aspect of modeling – illustrating the unseen mechanisms that lie in transitions.

As an example, Irene described the models her students had created that day regarding regeneration after several days observing regeneration in live planaria and an introduction to stem cells. Irene then pulled a stack of student models from her large pile of papers tucked inside a three-inch binder. She began distributing them throughout the group and highlighted specific features. “This is a student with basic science knowledge and skills. She sees stages, there’s something going on in between here and here.” Irene points to two consecutive images on the student’s paper, sets it in the middle of the table, and grabs another. “This is someone who would typically do nothing at all. This is a big step from that.” She picks up a third; “And here’s a more advanced one – a science Olympiad kid looks more like this,” then a fourth,

> This kid is more in between. They’re motivated, but they have difficulty expressing their thoughts in written form. This is pretty good. She is showing progressions. At first, she was having a hard time figuring out transitions, so I asked, ‘How is that happening?

Ada then picked up an additional example Irene had laid on the table, “This one knows how to show transitions!”

When the group discussed the chapter which encompasses assessment on May 6th, the group again expressed frustration around assessment. As in their previous conversations, the impetus was a modeling assignment, whereas the chapter discussed assessment of students’ explanations. After the group had created a model template for Elizabeth and Marie’s ecosystems unit, Ada expressed concern, “What I don’t know is how do I grade this?” Irene phrased this concern differently, indicating that when trying to teach in all the ways *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018) recommended,

> [formative assessment] is the first piece that falls off. I read this and see it. I see that I’ve dropped it. I had an index card that I had the kids write. Why is it important to take antibiotics as prescribed? And the second part they answer ties it back to the phenomenon. I collect the cards and read through them all, and now I have to decide what I’m looking for. It feels backwards.

Elizabeth also used the language of not knowing what she was looking for as she described the struggles she and Marie had been having trying to draft the model template. She was able to articulate that, in part, this frustration was a natural part of learning to teach new standards. Until they'd done it once, they wouldn't feel sure that they knew where they were going. Irene touched upon this as well, noting, "I don't think we can take the kids there, because I don't think WE'RE there yet." Irene did not mean that she and her colleagues should not be engaging students in modelling. She meant that they could not provide students a clear and concise model grading rubric before teaching each storyline several times and having an opportunity to look at resulting student work.

Mediating Elements

Multiple system elements mediated teachers' activity. Physical planning resources were gathered as tools to support development of storylines. Rules and the division of labor created a structure which both impacted teachers' decisions regarding what content to teach. Teachers drew upon one another's understanding of scientific sensemaking and literacy as well as their participation in multiple communities as a resource for their own learning as well as for students' learning.

Tools. Teachers relied upon a large body of tools to inform their understanding of planning storylines. These included *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018), the state standards, and additional resources gathered from a variety of sources including past and concurrent professional development opportunities.

All teachers used *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) as a tool for developing their own planning. Ada referred to the text as her "science bible" and Marie described it as her "vision." While talk during book discussions often centered on classroom activity, every participating teacher cited quotations and page numbers to support their recommendations to a colleague at least once. Most did so with regularity. They used the examples and tools presented in the book to design materials and activities for their own storylines. Often, this was successful. However, occasionally, aspects of the book were implicated in teachers' confusion such as Elizabeth's frustration around designing a model template on May 6th as discussed previously. Once Elizabeth gave up adherence to the structure presented in the day's focal chapter and considered model templates more broadly, her template evolved with relative ease. Irene also accessed *Ambitious Science Teaching* resources from the companion website (Lohwasser et al., n.d.) She watched the videos available for most chapters of the book and recounted their content for her peers during book discussions. She also reviewed the planning tools associated with each major practice and occasionally brought them to her colleagues' attention as well.

During her final interview, Marie reflected on how *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018) was mediating her instructional planning. She mentioned how the book seemed to simplify the pedagogy expected by the new standards into practical things she could implement in her classroom. She specifically cited the recommended summary table.

> I love that because it's like going back and looking at why we did everything, what did I get out of that? I will say, I didn't follow it exactly like the book said to do it. Instead, I gave it as a homework assignment. But, I'm still happy that I was like, 'Okay, you have to go back, and you have to think why did I do this? Does it help me answer the focus question? And, can I make a model, or how can I relate it to a phenomenon?' It also gave me ideas on how to practically implement sensemaking. It's not a free-for-all that we sometimes think it is.

In Marie's interpretation of a summary table, students were asked to complete the table for homework at the end of a storyline rather than build the table with peers throughout a storyline. Thus, students were asked to engage in sensemaking individually, rather than collectively. Even though her summary table homework assignment not exactly what Windschitl, Thompson, and Braaten (2018) had envisioned, Marie's thoughts whether the students or the teacher should be responsible for creating a summary table had shifted since it was discussed weeks prior during a book discussion. This shift enabled students to be sensemakers.

While standards may often be positioned as a rule within an educational activity system, teachers discussed the standards' performance expectations as a tool. Performance expectations were one way in which standards had been presented in the state standards (New York State Education Department, 2016). Each was worded as an observable student outcome which linked a disciplinary core idea, a cross-cutting concept, and a scientific practice. For example, one performance expectation referenced by book study discussion participants read as follows: "develop a model to describe the cycling of matter and energy flow among living and non-living parts of an ecosystem." Here, both the disciplinary core idea and the cross-cutting concept is the cycling of matter and energy flow, and the scientific practice is modeling. Performance expectations helped teachers decide which concepts where to be covered and to select activities which helped students explain a phenomenon. During the multiple occasions in which Irene accessed standards during discussion, she then read a performance expectation connected to her developing unit aloud. On March 11th, Marie noted, "I think eventually the performance expectations and evidence statements have what should be shown – they're kind of complicated, but I love these standards. It's all laid out: this is what we should have in our checklist." A month later, Mae echoed the same sentiment, "The performance expectation lets you cut through the weeds – what exactly do we have to do." The clarity regarding student learning expectations present in the standards may have partially mediated some of the frustration teachers' expressed regarding assessment. However, Marie's use of the word "eventually" in the quote above indicated that she, and perhaps others, felt that it would take teachers a while before they felt comfortable with their knowledge of these expectations and the assessments they would, but had not yet, create.

Another tool teachers used were publicly available graphic organizers which helped them deconstruct a performance expectation and use it to shape a unit. Irene was often seen carrying these around, printed on 11x17 paper. After the second workshop, she walked me through a graphic organizer, shared with her by a state-sponsored professional developer in a recent workshop (Appendix C). While Irene shared several graphic organizers, this specific one illustrates the 3 dimensions of the standards: Disciplinary core ideas (DCIs), Cross-Cutting Concepts (CCC's) and Science and Engineering Practices (SEPs) to guide lesson planning. Irene highlighted that the color coding used in this graphic organizer aligned with the color coding used in the standards when discussing each dimension. She noted that the professional developer who shared this with her also showed her how to break down a performance expectation into three parts which could also be color-coded to show their connection to each dimension.

Rules and division of labor. Within the book discussion activity system, rules and the division of labor were entangled with one another. While in other activity systems, the division of labor might be flexibly decided upon by its subjects, the aspects of division of labor implicated in teachers' discussions operated more like rules, in that teachers felt bound to their teaching roles.

Marie's multiple roles – as a science teacher, as a department chair, and as the book discussion facilitator mediated what was discussed during book study meetings as well how discussions were allowed to flow. During her final interview, Marie intimated that she perceived her colleagues as both similar and different to one another in their beliefs. "I wouldn't say we're similar people, but [we hold a] similar belief system, as much as we think we're different." Marie noted that one strategy she used to manage the differences in personalities and teaching styles of her colleagues during book study meetings was to frequently refocus the discussion on considering how teachers could apply ideas from *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) in upcoming instruction. She added,

> I don't want anyone to be a superstar. I mean, it's great that someone's a superstar, but you want the relationships to be positive. You don't want anyone to be intimidated. So I tried to focus on 'How can we take this and plan something together for the future,' versus 'This is how I used it in my classroom' because 'this is how I used it in my classroom' can become kind of a brag fest.

It is not clear from the data whether other book discussion participants shared the belief that sharing what they had tried already in classrooms constituted or could be perceived by others as bragging. There were, in fact, several occasions throughout book discussions where teachers, including Marie, did share their reflections upon strategies they had tried to implement. What is clear, however, is that Marie was able to facilitate discussions which could draw upon teachers' past and current teaching experiences in order to consider applications of *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018) in upcoming lessons.

The district's adoption of the conceptual progressions curricular model (NGSS Lead States, 2013) was an example of this entanglement. Similarly to the New York Science

Standards, the NGSS do not differentiate between sixth, seventh, and eighth grades. The conceptual progressions model is one of several presented in the NGSS that describes a learning progression schools could adopt in order to address the banded nature of the middle school standards. Marksboro Middle School selected this model to guide decisions around which standards and topics would be taught at which grade. According to Marie, the conceptual progressions model was intended to eliminate repetition of topics and establish vertical alignment across grades six through eight.

> The conceptual progressions model tells you how to do it, which is really nice because you see, … sixth grade [learns about] energy forces and motions, seventh grade waves, eighth grade weather, climate. So, you can see how a concept really beautifully weaves. And someone else did it, so I don't have to be blamed. No, I'm serious. The experts did it, I don't need to be blamed on the decisions. … I don't need to be blamed.

Marie noted that one of the benefits of the conceptual progressions model was that local teachers did not need to come to an agreement regarding who would teach what content. In essence, they farmed out determining their own division of labor to the model. Marie believed that teachers felt very tied to specific units or topics and would have felt uncomfortable if she, as department chair, told her fellow science teachers that they need to teach unfamiliar material. By implementing a model not designed at the local level, Marksboro was able to limit the degree to which teachers could resist adopting new content or engage in infighting regarding curricular decisions. However, Marie indicated that the model did not align with teachers' content expertise developed through their education and over their careers.

> The challenge, though, is we have totally different topics that we're teaching. ... I haven't taught genetics in 30 years, and when I did, I taught it at high school. So, I'm so busy

> trying to get the activities together and get the resources together like, what am I going to do tomorrow?

Even though Marie thought the conceptual progressions model limited the stress of deciding which teacher would teach which concepts, it created an additional stressor. Teachers were now responsible for planning units in which their knowledge of the topic was outdated or lacking. Teachers in this study worked to alleviate this concern by supporting one another's planning across grades. Throughout several conversations, Marie and Elizabeth ask Mae and Irene for guidance and support regarding the planning of their genetics storyline, a unit previously taught in the eighth grade.

The varying team-teaching structures across grade levels at Marksboro was also an aspect of the division of labor acting as a rule governing teachers' activity. This was especially evident when teachers discussed how to engage more of their peers in planning and teaching storylines. The school spans four grade levels – fifth through eighth grades. While seventh and eighth grade students have a double period of ELA and change classes for every subject, the structure is different for fifth and sixth grades. In sixth grade, students change classes for some classes, but have one teacher for ELA and one additional subject. In fifth grade, students have one teacher for all core subject areas and only leave their classroom for special area classes, as is common in elementary buildings. Fifth-grade teachers rarely attend science department meetings, as they span all subject areas and must balance between grade-level meetings and the various subject area department meetings. Participating teachers indicated that this would likely hinder fifth-grade teachers' interest and ability to attend to the recommendations of *Ambitious Science Teaching*. While unstated, it is also likely that the responsibility to teach multiple subjects may have been one reason no fifth-grade teachers participated in this book discussion.

Statewide exams represented a division of labor between state and local control over assessment. They operated as a rule by narrowing what teachers considered to be a valid summative assessment. While a statewide exam was given in eighth grade, seventh grade teachers expressed that the exam partly guided their work as well. Marie described her upcoming summative assessment as a "semi-real test." When asked by Mae what she meant by "semi-real," Marie indicated that a state science test was a real test. The state hadn't yet created a test aligned to the new standards, but she felt compelled to make her test look like what students would see on the current eighth-grade exam. Mae indicated that updated state tests were not expected until 2021, and Irene expressed frustration. "So, we can get up and running, but it will still be dicey for a few years until we can figure out the new tests. Great." She did not like that the feeling of being in limbo between new standards and old tests would continue for several years. While this conceptualization of state tests as a rule worked to limit the possibilities of what counts as an assessment, Elizabeth's reference to the state exams on March 25th demonstrated how the assessment worked to support sensemaking-oriented teaching. As the test's expectation was that eighth-grade students would interact with one representation in multiple ways, Elizabeth expressed she wanted students to do so during her lessons as well.

Marksboro Middle School's bell schedule also governed teachers' planning. The group bemoaned the short duration of class periods. Ada expressed that she'd had an hour in a previous district. Elizabeth noted that *Ambitious Science Teaching's* suggestions around summary tables "make sense in the extra fifteen minutes they say it should take, but with our schedule, no matter what you do, it's going to be chopped up between Friday and Monday." Similarly, Ada noted that because the Smithsonian science kits used at sixth grade assumed 50-minute periods, she could not fit in the entire unit before she needed to return the materials. Mae marveled at how the shortness of periods required students to make lots of quick changes between the thinking styles of the different disciplines throughout the day. She noted “it makes my brain hurt.” Though, she also expressed that the time crunch teachers were feeling could be worse, as a previous iteration of the building’s schedule had only allotted 34 minutes, rather than the current 39, to each class. Teachers discussed a previous attempt to improve the schedule, which had been led by teachers serving on the building leadership team, but that the implementation of state requirements around teacher accountability were implicated as a reason that schedule had never been adopted.

While teachers positioned standards as a tool, professional developers positioned them as a rule designed to foster challenging instruction. Grace described their cognitive demand on teachers and students as “at a bar that’s much higher than we’ve ever seen, specifically in science education. Rachel stressed that “they’re standards for ALL students. They’re standards that speak to the idea that we’re going to make students become adults who are going to be consumers of science and scientific information, and any number of topic that they need to filter through information and then get the facts that they perceive and synthesize into their own thinking and then to start to make decisions about.

What to teach? Rules and the division of labor were implicated in teachers’ discussion of which concepts needed to be taught in which storylines. Early in *Ambitious Science Teaching*, Windschitl, Thompson, & Braaten (2018) state, “Not every science idea in your textbook or curriculum is worth teaching” (19). Teachers spent considerable time discussing what science ideas were to be included in their future instruction. These conversations were shaped by standards and district policies.

Conversations in which teachers focused on what to teach were often shaped by a given performance expectation as well as teachers’ knowledge of students’ prior learning in the topic.

March 11th's discussion on sexual and asexual reproduction was a good example. Marie had mentioned that she did not know how she might assess her students in this area.

Irene: The point of your unit might not be the full explanation every time." (She trails off while she types on her computer) Got my standards! (She turns her computer to show them to everyone). Asexual reproduction does say to develop and use a model to describe asexual (She trails off again) It's the LS 3-2, performance objective. Do you want us to share what we did when we had to teach this?

Marie: Can we look at standard 1 more time? LS 3-2? (Marie opens her computer and begins navigating to the standards. Ada and Mae open their computers as well.)

Irene: It's under growth and development of organisms.

Marie: I have this a different way in my head. (She trails off as she uses her finger to track the line of text on her screen) Yeah. "Develop and use a model to describe how asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation (New York State Education Department, 2016)." I think they're saying Punnett squares could be used here.

Irene: But maybe not, they know genes come from parent to child, but with flatworm regeneration, they know they're going to get the same thing because there's only 1 parent – so they're clones, but they don't necessarily know the genes of the new child.

Marie: Like do you mean their proteins?

Irene: They know genes exist, but they don't know alleles. They do know cells; they know chromosomes; they know the generality of it all, but not the process.

Mae: You don't need a cells unit, you just to know the nucleus and the DNA, so that you know this is what they need a copy of.

Marie: There will be a cells unit, but I don't know if it is before this.

Mae: But when you do photosynthesis, you could talk about those organelles.

Irene: Some of those you can pull out of a title box of one unit and put them other places. Organically they can fit other places, it's how you structure it, instead of doing a cells unit, you could introduce the features, but what was good about our unit is that they actually saw the cells, and they were able to say this is what a one cell creature looks like… we look at the euglena and they ask what makes it green and we go back to chloroplast

Marie: So, the emphasis here (she tracks a line of text on her computer with her finger again) is on simulations, Punnett squares, etc. Asexual reproduction makes a copy. Sexual reproduction makes variation.

This discussion snippet demonstrates that examining the standards alone did not provide teachers with sufficient knowledge to decide what needed to be taught within a storyline. Irene's understanding of students' background knowledge was essential in helping Marie decide what to teach and what to let go. Additionally, teachers were sequencing the standards' performance expectations flexibly, rather than as a mandate for a specific unit. This is evident through Irene and Mae's example of breaking learning around cell structures into pieces of information to be learned across several units.

Topics taught in other grades also shaped conversations regarding what to teach in developing storylines. This was particularly evident when Marie asked Ada about the sixth-grade sex education unit in order to consider students' background knowledge in sexual reproduction for her developing seventh grade genetics unit.

Ada: Not cells! We talk about periods, and feminine products, etc.

Marie: You don’t talk about sex?

Ada: Nope.

Mae: They only get that at the end of eighth grade.

Ada: They do bring it up a bit, but it’s not the focus.

Mae: We need to start the conversation earlier

Ada: Talk to [the principal]. I’m trying.

Marie: Is it the health teachers?

Irene: The health teachers want it earlier too.

Mae and Ada:(simultaneously) Health teachers want it earlier too.

Ada: More and more girls are getting periods earlier and don’t know what to do, and there’s no conversation at home.

Division of labor and rules were discussed as limiting factors, rather than enabling factors in teachers’ efforts to design sensemaking-oriented instruction. Most limits were seen as negatively impacting teachers’ efforts. However, not all limits were seen as negative. Teachers appreciated how standards bounded and informed their planning.

Community. Teachers used one another’s understanding and experiences as resources throughout their participation in the book discussion group. All participants influenced the activity system through the resources developed within their own histories. For example, Elizabeth referred to her time as an instructional coach in a neighboring district several times throughout the study. During her initial interview, she indicated that it was through this role that she conceptualized her progression of learning wall and that considered how to incorporate teaching literacy strategies into science instruction. During a book discussion on May 8th, she relied upon cognitive coaching practices she’d used in this previous position in order to help

Irene and Mae think through the upcoming CER activity in their developing storyline described previously. After Irene commented that she'd found the discussion helpful, Elizabeth responded,

> You need an outside voice. It's helpful to you that I don't know all the stuff. I used cognitive coaching, I have the training, so that's what I did by asking those questions. I don't have the answers, but YOU do, and you figure them out thinking through like that.

Elizabeth's history as an instructional coach and training in cognitive coaching helped her to see Irene as capable of answering her own questions and working through challenging tasks in her own teaching. Elizabeth felt that it was by adopting a humble inquisitive stance that she could best help Irene.

Marie described how interacting with colleagues who approached planning differently than she did during the book discussion was meaningful.

> You have this group of people you can just bounce ideas off of, right? Elizabeth and I, we're not as organized as Mae and Irene. They organize everything to a 't'. … But that's very helpful to have colleagues that are similar, I wouldn't say similar people, but similar belief systems absolutely.

In this response, Marie indicated that she valued seeing how Irene and Mae were considering the same ideas as she and Elizabeth while co-planning storylines. While the two pairs of colleagues approached this collaboration differently, book discussions were an opportunity to cross-pollinate, as all book discussion members shared held shared visions for what they wanted to accomplish in their classrooms.

Other communities. While the science teacher book discussion group was the primary community operating within this system, participants self-identified as belonging to several communities which influenced their participation in the activity system. Beyond identifying as

Marksboro teachers, several of the teachers also lived within the Marksboro community. Elizabeth and Marie used knowledge of issues facing the Marksboro community when she incorporated the local overpopulation of deer into their ecology unit. During her final interview, Elizabeth she used deer populations as an example to support students' developing ability to make sense of data presented as ratios. Elizabeth's use of local data was one factor that increased student motivation during this activity as well as throughout the storyline. She recounted in her final interview that students' felt invested, as they were considering an issue they felt familiar with beyond school.

Teachers also identified themselves as belonging to various affinity groups. For example, Mae used her affinity for horses to understand science concepts such as the responsible use of pesticides. When discussing bacteria developing resistance to antibiotics, she made the following analogy:

> It's like in a barn, you don't use the same product every year. You gotta change it every year or the flies keep coming back. The ones that are resistant to one spray are not necessarily resistant to another. So, you need to keep changing it up on them.

By using her everyday experience as a resource for understanding, Mae was inadvertently demonstrating the type of thought processes promoted within *Ambitious Science Teaching* (Windschitl, Thompson & Braaten, 2018). Throughout their discussions, Mae also occasionally considered what experiences in their various communities students might draw upon as resources. While discussing what background knowledge students had around antibiotic resistance, Mae shared that she had a student whose older brother had contracted MRSA, and through related conversations with students, had come to understand that resistance was a word with which students were familiar. However, most talk of students' background knowledge did not make direct ties between a community and a resource for sensemaking. Rather, most talk assumed a generally shared or lacked bed of knowledge regarding individual words. For instance, in planning their initial genetics activity around the twins' appearance, Elizabeth remarked, "They will know characteristics. They won't know traits," positioning her students as a relatively homogenous whole.

Marie and Irene were involved in additional professional development opportunities considering *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) through New York's Master Teacher Program (State University of New York, 2020). As one aspect of the program, both were receiving instructional coaching from a science professor who had been a student of Mark Windschitl's. Marie felt that because of this historical relationship, the professor was very familiar with the text. She appreciated that he used the book's language as a shared body of knowledge when recommending instructional strategies for her to try. When Marie expressed frustration abound troubling student behaviors, he suggested that a change in the classroom discourse could address her concerns, rather than additional classroom management strategies. He then provided her additional support as she tested out talk moves discussed in the book. In her final interview, Marie noted that one of the reasons her learning through coaching had been "profound" was because it was rooted in and evolved from her daily classroom practices.

Workshops. Three science teachers, Marie, Elizabeth, and Irene engaged in the workshop series on disciplinary literacy with three "non-science" teachers, Charlotte, Joan and Emily. This workshop series operated as an additional community resource, as it provided the science teachers access to additional resources such as cognitive resources developed through new learning, perspectives beyond their community of practice and experience with additional physical tools.

Learning from workshops. Rachel and I designed each workshop to help teachers consider specific focal questions. While we developed the focal questions for the first workshop, participants created the focal questions for subsequent workshops. These questions as well as a theme in teachers' learning are presented in Table 4.2. Learning from each workshop is discussed below.

	Workshop 1	***Workshop 2***	***Workshop 3***
Focal Questions	What is sensemaking? How do we engage students in disciplinary practices?	What does sensemaking look like while reading across disciplines?	How is argumentation taught and supported across disciplines?
Learning outcomes	Framing questions and Examining and evaluating claims are important practices across the represented disciplines, even though they look a bit different in each discipline.	Reading isn't "just reading" print text. It can involve recursive interpretation of information presented in multiple modes and is shaped by the discipline in which one is reading.	Common language and multiple graphic organizers should be used as supports for students. To make common language effective, teachers from all disciplines need to be on board.

Table 4.2. Workshop focal questions and learning outcomes

In workshop one, Science, ELA, and Music, teachers agreed upon several disciplinary practices they felt were challenging for middle school students: framing questions and examining and evaluating claims. When asked which disciplinary practices were most challenging for middle school students, Elizabeth was the first to answer.

> Examining and evaluating claims is such a problem. I have kids that tell me that a relationship is increasing in their words. And then they draw this! (She holds up a sketch of a negatively sloped line on a coordinate plane.) And I just look at them like this (She makes an exaggerated quizzical look as she leans back in her chair.) And when I ask them to tell me about the relationship, then they tell me again that's it's increasing! I point to their graph and say, 'What's this doing?' They tell me, 'It's decreasing.' I don't know what to do!

Her understanding of examining and evaluating claims was rooted in her experience that her students don't notice how their claims are not supported by their own evidence. Other participants provided additional examples, expressing that students often accept what they're presented with as truth without questioning it, drawing upon classroom examples as well as examples from their lives beyond school. Irene introduced asking questions and framing problems as a practice related to the same situations and frustrations at hand. Again, the other teachers offered examples such as determining research paper topics in ELA and wondering about a composer's intentions in music. Charlotte identified the connection between both practices as establishing and building students' sense of agency in their own learning. To her, getting students to ask questions and think critically before accepting claims, she feels, was a way to help students actively shape their own learning, rather than merely consume what they might be given.

In workshop two, after same discipline groups worked through how to read their assigned disciplinary texts, they shared their reading processes with the group. The ELA teachers shared a fairly linear approach to reading a short story, a poem, and an encyclopedia entry. For each, they began their description of their reading process as beginning with the first line and ending with the last. While discussing the encyclopedia entry, they described scanning subheadings until arriving at one which might be important given their reading purpose and then returned to focusing on reading in a line by line manner. The science teachers shared an approach to reading a research journal article that involved jumping between sections and recursively moving between text and images. These differences in reading between the two disciplines were not seen by most teachers as that different from one another.

While debriefing this activity, Irene expressed,

> Yea, at first I was like ‘Oh no! We don’t give kids things like this (points to the research article)!’ But now, I’m thinking maybe we should. The going back and forth, not starting at the beginning and moving through each line until the end, thinking for ourselves and making our own conclusions, not just accepting what the author says, that’s all the stuff they need to do if they’re going to understand a high level of science.

When asked what we should focus on during the final workshop, Elizabeth indicated that after seeing the music scroll, she’d like to see what argumentation looked like in other disciplines, because she was finding it challenging in her classroom. Her colleagues nodded in agreement.

In workshop three, the group drew two conclusions from examining argumentation resources across disciplines. They agreed that common language across disciplines was helpful. Though argumentation was nuanced by varying expectations regarding what counted as valid evidence and reasoning by discipline, the concepts of Claim, Evidence, and Reasoning appeared in all disciplines. Teachers saw that, across disciplines, they could rely on students’ background knowledge of these terms and use that as a foundation to explain the nuanced differences in them within each discipline. Teachers also agreed that the use of a varied set of graphic organizers might benefit developing middle school students. If students felt one arrangement was not helpful for them, perhaps using a graphic organizer from another discipline might help them capture their thinking and teachers could scaffold their inclusion of disciplinary evidence and reasoning. The group concluded by indicating that they would like to run this workshop with their peers across all disciplines during the upcoming school year in order to better understand the nuanced differences between disciplines and establish buy-in regarding shared language.

Outsider perspectives. During workshop two, most participants found Joan's reading of a symphony's score to be instrumental in shifting their understanding of what it might mean to read within different disciplines. Unlike Emily and Charlotte's reading of fiction, non-fiction and poetry, and Marie, Elizabeth, and Irene's reading of a scientific research article and popular science text, Joan's reading of a symphonic score involved her whole body. Joan described reading music as "thinking in sound." She explained that conductors need to read up to 30 lines of musical notation on a page simultaneously, noting that "if you look at the pages, you can see there's different amounts of lines on different pages. That's because there's a different amount of instruments playing. So, you can't just read this line from the beginning to the end and think you have the whole viola part." Joan then moved to page 121 of the Coregliano piece (1999) where thirty separate lines of music were presented on the same page.

> There's a lot going on here. Even the font size is smaller, so you know that's going to be a lot to suss out. If I look here (circling the piccolo and flute lines with her marker, then the rest of the woodwind and brass instruments), I can follow the piccolo line with my finger and get a good idea of the flute at the same time. (She starts humming the flute part and moving her marker along the piccolo line.) Then at the same time, I can see that the bass clef woodwinds are keeping the beat. What is the beat here? (Her eyes move back a page. She picks up her marker and circles the time signature change at the top and bottom

> of page 120. Her foot starts tapping as she starts conducting in 12/8 time with her right hand.) So, it's about this pace. How do I know that? It says right here (top of 120) that the quarter note is 56 beats per minute, so I know 60 beats per minute really well and I just have to slow down a tiny smidge from here. So, then, if I come back to this page (121), I've got one finger up here kind of tracing the piccolo. I see the beat, and then I'm trying to work out all these little notes in here (points to all the other lines of music). It would take a number of readings before I actually got this piece. If I were going to conduct this, I almost need it memorized, and not just the sounds, but my role in how to make the sounds happen. When to cue people in, how to incorporate the cue into keeping time, who is loud when, who is quiet when. I'd really have to go through this piece like this a bit, then go through each individual instrument, and put it back together. But I have to be with the group too, because you can only do so much without the sound. So, I'd probably actually read this piece while listening to it being played as well. I'd find a number of recordings and listen along to each while reading through.

Joan's reading process was recursive, moving back and forth across pages and various elements of the text. Joan explained that this type of reading was in service to conducting. She later described how she might read the same page as a pianist, elucidating the difference that varied roles play in reading music – musician, conductor, etc. Within this description, Joan describes reading as a multi-modal process, in that she would read while listening to multiple interpretations of this piece.

During final interviews, Elizabeth and Rachel indicated that Joan's reading of the symphony score was mediating their understandings of literacy. Rachel described Joan as "phenomenal" and cited her reading in her final description of literacy. "It was difficult thinking of literacy in music, but there were so many things that you just needed to pull them out, and if you had that literacy, then you could put them back together. Elizabeth similarly stated

> What [music] literacy looks like and all of the different ways that can happen in a music classroom was just neat because I am so far removed from it. …She was able to articulate it so well and she saw all the connections.

Both Rachel and Elizabeth felt that their understanding was expanding because Joan's performance was so different from their own understandings of literacy and because she had mentioned that there wasn't just one way to read music, but multiple which could be employed strategically for a variety of purposes. They both felt such expansion was useful to their considerations of additional ways literacy might operate in a science setting.

Not all workshop participants found interaction with peers from different disciplines helpful. In her final interview, Marie noted that this aspect of the workshop series did not help her accomplish her own learning goals. She stated, "I'm still just trying to figure it all out for myself. I'm not there yet with trying to understand other disciplines." By "it," Marie meant her own teaching strategies. To her, the science instructional shifts she was working to implement required a great deal of time and effort. She felt she needed to make those shifts and understand them well before she could consider how understanding literacy in other contexts might support her science teaching.

Tools from workshops. Rachel and I created and assembled materials for teachers' use during the workshops which teachers then took to use with students. For the first workshop, we created a power point presentation with graphics, quotations, and descriptions of sensemaking and disciplinary practices, a graphic organizer for teachers to consider practices in their disciplines, a graphic organizer to support reading a summary of scientific research, and a biofilm simulation supported by a half-page handout on the use of cross-sections. Both Elizabeth and Marie took the reading graphic organizer and adapted it for use in their classrooms. After Marie used it, she shared in the book study that, "it worked really well!" Elizabeth shared a student's completed organizer roughly a month later. For the third workshop, Rachel and I curated rather than created materials. We assembled over 50 examples of graphic organizers for argumentation across the disciplines. At the close of this workshop, Irene asked for the resources used to be distributed to the group for their future teaching. Marie noted that the collection would also be useful in their developing plan to provide a similar workshop for fellow teachers across a larger variety of disciplines.

Tensions in the Activity System

Two tensions emerged within the activity system. The first was around time. Elizabeth described this tension in her final interview as tears welled up in her eyes.

> During the day when I have this community around me is usually when I'm lesson planning and asking questions and bringing student work to somebody and saying, 'Hey what do you think about this? Can you tell if they're understanding?' Then the grading part is happening in the evening and on the weekends. About five years ago, I was like, 'I'm done grading papers on the weekends. That needs to be my time.' I'm back to doing it again. Right now, I have no ideas where the balance is because there's not enough physical minutes to do a really good job of it. It's like you can do a good job planning and implementing, but then not really grade anything. …That's hard.

Elizabeth also stated that she did not see an end in sight for the demands she felt on her time. She thought it would take several years for her curriculum to stabilize. The next year's seventh graders would come to her with a different bed of knowledge than this year's as a result of the implementation of the conceptual progressions model. The year after that, the new exams would be rolled out, and Elizabeth felt that this would result in another round of instructional shifts. All in all, Elizabeth estimated that it would be another three to five years before she could feel that she'd accomplished the instructional shifts she was working to implement.

Time was also implicated in the creation of the workshop series. The planning team, originally conceived to include Grace and at least one literacy professional developer, consisted of only Rachel and myself due to constraints on individual's time. Rachel also felt the pressure of time. As a retired teacher, the state limited the number of hours she could work for the state-funded agency. Rachel surpassed those hours. She partially resolved the tension of time when we shifted from an employee to a volunteer when we moved the workshop series to Marksboro. Yet, Rachel's availability remained restricted by time. This influenced when workshop sessions could be held and impacted who could attend, as several interested teachers were not available during the scheduled workshops.

Expertise was also a source of tension within the system. This was noted by multiple book study participants as they discussed how they might involve fifth and sixth-grade teachers in future science professional development. These teachers taught multiple subjects. Developing expertise in science may or may not have been an area of current concern for them because they needed to balance developing expertise in response to demands being placed upon them in a variety of subjects. Marie indicated that she felt that even if asked to read portions of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) to discuss at a science department meeting, some would elect not to. Elizabeth felt this created tension with her own developing expertise, responding, "I do not want to move backwards because other people refuse to move forwards." Marie attempted to reassure her that she, and the rest of the book discussion participants were "ahead of the curve."

Being ahead of the curve also created tension for Mae and Irene. On two occasions during book discussions, Irene expressed frustration regarding the amount of time she felt she needed to spend on "old teaching." Old teaching referred to teaching concepts and skills which she knew would be covered on the current eighth grade exam but did not see aligning with either the new standards, the conceptual progressions model, her pedagogical understanding of storylines, or some combination thereof. She wondered if she was doing students a disservice by interrupting a storyline by inserting this material.

While not a member of the focal book discussion activity system, Rachel also felt the tension of being ahead of the curve. While very busy facilitating teachers' development, Rachel was dedicated to her own learning. She felt she had no "flashlight" directing her where to go next. Grace had led her to *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) and had helped her build her foundational understanding of the expectations of the new standards and how they might play out in classrooms. Yet, Grace announced in March that she would be leaving the professional development agency that summer. Rachel noted that in her final interview that I had been influential in helping her see literacy as a potential next step, stating, "You were guiding my way … I'm just glad I got to connect with your flashlight." Yet, Rachel wondered where she would look next in order to stay on the cutting edge of work being done to support science teachers.

Outcomes of the Activity System

There were three major outcomes of the book discussion activity system: changes in classroom activity, developments in teachers' understanding, and plans for future professional development. Marie and Elizabeth both noted changes in their classroom activity as students engaged with their developing storylines. Marie noted two students' questions as evidence of these changes. One asked her if carp populations might be another instance of the deer overpopulation phenomenon. She was impressed that he was connecting his own knowledge to classroom conversations of phenomena. A second student had asked whether a Venus flytrap would be considered to be a consumer or a producer. Marie was pleased that she'd responded not with an answer but with an opportunity for students to debate the question. As a result, they learned that sometimes the delineation between the two might not that straightforward. Elizabeth noted that she felt her students were

> not shy anymore to show what [something] means to them. … Now that they know that there's not just one correct answer and mine might be just as correct as the person next to me, I'm seeing way more coming out of them than I did before.

Elizabeth noted that students were beginning to recognize peers' contributions in more equitable ways than they had at the beginning of the year. It was not "just the smarty pants" who were talking and whose ideas were being taken up by peers. Elizabeth also noted in her final interview that incorporating both visual and written modes into modeling activities was allowing more students to confidently "show us what they're thinking and making sense of and understanding. … Sometimes they will start with the non-written portions, and then once they feel confident there, they tend to feel more confident in the written parts."

Teacher learning was also an outcome of the book discussion activity. Elizabeth presented her learning during the final interview as advice to others.

> When planning, don't be too ambitious at the beginning. Pick something and try it a few times, and it's okay if you're not trying to implement everything at the same time,

> because it is way overwhelming. That definitely, some parts of your teaching lend themselves better to certain chapters than others. And all of this requires a large amount of planning time to make sure you have your questions in order and are predicting responses of students, and you have some place to organize this information for them, whether it be a tracker of their own or something like a learning progression wall.

Elizabeth provided this advice several minutes after she'd described her frustration regarding the amount of time she was dedicating to this process. In this response, she seemed to be taking up information presented in the final chapter of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) in which the authors explain that some of their recommendations were to be considered several times throughout a school year, rather than every day. By using the phrase, "at the beginning," Elizabeth noted that learning to teach ambitiously is a process.

Marie also asserted that through her participation in the book discussions and in instructional coaching, she had learned to better facilitate class discussions. She felt her belief that oral discourse was a component of literacy had been reinforced.

> For years, I have said, 'Talk is an intermediary. Talk is literacy.' Obviously, I feel that way even more now. I'm looking at really how to get everyone talking. And, man oh man, it really gave me tools. Like, how do I eliminate [initiate/respond/evaluate] discourse? How do I get more kids involved? … Like, today, they're doing reading and note taking. So, I'm like, 'Tell me about your notes. Tell me what you found out. [You need to] really be purposeful and mindful of when you're walking, because kids do a lot of group work. This is nothing new – they work in groups all the time. But, when they do it, it's like, what conversations can you have with them while they're doing it? You know, whereas before it's like, I'm embarrassed to say this, but I think it was almost like

> I'm wandering around to make sure they're on topic, to more monitor. If they have a question, then I answer the question. I didn't utilize that time as well as I could have, which would be engaging in individual conversations with kids on the topic. So, now I'm much more purposeful about that.

In considering talk as literacy, Marie was also considering her role in fostering the types of discussion she felt would help students build understanding of science. Like Elizabeth, she couched her learning in advice to others regarding the need to consider teachers' questioning as a tool develop students' thinking.

Tentative plans for future professional development also emerged as an outcome of the activities described in this study. The book discussion group agreed that they would like to continue meeting during the next school year. In separate book discussions, Ada and Irene both indicated that they planned to spend time over the summer rereading and revisiting *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) and its companion website. During her final interview, Marie indicated that she was considering her colleagues recommendations and was planning how to involve fifth- and sixth-grade teachers in learning about how they might use some of the information in *Ambitious Science Teaching.* At the conclusion of the workshop series, participants indicated that they would like to conduct a workshop like workshop three with their peers across disciplines. All science teachers in this study indicated that they would continue to incorporate recommendations from *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) into future teaching.

Demonstrations of Understanding Scientific Sensemaking and Literacy During Book Discussions

In talking about literacy and sensemaking, teachers' developing understandings were informed by their book discussion group peers' understandings and classroom experience. In essence, teachers were participating in the same type of sensemaking activity they were looking to construct for their students. Each came with necessary resources for the others and sense was constructed between, rather than within, subjects.

Talking about Sensemaking

Teachers drew upon one another's definitions of sensemaking in book discussions. Sensemaking was positioned as an individual's efforts to figure something out, a group's effort to grapple with information through talk, and individual and group engagement in scientific practices. On April 8th, Marie asked the group if anyone had any upcoming "sensemaking activities"? Teachers then drew upon multiple definitions of sensemaking in a short exchange regarding Elizabeth and Marie's unfolding genetics storyline.

> Elizabeth – When we started this unit, they went in Google forms and they entered their traits into the questions I had set up. Things like eye color, ear lobes, etc. I printed it out and they get these graphs. I asked 'What's interesting? What questions do we have?' Kids ask why some traits appear more than other traits. So, then we do dominant and recessive stuff and some other activities, then they came back to answer each of their own question. I didn't leave them with the answer at the end of the day, they had to build it over the unit.
>
> Marie – But, some traits aren't more common because they're dominant. Some recessive traits are more common.

Elizabeth – Right, but they just needed some trends to ask why they're happening. It's not a lab anymore. It's an activity.

Marie – It's a sensemaking activity.

Elizabeth – You have to keep thinking 'stop and pause, get a tidbit, do more, get a tidbit'

Mae – So, it's now a true lab that it has to build over time and doesn't fit in just one period in just one day

Irene – It's like the ice melt lab for the climate change unit. It wasn't let's be done at the end of the period, we keep coming back and you think… oh my God! It IS a story! We keep going back until it makes sense. What we've been doing isn't bad, it's just disconnected. Now we're connecting it all.

Teachers discussed sensemaking as an important component of evolving storylines. Elizabeth described students' initial interaction with data as an activity rather than a lab, which Mae later described as a "true lab." The shift from labs to activities was one way teachers were considering how students' make sense over time, breaking the notion that a lab is a discrete period of time – often one class period – where correct outcomes or results are known by the teacher ahead of time. Elizabeth's prompt to her whole class encouraged students to engage in the scientific practice of asking questions while considering a representation of data. She reported that this practice then shaped students' engagement in activities throughout the storyline. Students were responsible for considering their own questions, thereby engaging in sensemaking as an individual. However, students also used one another as resources. This was done through the initial collection and discussion regarding the distribution of observable genetic traits within the class and was also implied through Elizabeth's 'get a tidbit' line. She used this same phrase during her initial interview when she described how students needed to use peers' chunks of understanding in order to further develop their own and how arriving at an explanation was the goal of the entire group. While discussion how the multiple aspects of Elizabeth's teaching represented sensemaking over time, Irene comes to the conclusion that sensemaking is the end-goal of a storyline.

Talking about Literacy

During initial interviews, literacy had been described as communication and as tools by science teachers. Professional development providers had also initially described literacy in connection to the scientific practices included in the standards; however, this understanding had not been evident in science teachers' descriptions. However, some conversations during teachers' book discussions implicated all three themes.

Literacy as communication arose through teachers' discussions of functional language. Windschitl, Thompson, and Braaten's (2018) definition of functional language positions it as "communicative acts" (162). Throughout their discussions, teachers considered five functional language constructions: cause and effect, sequencing (before, during, after), inferring, summarizing, and arguing or explaining through the use of a CER structure.

Literacy as skills or tools arose through teachers' discussions around notetaking. Frank felt frustrated by parents who were asking to be given copies of class notes.

> It's not 1986. I try to explain to them [parents] that it looks do different now than what they remember from their own school days. It's fill in this blank, draw a picture here, or their own notes in short little spurts. They need to be trying this on their own.

Frank believed taking notes was a skill that middle school students needed to develop and that it was being adequately scaffolded by teachers. On March 25th, Marie noted that she didn't feel as certain about the efficacy of her own note-taking scaffolds.

> In an ideal world, when you need information, you'll go to a video and pause it as you take notes, but they [students] don't get the pausing thing. It's a literacy skill. So, I pause it. I write down the main idea and then I tell them the main idea. Inevitably, someone goes, 'Wait, what do I need to write down?' But if I say, 'Copy down what I just wrote.' It's no better. She's not learning to take the information, listen to the nugget, and learn it. They just want me to tell them what's most important.

Marie expressed that her initial solution, to do the notetaking and have students copy it, does not apprentice them into when or how to use notetaking as a tool for science learning.

In discussing literacy as communication and as skills or tools, teachers also drew upon the idea that literacy was tied to scientific practices. While the use of the word literacy was rare in teachers' conversations, it was used five times during the March 25th book discussion focusing on the chapter, "Supporting ongoing changes in students' thinking: Introducing new ideas."

Literacy was conceptualized as attention to vocabulary on this day. This began when Elizabeth exclaimed, "Here's where all the literacy is!" as she pointed to a page of recommendations to consider when planning direct instruction. As teachers began to discuss vocabulary, Frank, the special education teacher, became visibly frustrated. He questioned the goals and practices of vocabulary instruction he considered common across disciplines.

> It's the same with processes in math. Who cares which property something is – transitive, communitive? As a content expert, it's easy for you, but for a kid who's struggling to stay with you, they're five steps behind. Just when they are starting to understand, you force them to label it all the time. Then you kill it. You've killed them.

Frank's use of the term "they" here likely refers to students identified as having a learning disability. As he delivered this critique, his whole body appeared tense and he used more extreme gestures and a louder volume than in most of his participation. Marie interpreted hi words to mean that middle school teachers shouldn't be focused on students' memorizing vocabulary when she responded that knowing some vocabulary was necessary. Ada noted, "There's a difference between getting exposure and getting tested." She mentioned that when we ask kids to use vocabulary before they understand the concept it refers to, "It's like you're borrowing the word. You use it and give it back." Elizabeth later noted that the activities kids engage in throughout a storyline should give kids access and exposure to the vocabulary needed to construct a scientific explanation of the phenomenon, adding, "I'm realizing activities are getting the kids vocabulary just in time." By just in time, Elizabeth was referring to the sequencing of activities and sensemaking activities.

Later in the same discussion, literacy was used again. Three descriptions of literacy were implicated in this conversation.

> Elizabeth – On state exams, they have multiple questions about the representation, so I want them to understand sometimes you have to do multiple things with the same representation, especially with new standards, there's so much there than just a 'look for this.'
>
> Frank – That's a skill they need to have.
>
> Mae – That's scientific literacy, they need to know how to observe and explain in words, but it can be frustrating when you don't have the words.
>
> Elizabeth – So this chapter is scientific literacy more than other chapters.
>
> Ada – I agree.
>
> Marie – It's just different practice. Modeling etc., is literacy, but this is more us thinking about when and how we present this, these skills.

Elizabeth – And how much. But how much is hard. I find that how much I need to give changes over the day, as I feel out the kids.

Here, the three themes noted in participants' descriptions of literacy during initial interviews were present. As Elizabeth discussed the type of tasks which have been on recent eighth-grade state science exams, Frank identified interacting with a representation in multiple ways as a skill. This utterance led to Mae identifying the skill as scientific literacy; however, this is not the only way Mae described literacy here. In adding her thoughts around observing and explaining, Mae also described literacy as communication. Unlike in other conversations; however, communication here was not positioned as multimodal. Marie introduced multi-modality as she connected literacy to scientific practice, specifically calling out modeling. She finished by equating scientific practices to skills. Throughout this exchange, no one disagreed with another's description of literacy. All three descriptions of literacy – as communication, as skills or tools, and as scientific practices were accepted as valid and positioned as unified.

More frequently, however, a consideration of literacy was implied and details which could point toward a teachers' understanding based on one of these conceptions remained occluded. When discussing multiple representations of the phenomenon in Mae and Irene's storyline, Irene often used the phrase "do the" followed by the topic of the passage, for example "do the spiny mouse". As the spiny mouse was a reading passage, caught up in "do the" is whatever strategies, supports, and activities Irene intended to, or didn't intend to, incorporate. Irene was not unique in using this language when discussing the use of passages and activities familiar to the group.

Summary

Educators described scientific sensemaking and literacy as individual and social processes. Sensemaking was further described as a purpose-driven activity in which students "grappled" with scientific phenomena using "tidbits" of information gathered through activities and interactions with representations. Literacy was described as more than reading and writing. Talk was noted as a defining feature of literacy when described as communication. Literacy was also described as a set of skills or tools students used when interacting with a text, defined broadly.

During book discussions, which was the focal activity system, teachers discussed scientific sensemaking and literacy as individual and social activities. Additionally, they discussed the connection of between the standards' incorporation of scientific practices and each of this study's focal constructs. Scientific sensemaking was positioned as an instructional activity to be included in a storyline as well as a process which occurred throughout a storyline. Vocabulary and academic language were called out as specifically relating to literacy.

Teachers' demonstration of their understanding of sensemaking and literacy was mediated by several elements. This included tools such as the recommendations presented in *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) and additional planning resources participating teachers introduced into the system. Rules and the division of labor seemed to be entangled within this system as teachers felt bound by district and state policies regarding who needed to teach what concepts and the time they were given to do so. Teachers' participation in multiple communities, including the book discussion group, workshop series and other professional development also mediated their activity. Educators felt tension regarding time and their status as being "ahead of the curve" regarding standards implementation. Despite these tensions, and in part because of them, teachers described their learning, student learning, and opportunities for future development as outcomes of the book discussion group.

CHAPTER FIVE: DISCUSSION

"We need to follow where it feels like this." – Irene

This study explored eleven educators' understandings of literacy and sensemaking and how these understandings shifted through participants' involvement in professional development using a qualitative CHAT analysis supplemented by ANT. Nine of the educators were teachers in Marksboro Middle School and two were professional developers at a regional agency serving Marksboro. Five of the nine teachers taught science and were consistently involved in a book discussion group focused on *Ambitious Science* Teaching (Windschitl, Thompson, & Braaten, 2018). The remaining participants interacted with the science teachers during book discussions, a workshop series on literacy across disciplines, and/or through other professional development opportunities beyond the scope of this study. Research questions asked were: 1) How were middle school teachers and professional development providers understandings of scientific sensemaking and literacy demonstrated during their participation in professional development? 2) How were these understandings mediated by the *Ambitious Science Teaching* book discussion activity system?

In this chapter, I provide a brief summary of findings in answer to these questions and discuss their connections to relevant current research. I will then discuss scientific sensemaking as observable through actions within the activity system and literacy as observable through operations within the system. I further consider the connected nature of scientific sensemaking and literacy by including considerations of equity. I also address this study's limitations as well as its implications for future research regarding literacy in science instruction.

Summary of Findings

In initial interviews, educators described scientific sensemaking as a purpose-driven action undertaken by students. Science teachers used the term “grapple” to describe this action, implying that students may be fighting with limited and competing ideas in order to figure something out. Educators’ definitions of sensemaking included three things students are asked to grapple with: scientific phenomena, information obtained through activity, and representations. Sensemaking was described as both an individual’s cognitive efforts to figure something out as well as the efforts of a group. The science teachers interviewed both described sensemaking as progressing from individual’s initial thoughts to a small group conversation, and a whole class conversation working towards developing a consensus understanding.

In initial interviews, educators described literacy as more than reading and writing. While several noted the importance of these components, all interviewed participants also saw value in considering other components, such as talk, as important when considering literacy in the science classroom. Educators described literacy as multimodal communication. This involved students’ consumption and production of scientific texts such as charts and graphs. It also included teachers’ use of multiple media such as videos and images to provide students access to multiple representations of a phenomenon. Literacy was described as a set of skills or a “toolbox” students used to navigate texts – both print and multimodal.

Professional developers made explicit connections between literacy and scientific sensemaking in initial interviews, while others did not. Grace and Rachel both cited one or more scientific practices included in the NRC’s *Framework* (2012) and New York State Science Standards (New York State Education Department, 2016) in describing how they saw literacy playing out in science classrooms. Non-science teachers' descriptions of sensemaking and literacy were both so broad that little could be found to distinguish one from the other.

Educators' multiple conceptions of sensemaking and literacy were demonstrated through their participation in the book discussion activity system. As was noted in interviews, teachers discussed sensemaking as a discrete activity within a storyline which involved structured time for students to grapple with a phenomenon using information and multiple representations individually followed by small group and whole group conversations. Teachers also discussed sensemaking as a process occurring over time throughout a storyline which could be supported by activities which included interactions with representations, materials, and supported peer talk. Central to teacher's discussions of sensemaking were structuring opportunities for students to model and explain scientific phenomena in the storylines they were currently crafting for their classrooms.

In discussion, the term literacy was invoked when teachers discussed functional language and vocabulary. Teachers shared an understanding that in science, often vocabulary words encompass a target concept for students to learn. To develop an understanding of the word, teachers felt students first needed to develop an understanding of the concept and the word could be provided afterwards through direct instruction. However, they felt understanding functional language could help students engage in activities designed to give them "tidbits" of information necessary for ongoing sensemaking.

Teachers' demonstrations of their understanding of literacy went beyond their use of the actual term. When crafting materials to support students' modeling and explanations, teachers discussed how the materials conveyed expectations regarding the amount of writing that might be necessary to convey an idea. Teachers discussed how the wording and sequencing of a teacher's questions could be used to increase participation as well as to focus students' attention on information useful to understanding the focal phenomenon. Teachers also curated collections of multiple representations of focal phenomena. These text sets included news articles, videos, graphs and charts. Discussion regarding how to support students' during their interactions with representations focused on notetaking and teacher-facilitated discussion.

Unlike during interviews, teachers' actions demonstrated understandings that appeared to position the two constructs as connected. Marie equated literacy to the scientific practices and her book discussion peers agreed with this assertion. Writing in science notebooks and summary tables was positioned as a support for students' individual sensemaking. A "conversation helpers" handout was used to help students enter sensemaking discussions. Throughout teachers' collaborative activity in book discussions

Educators cited multiple activity system elements as being instrumental to their developing understandings of sensemaking and literacy. Teachers drew upon a variety of tools to inform their work. Beyond the focal text, *Ambitious Science Teaching,* teachers incorporated tools gathered from their previous teaching experience, their applicable state standards, their participation in other professional development opportunities, and from their own internet searching. Through discussion, book study participants gained access to their peers' tools, knowledge, and perspectives. Interviewed participants cited the importance of these community interactions in facilitating the development of their evolving storylines. Some participants found interaction with cross-disciplinary peers to be helpful as well. Marie's "I'm not there yet" comment indicated that teachers' learning about disciplinary literacy might happen in layers, as suggested by Ippolito, Dobbs, and Charner-Laird (2016). There might need to be a certain amount of understanding built around literacy within one's discipline before being ready to consider connections between disciplines.

Discussion of Findings

Scientific Sensemaking and Literacy

What emerged from teachers' words and actions in the focal activity system was the insight that scientific sensemaking and literacy were connected to one another for these individuals. When their actions were guided by a consideration of scientific sensemaking, literacy seemed to follow. Roth and Lee (2007) described actions and operations as a dialectic entity. Operations, conditioned over time, become fibers in the thread of action. CHAT scholars represent dialectical entities by inserting a line between the two inseparable words of phrases: sensemaking|literacy. Science educators in this study used the term *sensemaking* to frame their discussions of scaffolds for student learning. However, the scaffolds they created may have also worked to support students' literacy as a component of sensemaking.

Supporting scientific sensemaking. Developing teaching practices to support students' sensemaking was the object of the book discussion group, the focal activity system in this study. As detailed in Chapter Four, in CHAT, an action is a deliberate undertaking in pursuit of an object. Teachers' actions demonstrate and shape their collective and individual understanding of sensemaking.

After four participating science teachers' brief introduction to the text the previous summer, the group selected *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018) as a tool to shape their instruction. This was a deliberate choice as other texts, such as Schwarz, Passmore and Reiser's (2017) book on scientific practices, that at least one member of the discussion group had been exposed to the previous year, also discuss sensemaking and provide recommendations for teachers.

Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018) shaped teachers understanding of sensemaking by focusing their planning around two scientific practices, modeling and explanation, and by providing the core set of teaching practices. Through their discussions of the book and their concurrent instructional planning efforts informed by its recommendations, teachers demonstrated an understanding that sensemaking is both a specific activity to be planned into storylines and a process that occurs throughout a storyline. The former is apparent through teachers' use of the phrase "sensemaking activity." Sensemaking activities consisted of small-group activities followed by whole-class conversation. They were situated primarily during the middle of storylines. *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) mediated this understanding through its inclusion of a chapter specifically calling out sensemaking. The chapter was positioned in the middle of the text and was one of three focused on supporting ongoing changes in students' thinking.

Sensemaking was considered as a process over time when teachers considered the recurring role a phenomenon throughout a storyline. Sensemaking was initiated at the beginning of a storyline. The phenomena used by this group of teachers was each presented using videos. Teachers then asked students to describe what was happening and form conjectures and questions about how the phenomenon might work in whole-class conversations. The subsequent activities were designed to support students sensemaking by giving them "tidbits" of information at a time to "grapple" with. Additionally, teachers saw these activities as building conceptual knowledge that could then be paired with scientific vocabulary "just in time" for a subsequent sensemaking activity. *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) mediated teachers' understanding of sensemaking as a process through its introduction of the summary table. It was during this discussion that teachers explicitly discussed the importance of returning to a focal phenomenon throughout a unit. Conversations regarding the summary table also led teachers to consider how potential activities might contribute to students' sensemaking. Those that helped provide a "tidbit" necessary to develop a scientific explanation needed to be included. Others, which might relate topically and might have been seen as important in previous years, should be reworked or cut.

Designing and teaching storylines while reading and discussing, rather than after, was another deliberate action through which teachers' understanding of sensemaking was developed. This action was a source of tension within the system. Teachers expressed frustration when they read something that they felt could have helped them better design an activity they'd already taught. This was evident through Irene's first comment at the beginning of this chapter, "Obviously, if we had looked at [*Ambitious Science Teaching*] first, this [activity] would have been completely different." Yet, it was through designing storylines that teachers engaged in their own sensemaking process regarding supporting students' sensemaking. The concept of a storyline served as a focal phenomenon. Through incorporating their evolving storylines into book discussions, teachers grappled with "tidbits" of information at a time. Teachers tested and refined their developing understanding by teaching and reflecting on their evolving storylines.

Supporting sensemaking|literacy. Sensemaking|Literacy can be seen in educators' descriptions and discussions of each construct. Both sensemaking and literacy are described as individual "figuring out," grappling with ideas to create explanations through student discourse, and as engagement with scientific practices. In discussion, teachers rarely used the terms "literacy" and "sensemaking." Rather, they discussed instructional practices and the design of activities, templates, and other learning aides for students. Thus, it was difficult, if not impossible, to discern teachers' discussions of sensemaking from their discussions of literacy.

Movement toward hybridity (Hinchman & O'Brian, 2019) implies a coexistence of multiple orientations toward literacy in a discipline. Evidence of Tuckey and Anderson's (2008) three orientations toward literacy in science can be seen throughout educators' descriptions and teachers' discussions.

Content orientations. Teachers' primary focus throughout discussion was on supporting students' science content learning. Tuckey and Anderson (2008) note a schism in content orientations between a focus on developing one's mastery of factual knowledge and on developing one's ability to act in scientific ways. Marksboro teachers' activity indicated an incorporation of the latter perspective. This is evident in teachers' frequent references to the standards' performance expectations which incorporated disciplinary core ideas, cross-cutting concepts, and scientific practices. Teachers used the three-dimensional performance expectations as a tool to decide what scientific ideas students needed in order to grapple with a given phenomenon and through what practice-based activities they could develop that knowledge. The perspective of scientific sensemaking as content was also evident in professional developers' descriptions of recent changes in the field. Rachel mentioned that teachers would now need to accept a variety of arguments as valid student responses, rather than a singular scientific "fact" as correct. Teachers' focused their discussion on four of the eight scientific practices in the standards: asking questions, modelling, argumentation, and explanation. Each of these practices was discussed both as an individual and as a social tool for sensemaking.

Strategies orientations. Teachers' descriptions of literacy also drew upon strategy orientations. Tuckey and Anderson (2008) describe strategy orientations as those focused on helping students gain agency in their use of scientific texts. Elizabeth's description of literacy as a toolbox and her teaching of specific note-taking strategies are examples of a strategies orientation. In book discussions and workshops, teachers discussed the incorporation of several strategies to facilitate students' interactions with disciplinary texts. By and large, these strategies represented adaptations of content area literacy strategies intended for use across disciplines (Gillis, 2014). All book study participants discussed Venn diagrams, sentence frames, and a variety of graphic organizers as strategies woven into their developing storylines to support students' developing thinking. However, teachers did not discuss their incorporation as a support for students' literacy. Rather, these strategies were positioned as in service to students' engagement in scientific practices and with scientific ideas.

In discussion, teachers referred to vocabulary and functional language as literacy. Their discussion of strategies to support these constructions of literacy were limited. Marie mentioned that general literacy strategies used in other content areas to support vocabulary did not align with her understanding of the work required for students to develop the content knowledge represented by science vocabulary terms. Teachers did discuss the use of direct instruction as a support for students' developing knowledge of vocabulary and functional language. This instruction was described as occurring "just in time." They believed that functional language should be taught just before students needed to use it in a sensemaking activity. Yet, direct instruction of vocabulary terms should happen just after an activity in which students have built an understanding of the concept. Teachers' instruction is then intended to introduce the term as a representation of that conceptual understanding.

Discourse orientations. Educators talk around literacy and sensemaking also drew upon discourse orientations. Tuckey and Anderson (2008) describe discourse orientations as those that consider literacy in science as supporting students' apprenticeship into scientific ways of being, including linguistic practices. Roth and Lee's (2007) description of literacy as collective praxis in a citizen science activity system is representative of a discourse orientation. Discourse orientations were implicated as teachers discussed supporting students' equitable engagement in sensemaking conversations. Teachers discussed back pocket questions, grouping considerations, and the use of written scaffolds as supports for students' sensemaking through talk.

Like Roth and Lee (2007), teachers wrestled with the compatibility of some aspects of a discourse orientation with the goals of middle school science education. All teachers in the book discussion group wrestled with questions around how to measure individuals' knowledge and learning under a framework in which consensus was the goal. The pedagogies supported by *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) positioned class consensus as the desired outcome of a storyline. However, the current format of the statewide eighth-grade science assessment was designed to measure students' individual mastery of scientific knowledge. Irene felt she needed to interrupt her storyline to insert "old teaching" in order to prepare students for this assessment. Marie felt bound to assessing individual students in ways that mirrored the state assessment, even though students would not take it until the following year. Elizabeth mentioned that she wouldn't feel that she knew fully what she was doing until she saw state assessments aligned to the new standards and used this to further develop her storylines. As a group, teachers wrestled with developing rubrics which provided specificity for grading purposes, but which also accounted for variability between students. While unstated, these struggles indicate that teachers still see assessment of individual learners as an important component of middle school science. This causes tension as they begin considering how to develop and assess consensus.

Addressing uncertainty. Literacy was not an explicit aspect of the book discussion activity system's object. By and large, teachers' understanding of literacy was not made apparent by their actions, such as using a CER structure other than the one described by Windschitl, Thompson and Braaten (2018), and was often occluded by teachers' use of ambiguous language around literacy tasks such as "do the spiny mouse". Rather, literacy seemed to emerge through teachers' operations involved with planning storylines informed by *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018). As detailed in Chapter Two, operations in a CHAT framework are responses to contextual factors that are caught up in subjects' actions. Operations involve un- and sub-conscious decisions and routinized behaviors. While literacy was rarely explicitly discussed by teachers, it was implicated in many of their developing activities and storylines. An exploration of Latour's (2008) five types of uncertainty can help to more deeply consider the discussion of literacy as an operation and work to unpack the possibilities of what teachers meant by their vague allusions to literacy, of how these understandings came to be, and of how they came to be a part of the book discussion activity system.

Uncertainty from group formation. The uncertainty of group formation requires an exploration of when an activity "began." All participants in this study came to the activity with significant histories in education. All are certified teachers with years of experience. Some participants, Rachel, Marie, and Joan have more than twenty years of teaching experience. The educators' interviewed in this study reported having participated in professional development throughout their careers. As noted by both Joan and Marie, literacy seems to be a recurring theme in education. Grace was learning more about literacy through publications from the state's education department and interaction with university literacy faculty. Rachel's understanding of literacy was shaped by her enrollment in a content-area literacy class in the 1980's. During her doctoral work, Marie had enrolled in an elementary literacy class and had participated in literacy professional development at Marksboro. Elizabeth had served as an instructional coach across disciplines and had received to support literacy using AVID strategies (AVID/Closing the Achievement Gap in Education, n.d.). Marie, Joan, Elizabeth, and Charlotte mentioned that they had previously taught interdisciplinary project-based learning units with their peers across subject areas. All these previous activities likely contributed to individuals' understanding of literacy before the book discussion activity system formed. Thus, they'd had time and experience to operationalize their understanding of literacy – to address it in their planning without giving it much thought.

Uncertainties from actions and actors. Teachers' book discussion activity occurred in response to three changes: new standards, a new curricular model, and new pedagogical recommendations and resources. These stimuli translated the expectations and understanding of actors at a systemic level for teachers at a local level. Thus, teachers may have interpreted intended and unintended messages conveyed by the standards, documents outlining the conceptual progressions model, and resources they accessed as indicative of what national and state science education experts expected them to do within their local context. Examining how literacy is conceptualized in documents regarding each of these stimuli can inform a discussion of these teachers' understanding.

Connections to literacy are not a primary consideration of the New York State Science Standards. Teachers' accessed the new standards through the state education department's website (New York State Department of Education, 2016). The standards for grades six through eight are banded and organized topically (e.g. natural selection and adaptations, Appendix D). For each topic, the standards are presented first as a collection of performance expectations. This font used is bold and larger than all other font on the page. Following the performance expectations is a section identifying science and engineering practices, disciplinary core ideas, and cross-cutting concepts to be addressed when teaching the identified topic. The standards page(s) for each topic conclude with sections connections to other science standards in the grade band, science standards across grade bands, and to the state's Next Generation Learning Standards for ELA/Literacy and Mathematics. The three-dimensional science and connections sections are written in a very small font, and much of it is not bolded. Connections to ELA/Literacy and mathematics often run onto a second page. Given this page layout, it is not surprising that teachers did not mention literacy connections when discussing the science standards. Their discussions of standards were dominated by attention to performance expectations, which they believed to encompass everything else on the page. The reference to ELA/Literacy may also cause science teachers to view addressing these standards as the role of ELA teachers. The state has published Next Generation Learning Standards for Literacy in History/Social Studies, Science and Technical Subjects which outlines specific standards for literacy in sixth- through eighth-grade science (New York State Education Department, 2017). ELA is not mentioned in the title, nor is it mentioned throughout the document. The literacy standards cited within the science standards are direct quotations from this document, and yet are referred to as ELA/Literacy standards.

The conceptual progressions model course map (NGSS Lead States, 2013) may contribute to teachers' understanding that the performance expectations are the most important component of the standards when designing curricula. The initial description of this model states that the map "arranges PE's" (p.7). The organizational figures included in this document also organize standards by their performance expectations. Like the New York State Science standards detail connection to the state's Next Generation Standards for literacy, the NGSS outline connections to the Common Core standards for literacy. However, these connections are not mentioned within the appendix outlining the conceptual progressions model. As performance expectations seem to receive first billing and consideration of connected literacy standards seems, it is possible that adopting the conceptual progressions model also contributed to the ways literacy was carried out as an operation within this study's book discussion activity system.

The planning resources accessed by science teachers during book discussions did not sufficiently attend to literacy. While *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) discusses supporting student talk, multimodal modeling, and development of written explanations, it does not provide recommendations for how reading might be used to support students' sensemaking. The planning templates Irene shared with her colleagues contained boxes to guide teachers' thinking in response to performance expectations. They used additional boxes and color coding to support teachers' consideration of science and engineering practices, disciplinary core ideas, and crosscutting concepts. However, they did not include any supports for teachers' consideration of the state standards for literacy in science. The Wonder of Science website accessed by teachers provides graphic organizers connected to seven of the NRC Framework's eight scientific practices (Anderson, n.d.). Conspicuously absent is obtaining, evaluating, and communicating information – the practice added after public comment indicated that the framework did not adequately address literacy.

Uncertainty from the social construction of knowledge. When describing this source of uncertainty, Latour (2008) encourages a consideration of information taken as fact to be reconsidered as current answers developed in response to concerns about the natural world. Teachers assumed that focusing on sensemaking would help students better learn science in light of the new standards as fact. Yet, the state's eighth-grade science assessment which would be expected to measure students' mastery of these standards was not expected to be implemented for another two years. Teachers hypothesized, both in book discussions and in final interviews, that their storylines would likely change once they knew what this assessment looked like. Thus, they acknowledged that facts shift. While considerations of developing consensus explanations as a whole class and supporting sensemaking through facilitation of students' talk dominated teachers' implicit considerations for literacy during book discussions, their considerations may look different if the eventual text communicates something different about the state's expectations.

Uncertainty from the nature of research. My role and study design may have impacted how teachers' understanding of literacy is represented in this study. It is not possible to capture all of what happens in the field using fieldnotes, only what is perceived by the researcher. While I used direct quotations wherever possible, I did not audiotape book discussion sessions. This creates a degree of uncertainty in the data regarding what was actually said. It is possible that teachers used the word literacy more than was captured by fieldnotes. Conversely, my presence in the setting may have served as a stimulus for teachers to consider literacy more than they might have otherwise. Elizabeth's exclamation, "this is where all the literacy is!" is evidence that might support this possibility. The literacy across the curriculum workshop series, and my co-facilitation of it may have also impacted teachers' understanding of literacy and attention to it during book discussions. Science teachers signed up for this workshop series knowing that it was a part of this study. Both Marie and Elizabeth mentioned during book discussions that they had adapted a graphic organizer used in the workshop series for use in their genetics storyline. Perhaps they did this to demonstrate to me something they thought I wanted to see. Perhaps they did this because it filled an actual need in their storyline. Given the nature of this study, it is not possible to differentiate between these motivations.

Additionally, much of what I coded as literacy fell under the code "implied?." While useful in identifying moments when teachers may have been discussing students' reading, writing, and talk, this code represents my view of these activities. The science teachers in this study may or may not see the use of pictures and words in students' models as an example of literacy; they may or may not consider talk an element of literacy, but I do. When planning storylines and discussing *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018), teachers may or may not have been deliberately considering literacy. All I have is my interpretations of their words and actions as evidence of what they may or may not have been thinking.

Equitable Engagement or Equitable Sensemaking?

This study agrees with Rodriguez (2015) and extends the work of Tuckey and Anderson (2008) by proposing a focus on equity as a fourth orientation toward literacy in science necessary for hybridizing disciplinary literacy (Hinchman & O'Brien, 2019). As the research in science education begins to push for equitable sensemaking, it may pull literacy education in science to do the same. Considerations of content, discourse, and strategies were implicated as aspects of both literacy and sensemaking.

As described in Chapter Four, consideration of students' equitable engagement in sensemaking was an implied object of the activity system. It was evidenced in teachers' discussions of how to "accept all answers" and use students' misconceptions as a resource for learning. It was also implicated in teachers' occasional comments regarding how a specific recommendation from *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018) might support "ELL's" and "struggling students." Additionally, it was a specified focus of the authors of *Ambitious Science Teaching* (Windschitl, Thompson, & Braaten, 2018, p.10).

Conversations around equitable engagement were shaped by the teaching practices outlined by Windschitl and Calabrese Barton (2016) operationalized as ambitious science teaching by Windschitl, Thompson, & Braaten (2018). Teachers found anticipating students' responses during sensemaking conversations challenging. This anticipation was one action Elizabeth noted as taking up significant amounts of her time.

Like the teachers in Haverly, Calabrese-Barton, Schwarz, and Braaten's (2020) study on supporting equitable sensemaking, teachers reported "try and see" and "wait and see" strategies to "make space" for student contributions. Haverly et al. (2020) noted that the challenge of anticipating students' responses is common for teachers just beginning to plan for students' sensemaking. They found that as a result, teachers' practices to make space for students' equitable engagement are often improvisational in nature. As this study did not incorporate classroom observations, I was not able to see teachers' classroom improvisations; however, teachers did discuss them in general terms. Teachers discussed "try and see" strategies such as promoting positive student discourse through the use of the "conversation helpers" handout. They also described "wait and see" strategies when they didn't know how to respond or how to integrate a student's response into the conversation. Teachers reported the phase, "tell me more" to be a useful way to buy themselves thinking time to decide what to do with an idea. This strategy "makes space" for an individual student to further discuss their idea, thereby legitimizing the students' contribution to classroom discussion.

One purpose of "making space" in sensemaking is to shift epistemic agency from the teacher to the students (Haverly et al., 2020). When such shifts happen, either students construct their own scientific knowledge, or it is co-constructed between the students and the teacher. Elizabeth alluded to the co-construction of knowledge through her initial description of sensemaking. She concluded with the line, "We need all pieces of information we can gather so we can see what pieces we are missing or are fuzzy on that we need to know," legitimizing "all pieces of information" and positioning herself as part of the collective group of sensemakers, rather than as the scientific authority. Elizabeth noted the effects of this shift in describing how classroom discussions changed after she and students had worked through several storylines. She was noticing that more students were sharing their developing thoughts in discussion and that more students were recognizing others' ideas as valid resources. In her final interview, Marie also described "making space" through her Venus Fly Trap example. She altered the course of her developing storyline to incorporate a debate inspired by students' question regarding the categorization of a Venus Fly Trap as a consumer or producer. By doing so, the student and his peers were given the opportunity to grapple with scientific categorization in ways that built upon the student's everyday knowledge and sense of wonder.

However, there is a difference between considering students' equitable engagement in sensemaking and considering students engagement in equitable sensemaking. Haverly et al. (2020) define equitable sensemaking as "classroom interactions – typically grounded in an epistemic stance privileging particular ways of knowing and talking – expand, thereby shifting historicized relations of power and position. … [It] leverages students' ideas, experiences and cultural resources while disrupting power structures" (p.63). They note that there are ways for students to contribute to classroom conversations that do not result in a shift epistemic agency from the teacher to the students.

While equitable engagement considers making sure all students get to participate in scientific sensemaking, engagement in equitable sensemaking considers whose sense matters and what goal sensemaking is serving. The National Academies' (2016) report on science literacy claimed that the communities most in need of a collective sense of science literacy are often those who have been denied access and the types of education needed to develop communities' collective science literacy. Brown's (2005) study of high school science students of color indicated that students perceived the science classroom discourse as divergent from their everyday experiences and language. By overlooking the impact of students' community cultural wealth (Yosso, 2005) on their individual and social sensemaking processes, teachers may be reconstructing the same systems of power they aim to disrupt by considering equity.

Largely absent from book study discussions was the role of students' identities in sensemaking. In her initial interview, Marie questioned the goal of science education being to produce future scientists. She and others defined the goal of science education as informing individual students' future decision-making and thinking around scientific issues. Yet, their conversations often framed students as a collective. In doing so, they may have neglected the diverse funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) individual students and groups of students might access when engaging in sensemaking. While the anchoring event of the multiracial twins begged a brief exchange regarding race as an uncomfortable topic to breach in a Marksboro Middle School classroom, race, ethnicity, and gender were conspicuously absent from teachers' discussions. Linguistic diversity and (dis)ability were referred to occasionally, albeit as deficiencies to be remediated. Statements such as "this will help our ELL's" or "this would be good for our struggling students" uttered throughout book discussions labeled diverse groups as homogenous and in need of the same supports.

The lack of attention to considerations of equity similarly pervaded the workshop series on literacy across the disciplines. While Rachel and I had initially intended to incorporate Moje's (2015) four E's heuristic as a critical component of disciplinary literacy, we fell short. During the first workshop, we were able to create collaborative learning experiences around the first two E's – engaging in disciplinary practices and engineering opportunities for literacy, but were not able to incorporate the third and fourth E's – examining the language of the discipline and evaluating when to (not) use disciplinary language. In part, this was a result of time limitations. However, it was also largely due to our own ideas that disciplinary teachers might not be "ready" for such conversations around language. This fear was built upon the assumption that incorporating disciplinary practices in the ways intended by the state science standards was a large paradigm shift for science teachers. As with teachers' discussions, our decisions may have been short sighted and may have worked to further reify the dominance of disciplinary discourses over everyday social and cultural discourses.

The superficiality of educators' considerations of equity in this study may demonstrate the same concerns regarding power, equity and diversity in science education raised by Rodriguez (2015), Morales-Doyle, Price, and Chappell (2019), and others. All participants were "well intentioned white people" (Applebaum, 2010), and "good girls" (Mattsson, 2015) who wanted to do right by students. In many ways, teachers' enthusiastic efforts to reinvent their teaching did create opportunities for students draw upon their knowledge, experiences, repertoire of cultural and developing disciplinary practices. Teachers discussed how to position students' ideas and misconceptions as class resources akin to the recommendations offered by Campbell, Schwarz, and Windschitl (2016). However, when the dominant stances remain unquestioned and uncomplicated, they are reified and maintained (Baker-Bell, Butler & Johnson, 2017).

However, the educators in this study are not solely at fault for the lack of attention to equitable sensemaking. Calabrese-Barton and Tan (2019) noted that systemic injustices play out in local activities. Marksboro teachers were reaching out for tools and resources to shape and support their pedagogical shifts. Yet, many of the tools available to them perpetuated the unquestioned dominance of the epistemic practices of science and color-blind science teaching. The new standards incorporated eight science and engineering practices. However, as noted in chapter two, the majority of "expert" participants in studies of scientists' literacy practices have been white male professors at research institutions. While working to enculture students into epistemic disciplinary practices, the National Research Council's *Framework* (2012) and associated standards may ignore the practices diverse groups use to make sense of science beyond the academe. As noted by Rodriguez (2015), this may be due in part to the lack of diverse representation on the committees that drafted both the *Framework* and the NGSS standards. This may have been further exacerbated by the absence of an equivalency to the NGSS equity and diversity appendix in the New York State Science Learning Standards.

The currently available storylines and instructional resources teachers accessed also failed to support their consideration of sensemaking in service to pressing socio-scientific issues in non-dominant communities. While the genetics storyline began with observations and questions regarding multi-racial twins, the resulting storyline missed opportunities to consider the genetics of race. Such inclusion could have challenged racism and helped students build inclusive worldviews within and beyond science. Similarly, the antibiotic resistance unit could have taken up considerations of inequity in the American healthcare system. Patients without access to adequate medical coverage may stop taking antibiotics before their prescription runs because they are feeling better and save the remaining doses to self-treat a future infection.

While such a practice may work for the individual in the short term, it may contribute to the development of antibiotic-resistant strains whose treatment may require even more expensive specialty antibiotics down the line. By not incorporating social justice implications and applications of science knowledge and scientific sensemaking, storyline developers and science teachers run the risk of continuing to deny marginalized communities and their members access to the scientific literacy which could empower them as change agents.

Consider the recent film, *Dark Waters,* based on Robert Bilott's cases against industry giant, DuPont (Ruffalo, Vachon, Koffler, & Haynes, 2019). A farmer, Wilbur Tennant, built knowledge of a social justice science issue (Morales-Doyle, 2017) through his knowledge of his land and cattle. As evidence, he filmed incidents of his cows behaving irregularly, froze abnormal bovine anatomy obtained through his own "autopsies", and encouraged Billot to take a look with his own eyes, rather than relying on scientific environmental impact reports. While Tennant had correctly deduced that DuPont was poisoning the local waters, the farmer's knowledge had been dismissed as "crazy" by those in power. In the film, even as Billot thought he was helping, Tennant noted, "You're one of them," meaning the lawyer was part of the dominant, privileged class still dismissing the legitimacy of the farmer's knowledge. Where in the standards is the space for this farmer's legitimate sensemaking practices? Where are published storylines that take up issues such as environmental racism and classism? How does a lack of consideration of these absences implicate well-meaning White female teachers as "one of them"?

If available tools and resources do not adequately consider diverse ways of knowing, teachers must create them for themselves. Lee, Goggins, Haas, Janusyk, Llosa, & Grapin (2019) discuss making everyday local phenomena phenomenal, meaning that they draw students into science learning and provide multiple in-roads via which students may be able to draw upon their own experiences. By building a sensemaking opportunity around an issue of local concern, Elizabeth and Marie began to build a bridge between community knowledge and disciplinary expertise through their incorporation of data regarding a local overpopulation of deer. However, Calabrese-Barton and Tan (2019) note that more than a bridge is required in order for those who have been "missing" (Tedesco & Bagelman, 2017) from scientific spaces to be welcomed as legitimate members of the community of practice. These bridges must be used to create "more expansive opportunities to learn and to become in ways that matter across scales of activity. In this way, youths' criticality speaks back against accounts that frame their lives and communities in deficit ways" (624). The number of deer in the area is not a concern which "makes present" (Calabrese-Barton & Tan, 2019) the concerns of Marksboro's non-dominant communities.

Moje (2015) noted that scholars who had taken up her (2008) notions of disciplinary literacy had, by and large, not attended to the critical implications of the construct. Through the third and fourth E's in her four E's heuristic, Moje illustrated how teachers could teach students to examine disciplinary language and evaluate when it served (or did not serve) their communicative purposes. Lizárraga and Gutiérrez (2018) argue for a syncretic approach to literacy, one that respects and integrates the entirety of individuals' linguistic and sociocultural repertoires (Gutiérrez & Rogoff, 2003). If using such an approach, teachers should "identify moments where hierarchy can be flattened and expertise redistributed" (Lizárraga & Gutiérrez, 2018, p.45). Students should be engaged in a "playful pushing of boundaries of identity and experience that expand who they are as makers of literacy," (p.40) and I would argue as makers of sense. While disciplinary literacy has invited students to play with disciplinary "identity kits" (Gee, 1989), it has not considered how other "identity kits" may be useful in developing teachers' and students' expansive learning in the disciplines or in equitable transformations of the disciplines. Rachel noted in her initial interview that she felt the move toward sensemaking aligned with how young children wonder about and investigate the world. By considering equity as an orientation to literacy in science, literacy and science scholars and educators could meaningfully expand students' engagement in sensemaking|literacy.

I would like to end this discussion on a note of hope. Gutiérrez (2012) described consequential learning as involving considerations of what counts as expertise and imagining new social futures. The deer activity as well as teachers' attention to equitable engagement in sensemaking and their overarching goal to consider equity as a component of sensemaking-oriented instruction indicates that Marksboro teachers have the capacity to consider and integrate bridges between science and the community into their development of storylines. Windschitl, Thompson, Braaten, and Stroupe (2012) studied a group of novice teachers' development of ambitious teaching through tool use. They found that the core practices operationalized through physical planning tools did not directly mediate teachers' practice. Rather, it was through the body of resources developed by the community of practice and through interactions between members of the community of practice with the support of knowledgeable others that teaching practices were refined. Even though the Marksboro science teacher community of practice is far from "novice" in terms of their teaching experience, they are novices to sensemaking-oriented science instruction. As Engeström (2001) noted, learning in activity systems is expansive, with internalization often occurring before externalization. As this study examined teachers' early attempts to collectively explore sensemaking-oriented science instruction, internalization is an expected result, externalization may come later. Teachers refined teaching strategies and tools – both those available to them and those they created – in order to support students' equitable engagement in sensemaking. These efforts resulted in initial attempts to support students' engagement in equitable sensemaking through considering local connections. As Marksboro teachers continue to examine and refine their teaching practices through future iterations of their current storylines and of their conversations around *Ambitious Science Teaching*, perhaps mentions of "who's not talking" may turn into a closer examination of how to "make present" and "make space for" non-dominant ways of knowing science (Calabrese-Barton & Tan, 2019; Haverly et al., 2020) and for justice-centered science pedagogy (Morales-Doyle, 2017).

Limitations

The tools used in CHAT analyses such as triangle diagrams, tensions, actions, and operations are useful in describing some of the complexity in educational systems. Yet, the complexity of reality is often far greater than what can be captured and analyzed, even with tools designed for that purpose (Yamagata-Lynch, 2007, 2010). While teacher learning is a social act, it is also an individual one. As the focal unit of analysis is the activity system, CHAT analyses are limited in how they may address agentive domains of the individual (Roth, 2009). Factors such as an individual educators' emotions, motivations, and considerations of equity not captured in this study's data likely impact how they interact with new learning in professional development settings. Additionally, this study examined the activity system of one localized case, which limits the generalizability of findings. The participants in this study could be described as fairly homogenous in their identities as ten white women and one white man. Additionally, though the students in participating teachers' classes do come from a variety of backgrounds, their collective demographics do not reflect those of the broader US middle school context, in that few are multi-lingual students and/or identify with non-dominant racial and ethnic communities. However, as is characteristic of naturalistic inquiry (Lincoln & Guba, 1985, 1989), this study aimed to provide a rich, contextualized description of the focal activity systems and therefore a localized "truth" which may be transferable to similar contexts, rather than generalizable. In terms of their attention to shifting standards, curricula and pedagogy, the activity of Marksboro science teachers' community of practice represents an ideal which may be useful to consider when beginning to work with science teachers in other contexts.

Nevertheless, this study has several limitations. Teachers in this study had access to an extensive array of professional development opportunities which may not be available to their counterparts in other settings. While their engagement in professional development opportunities beyond the scope of this study certainly contributed to their developing understandings regarding teaching aligned to the *Framework* (NRC, 2012) and NYSSLS (New York State Education Department, 2016), it may have complicated my description of their book discussion activity system, as it was often unclear where ideas came from which were not directly from the focal text. My description of their activity system is also incomplete, as I was not present for the first three discussions. In these early chapters, Windschitl, Thompson, and Braaten (2018) do directly discuss equity as well as providing advice around the early phases of planning sensemaking-oriented science instruction. The scope of my study was also limited to educators' discussions and engagement in professional development. My descriptions of their evolving storylines and use of strategies from *Ambitious Science Teaching* (Windschitl, Thompson, and Braaten, 2018) are limited to their speculative and reflective conversations. If I had had access to teachers' instructional plans or classrooms, I may have been able to get a sense of what it meant to "do the spiny mouse" as well as how students engaged in scientific sensemaking.

Significance and Implications for Future Research

This study is significant because it connected divergent lines of research exploring teaching for scientific sensemaking and incorporating literacy into science instruction. Literacy researchers and science education researchers have explored literacy and sensemaking in science classrooms separately. Limited work, which is outlined in Chapter Two, has connected these two constructs. This study built upon literature in both fields to position literacy and scientific sensemaking as overlapping constructs with shared instructional implications. Additionally, it described the work of an activity system consisting of educators with backgrounds in both fields. In exploring this collaboration, this study provided insight regarding how sensemaking and literacy may operate as a dialectical entity as well as how issues of equity and social justice pervade the teaching of both constructs. Thus, findings may have implications for educators, professional development providers, and researchers involved in creating and implementing scientific phenomena-based curricula with sensemaking goals.

This study is significant to the growing body of literature regarding scientific sensemaking. While scientific sensemaking has been positioned at the goal of *Framework*-aligned science teaching (National Research Council, 2012), little work has explored how practicing educators conceptualize the term and operationalize it within their teaching. Additionally, while several studies have explored how sensemaking may arise from students' development of explanations or arguments, less work has explored how it may arise from a concerted integration of a number of scientific practices. This study demonstrates how one group of teachers considered sensemaking when adapting published science teaching resources for local use. Future work in scientific sensemaking should consider how teachers "make space" for diverse sensemaking repertoires as well as the development of storylines centered around social justice science issues, rather than the explanation of natural phenomena.

This study is also significant to the growing body of literature regarding literacy across the disciplines. It drew upon Moje's (2015) model for developing literacy in science by focusing on the practices of the discipline. Through its discussion of literacy within activity conducted by a science teacher community of practice, it provided insight into the development of content-area teachers' understanding and use of literacy in ways that address the unique discourses of the disciplines. Thus, findings may have implications for literacy coaches, professional development providers, and researchers interested in improving literacy teaching within the disciplines. Future work in disciplinary literacies should consider how attention to literacy serves content-learning purposes, such as scientific sensemaking, as well as how it can be used to examine the roles of power, equity, and diversity within disciplinary learning.

This study is significant for those who wish to consider the intersection between science education and literacy education fields. It found that educators' understanding varied and that participants cited different activity system elements as mediators of their developing understanding. Parallel descriptions of sensemaking and literacy indicate that the two constructs may represent an action|operation dialectical entity, thereby hybridizing the fields. By examining the sensemaking|literacy as a dialectic, this study found that efforts to consider literacy in science could benefit from positioning it as an operational component of sensemaking as well as from considerations of equity. Future work into sensemaking|literacy may benefit from using Actor Network Theory (Latour, 2008) as a theoretical framework and from using professional development models such as lesson study (Lewis & Tsuchida, 1999) which facilitate deliberate consideration of instructional moves which may have become routinized.

This study provided insight into the ways in which a local context mattered in how educators developed understanding around scientific sensemaking and literacy across professional development activities. This description may be useful for others seeking to work with teachers' around scientific sensemaking and literacy. The tensions regarding equity which arose within the book discussion activity system are likely to provide insight regarding more generalized tensions within the field. Professional developers who work with local communities should help teachers identify social justice science issues and assist in the creation of justice-oriented storylines which promote both equitable engagement and engagement in equitable sensemaking.

This study has implications for literacy professionals working with science teachers. This study indicates that middle school science teachers may incorporate attention to literacy more frequently than was determined by the Banilower et al. (2019) study. Literacy professionals would do well to consider the ways literacy operates within the discipline and within science classrooms and attend to the ways in which science teachers operationalize literacy when discussing the sensemaking processes of their disciplines. This study suggests that one way to accomplish this might be through a scientific sensemaking stance. Rather than promote adapting content area literacy strategies which science teachers may see as serving a purpose other than developing scientific thinking, literacy professionals should first take stock of the learning goals and epistemologies of a discipline, as well as strategies science teachers are already using to help students make and track sense. Then, literacy professionals and disciplinary teachers should collaboratively consider how literacy can be strategically deployed as a specialized tool for accomplishing disciplinary goals, rather than considering a disciplinary classroom as a good place for the infusion of a broad array of literacy activities and strategies. Additionally, literacy professionals should consider how to support disciplinary teachers as they work to implement justice-centered pedagogies (Morales-Doyle, 2017)

Future studies emanating from either the literacy or science field should adopt a hybridizing approach (Hinchman & O'Brien, 2019) to (re)unify the discipline of science with its linguistic practices. Such studies may rely upon collaboration between science and literacy researchers so that the histories and cultures of each field can be taken into account. They may also involve science teachers and literacy professionals exploring how knowledge of one another's domains may help them to adopt syncretic approaches (Lizárraga & Gutiérrez, 2018) in their own disciplines. Studies like this one should be conducted in a variety of school contexts and with participants from diverse cultural identities to explore more generally how teachers describe the resources students use for sensemaking|literacy.

Future observational studies should also be conducted in science classroom spaces where students are actively engaged in scientific sensemaking. Such studies can determine the validity of the sensemaking|literacy construct through an exploration the ways teachers and students draw upon students' linguistic and sociocultural resources. These studies should be conducted in a variety of classroom contexts in order to capture the widest array of diverse resources students may bring to the activity.

Future studies of sensemaking|literacy must examine the ways in which Whiteness and other dominant identities reify the systems of power that simultaneously mandate and threaten equity-oriented stances toward teaching. This includes exploring the sensemaking|literacy practices of experts beyond the academe, and subsequently, how teachers can playfully engage students in trying on such identities in order to build an expansive understanding of science (Engeström, 2001; Lizárraga & Gutiérrez, 2018).

Lastly, additional studies like each of those noted above should be conducted to examine hybridizing disciplinary literacy in additional subject areas. While sensemaking is a term used in science education, it is possible that its use may not make sense in other disciplinary spaces. In each discipline, researchers and literacy professionals working with disciplinary teachers should work to uncover and adopt the language used by disciplinary insiders, rather than adopting the language of literacy which could foreign to the nature and activity of the discipline.

Conclusion

The purpose of this study was to examine educators' descriptions of scientific sensemaking and literacy as well as to describe how elements of the teachers' activity system mediated their developing descriptions. It used CHAT both as a theoretical framework and analysis scheme. It found that educators' descriptions varied, yet this variation mirrored variation seen in the literature from both fields. It found that participants found varying arrays of activity system elements influential to their developing descriptions. Through considerations of the cultural and historical components of CHAT, this study uncovered tension between educators' goal to consider equity and the outcomes of their activity. This study is significant in that it informs future work aiming to take an equitable hybridized stance toward the role of literacy in science, and in the disciplines more broadly.

Appendix A: Research Reading Graphic Organizer Used in Workshop One

As you read each paragraph, fill in a row of the following chart:

Important words or phrases	What's this paragraph saying? (Summarize in 1-2 sentences max)	What does it make me think or wonder about how or why people get sick?

Appendix B: Semi-structured Interview Protocols

Initial Interview

Demographic Questions

- What is your current position?
- Have you held other positions? If so, what?
- What certifications do you hold?
- How many years have you been teaching?
- What is your age?
- What is your gender?
- What is your race and ethnicity?

For teachers - Why are you participating in this professional development workshop series which will focus on literacy in middle school science instruction?

Depending on responses, I will follow up with prompts into the following areas:

- Goals of middle school science education
- Understanding of New York State Science Standards (2016 version)
  - Comparison to previous versions
- Scientific sensemaking
- Literacy in science learning
  - Definition and role of text

For professional developers – What do you hope teachers take away from this professional development workshop series which will focus on literacy in middle school science instruction?

Depending on responses, I will follow up with prompts into the following areas:

- Goals of middle school science education

- Understanding of New York State Science Standards (2016 version)
    - Comparison to previous versions
- Scientific sensemaking
- Literacy in science learning
    - Definition and role of text

For professional developers – What do you hope to take away from your experience facilitating this professional development?

General follow-up prompts which will be used to elicit more detailed responses:

- Why do you say that?
- How did you come to understand that?
- How can middle school teachers accomplish/address/develop _______?
- What might that look like in a middle school science classroom?
- What might be the benefits of teaching _______?
- Do you see any barriers or challenges in teaching ________?
- For professional developers – How might you facilitate middle school teachers' developing and understanding of ______?

Final Interview

We’ve just concluded a workshop series which focused on literacy in middle school science instruction. Can you tell me about your experience in that workshop series?

Depending on responses, I will follow up with prompts into the following areas:

- “Take-aways” from the workshop series
- For professional developers – perception of teacher’s “Take-aways”
- Collaboration with literacy-focused peers
- Goals of middle school science instruction
- Understanding of New York State Science Standards (2016 version)
    - Comparison to previous versions
- Scientific sensemaking
- Literacy in science learning
    - Definition and role of text

Professional Development Activity System Questions:

What is your overall goal when engaging in professional development?

Have you faced any barriers or hurdles you have come across when trying to achieve this goal?

What resources have been helpful in working towards that goal?

Who and what places, organizations make up your support community as you work toward that goal?

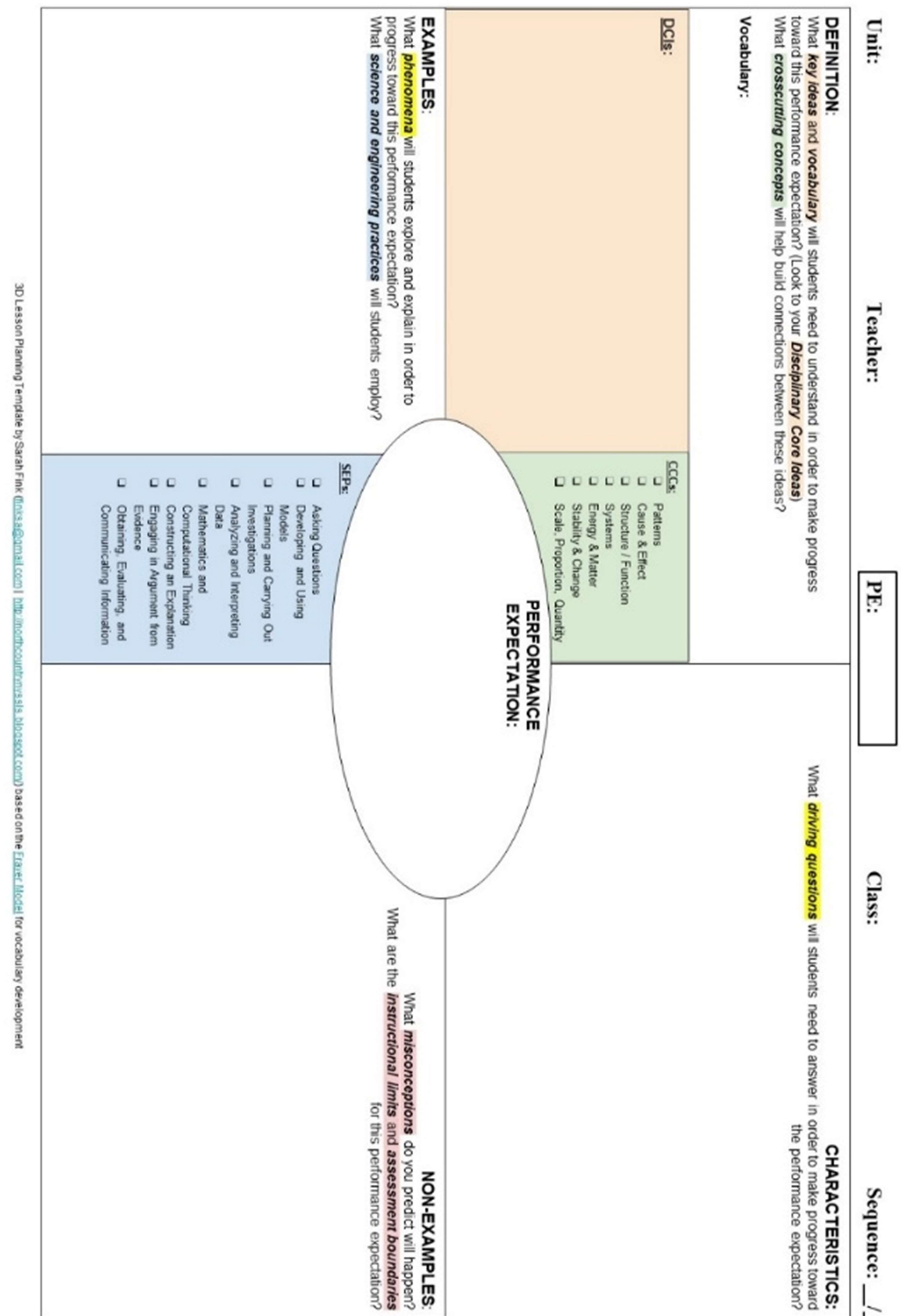
How many hours of professional development would you estimate you have attended this year?

General follow-up prompts which will be used to elicit more detailed responses:

- Why do you say that?

- How did you come to understand that?
- How can middle school teachers accomplish/address/develop _______?
- What might that look like in a middle school science classroom?
- What might be the benefits of teaching _______?
- Do you see any barriers or challenges in teaching ________?
- For teachers -What suggestions do you have for future professional development offerings?

Appendix C: Planning Tool Introduced by Irene



Appendix D: New York State Science Learning Standards Example

New York State P-12 Science Learning Standards

MS. Structure and Properties of Matter

Students who demonstrate understanding can:

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of particulate-level models could include drawings, 3D ball and stick structures, or computer representations showing different substances with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the individual ions composing complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to the qualitative interpretation of evidence provided.]

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and phase (state) of a substance when thermal energy is added or removed. [Clarification Statement: Emphasis is on qualitative particulate-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of phase occurs. Examples of models could include drawings and diagrams. Examples of particles could include ions, molecules, or atoms. Examples of substances could include sodium chloride, water, carbon dioxide, and helium.]

MS-PS1-7. Use evidence to illustrate that density is a property that can be used to identify samples of matter. [Clarification Statement: Emphasis should be on students measuring the masses and volumes of regular and irregular shaped objects, calculating their densities, and identifying the samples of matter.]

MS-PS1-8. Plan and conduct an investigation to demonstrate that mixtures are combinations of substances. [Clarification Statement: Emphasis should be on analyzing the physical changes that occur as mixtures are formed and/or separated. Examples of common mixtures could include salt water, oil and vinegar, and air.] [Assessment boundary: Assessment is limited to separation by evaporation, filtration and magnetism.]

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

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to predict and/or describe phenomena. (MS-PS1-1),(MS-PS1-4)

Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS1-8)
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. (MS-PS1-8)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-PS1-7)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 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. (MS-PS1-3)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- (NYSED) Substances are made of one type of atom or combinations of different types of atoms. Individual atoms are particles and can combine to form larger particles that range in size from two to thousands of atoms. (MS-PS1-1)
- (NYSED) Each substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3),(MS-PS1-7) (Note: This Disciplinary Core Idea is also addressed by MS-PS1-2.)
- (NYSED) In a solid, the particles are closely spaced and vibrate in position but do not change their relative locations. In a liquid, the particles are closely spaced but are able to change their relative locations. In a gas, the particles are widely spaced except when they happen to collide and constantly change their relative locations. (MS-PS1-4)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)
- (NYSED) The changes of state that occur with variations in temperature and/or pressure can be described and predicted using these models of matter. (MS-PS1-4)
- (NYSED) Mixtures are physical combinations of one or more samples of matter and can be separated by physical means. (MS-PS1-8)

PS1.B: Chemical Reactions
- (NYSED) Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different particles, and these new substances have different properties from those of the reactants. (MS-PS1-3) (Note: This Disciplinary Core Idea is also addressed by MS-PS1-2 and MS-PS1-5.)

PS3.A: Definitions of Energy
- (NYSED) The term "heat" as used in everyday language refers both to thermal energy (the motion of particles within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4)
- (NYSED) Temperature is not a form of energy. Temperature is a measurement of the average kinetic energy of the particles in a sample of matter. (secondary to MS-PS1-4)

Crosscutting Concepts

Patterns
- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-1),(MS-PS1-7),(MS-PS1-8)
- Graphs, charts, and images can be used to identify patterns in data. (MS-PS1-1),(MS- PS1-4)

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Structure and Function
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)

Influence of Science, Engineering and Technology on Society and the Natural World
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3)

Connections to other DCIs in this grade-band: **MS.LS2.A** (MS-PS1-3); **MS.LS4.D** (MS-PS1-3); **MS.ESS2.C** (MS-PS1-1),(MS-PS1-4); **MS.ESS3.A** (MS-PS1-3); **MS.ESS3.C**

Articulation of DCIs across grade-bands: **5.PS1.A** (MS-PS1-1); **HS.PS1.A** (MS-PS1-1),(MS-PS1-3),(MS-PS1-4); **HS.PS1.B** (MS-PS1-4); **HS.PS3.A** (MS-PS1-4); **HS.LS2.A** (MS-PS1-3); **HS.LS4.D** (MS-PS1-3); **HS.ESS1.A** (MS-PS1-1); **HS.ESS3.A** (MS-PS1-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The text in the "Disciplinary Core Ideas" section is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas unless it is preceded by (NYSED).

New York State P-12 Science Learning Standards

New York State Next Generation Learning Standards Connections:

ELA/Literacy –

6-8RST1	Cite specific textual evidence to support analysis of science and technical texts, charts, graphs, diagrams, etc. Understand and follow a detailed set of directions. (MS-PS1-3)
6-8RST7	Identify and match scientific or technical information presented as text with a version of that information presented visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-1),(MS-PS1-4)
6-8WHST.8	Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source by applying discipline specific criteria used in the social sciences or sciences; and quote or paraphrase the data/accounts and conclusions of others while avoiding plagiarism and following a standard format for citation or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-PS1-3), (MS-PS1-7)

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-PS1-1), (MS-PS1-8)
MP.4	Model with mathematics. (MS-PS1-1)
NY-6.RP.4	Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-1),(MS-PS1-7)
NY-6.NS.5	Understand that positive and negative numbers are used together to describe quantities having opposite directions or values. Use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS1-4)
NY-8.EE.3	Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. (MS-PS1-1)

*Connection boxes updated as of September 2018

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea. The text in the "Disciplinary Core Ideas" section is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas unless it is preceded by (NYSED).

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Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 95*(5), 818-903.

Wright, K. L., Franks, A. D., Kuo, L., McTigue, E. M., & Serrano, J. (2016). Both theory and practice: Science literacy instruction and theories of reading. *International Journal of Science and Mathematics Education, 14*, 1275-1292.

Wright, T. S., & Gotwals, A. W. (2017). Supporting disciplinary talk from the start: Teaching students to think and talk like scientists. *The Reading Teacher, 71*(2), 189-197.

Yamagata-Lynch, L. C. (2010). *Activity Systems Analysis Methods: Understanding Complex Learning Environments*. New York, NY: Springer.

Yamagata-Lynch, L. C. (2007). Confronting analytical dilemmas for understanding complex human interactions in design-based research from a cultural-historical activity (CHAT) framework. *Journal of the Learning Sciences, 16*(4), 451-484.

Yendol-Hoppey, D., Dana, N. F. & Hirsch, S. (2010). *Powerful professional development: Building expertise within the four walls of your school*. Thousand Oaks, CA: Corwin.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education, 8*(1), 69-91.

Zangori, L. & Forbes, C. T. (2016). Development of an empirically based learning performances framework for third-grade students' model-based explanations about plant processes. *Science Education, 100,* 961-982.

Heather Waymouth

Academic Specializations

Disciplinary Literacy
Literacy Interventions

Education

Ph. D. Literacy Education, Syracuse University Exp. May 2020
Committee Chair: Dr. Kathleen Hinchman
Dissertation Title*:* Middle School Educators' Understanding of Scientific Sensemaking and Literacy Through Collaborative Professional Development: A Cultural-Historical Activity Theory Analysis

M. S. Adolescent Literacy Education, Syracuse University 2008

B. S. Childhood Education, SUNY Geneseo, 2nd Major: Biology 2006

Teaching Certifications

Grades 5-12 Literacy Specialist, New York State Professional Certification
Grades 5-12 Biology, New York State Professional Certification and Extension
Grades 5-12 General Science, New York State Professional Certification and Extension
Grades 1-6 Childhood Education, New York State Professional Certification

Post-secondary Teaching Experience

Graduate Teaching Experience

Literacy Across the Curriculum Instructor, Syracuse University Sum. 2019
Literacy Clinic instructor/field supervisor, Syracuse University Sum. 2016-2018
co-instructor sum. 2016-2017
Teaching Mentor, Graduate School, Syracuse University 2016-2019

Undergraduate Teaching Experience

Literacy Across the Curriculum Instructor, Syracuse University Sp. 2017-2020
Undergraduate Biology Lab Instructor, SUNY Geneseo Fa.2005/Sp.2006

K-12 Experience

Classroom Teaching and Supervision

Field placement supervisor, Syracuse University 2015-2019
Literacy Across the Curriculum – 6th-8th grades, Syracuse CSD, NY
Literacy Clinic – 5th-8th grades, Solvay UFSD, NY
High School Literacy Specialist, Honeoye Falls – Lima CSD, NY 2008-2015
8th School Summer School Teacher, Watertown CSD, NY 2009
2nd Grade Long Term Substitute Teacher, Liverpool CSD, NY 2008
3rd grade Math Intervention Temporary Teacher, Mason City Schools, OH 2007

Extracurricular K-12 Experience

Tutor, ages 12-18, Rochester Area, NY 2010-2017
In Reading, Executive Functioning, SAT/ACT prep, College applications prep, Global History, AP Literature & Language, and Chemistry
Venture Crew Advisor, ages 14-21, Crew 10, Honeoye Falls, NY 2009-2015
Youth-run Business Consultant, ages 14-21, 3 of Hearts LLC, Mendon, NY 2009-2013
Assistant JV/Varsity Swimming/Diving Coach, ages 13-18, Honeoye Falls – Lima, NY 2009-2015
Assistant Age Group coach, ages 5-14, Mason Manta Rays, Mason, OH 2007
Head Summer Swim Coach, ages 5-18, Wyoming Swordfish, Wyoming, OH 2006
Summer Swim Coach, ages 5-18, Montgomery Makos, Montgomery, OH 2004, 2005
Head Coach 2005

Service

National Service

Journal of Language and Literacy Education Peer Reviewer 2019-present
Literacy Research Association, Conference Proposal Peer Reviewer 2019
Literacy Research: Theory, Method and Practice, Peer Reviewer 2018
Journal of Adolescent and Adult Literacy, Peer Reviewer 2016-present

Regional Service

Central New York Reading Council, President 2018-present
NYSRA Membership Excellence Award, 2019
ILA Honor Council Award, 2018
Central New York Reading Council, Membership Chair 2017-2018
ILA Honor Council Award, 2017

University Service

International TA Language Assessment Review Committee, Syracuse University 2018-2019
School of Education Graduate Council, Recorder, Syracuse University 2018-2019
School of Education International Student Mentor, Syracuse University 2018-present
Teaching Mentor Selection Committee, Syracuse University 2018, 2019
Meredith Professor Selection Committee, Syracuse University 2017
Mix it Up! Facilitator, Slutzker Center for International Students, Syracuse University 2016-2018
School of Education Assembly, Student Representative, Syracuse University 2016-2017

School District Service

Co - High School Special Education Curriculum Articulation Resource Educator, Honeoye Falls – Lima 2013-2015
Professional Development Planning Committee Member, Honeoye Falls – Lima 2012-2015
Co – High School Instructional Support Team Facilitator, Honeoye Falls – Lima 2011-2015
Literacy Leadership Team Member, Honeoye Falls- Lima 2011-2013
High School Improvement Team Member, Honeoye Falls – Lima 2010-2012

Memberships in Professional Organizations

American Education Research Association
Literacy Research Association
International Literacy Association
New York State Reading Association

Central New York Reading Council
The Reading League

Honors and Awards

New York State Reading Association Senator Donovan Memorial Scholarship, $500	2019
Outstanding Teaching Assistant Award, Syracuse University	2019
School of Education Research and Creative Grant, Syracuse University, $1000	2019
Certificate in University Teaching, Syracuse University	2018
Graduate Student Organization Travel Grant, Syracuse University, $250	2018
School of Education Travel Grant, Syracuse University, $400	2017,2018
Phi Beta Delta International Honors Society, Syracuse University	2017
William D. Sheldon Fellowship, Reading and Language Arts, Syracuse University, $3000	2016
Asset Builder Award, Youth Bureau, Monroe County, NY	2011
Diversity Award, Honeoye Falls – Lima CSD, NY	2010
Jennifer Guyer Divico Award, Swimming and Diving Team, SUNY Geneseo	2006
Beta Beta Beta Biology Honors Society, SUNY Geneseo	2004
Golden Key Honors Society, SUNY Geneseo	2004
Phi Eta Sigma Honors Society, SUNY Geneseo	2003

Publications and Presentations

Academic Publications

1. **Waymouth, H.** (2018) Transforming teaching and learning: No more telling as teaching: A book review. *Journal of Adolescent and Adult Literacy, 62*(3), 352-354.
2. Newvine, K., **Waymouth, H.,** & Hinchman, K. A. (2018). Critical experiences with assets-based literacy intervention: A social design experiment. In K. Zenkov & K. Pytash (eds.) *Clinical Experiences in Teacher Preparation: Critical, Project-based Interventions in Diverse Classrooms.* New York, NY: Routledge.
3. Jang, B. G., Henretty, D., & **Waymouth, H.** (2018). A pentagonal pyramid model for multifaceted differentiation in disciplinary literacy instruction. *Journal of Adolescent and Adult Literacy 62*(1), 45-53.
4. Chandler-Olcott, K., Dotger, S., **Waymouth, H.**, Crosby, M., Lahr, M., Hinchman, K. Newvine, K., & Nieroda, J. (2018). Teacher Candidates Learn to Enact Curriculum in a Partnership-Sponsored Literacy Enrichment Program for Youth, *The New Educator, 14*(3), 192-211.

Academic Conference Presentations

1. **Waymouth, H.** & Busa, H. (December, 2019). *Seeing sensemaking as literacy through collaborative professional development.* Refereed paper session at the annual Literacy Research Association Conference. Tampa, FL.
2. Zeneli, A. & **Waymouth, H.** (December, 2019). *Kosovan youths' critical engagement: A think-aloud study*. Refereed roundtable session at the annual Literacy Research Association Conference, Tampa, FL.
3. **Waymouth, H.,** Hinchman, K., Newvine, K. (2018, November). *Preservice literacy specialists understanding of assets-based literacy intervention*. Refereed paper session at the annual Literacy Research Association conference, Indian Wells, CA.
4. Zenkov, K. et al. (2018, November). *Critical, project-based clinical experiences in literacy.* Refereed alternative format session at the annual Literacy Research Association conference, Indian Wells, CA.
5. Zeneli, A. & **Waymouth, H.** (2018, December). *Kosovan youths' critical engagement with culturally traditional texts.* Refereed poster session at the annual Literacy Research Association conference, Indian Wells, CA.
6. Chandler-Olcott, K., Dotger, S., **Waymouth, H.**, Hinchman, K.A., & Newvine, K. (2017,

December). *Learning to teach literacy through Japanese lesson study in a university-school partnership.* Refereed paper session at the annual Literacy Research Association conference, Tampa, FL.

7. Hinchman, K.A., **Waymouth, H.**, & Newvine, K. (2017, November). *Assets-Based Literacy Intervention: Design, Implementation, Preliminary Results*. Feature session at the annual York State Reading Association Conference, Saratoga Springs, NY.
8. **Waymouth, H.** (2017, October). *Enriching literacy instruction with morphology.* Refereed presentation at the annual conference of the Reading League, Cazenovia, NY.

Professional Development Offerings and Invited Presentations

1. **Waymouth, H.,** Smith, P., & Wright, T. (2019, August). *Universal Design for Learning.* Mandatory session at Syracuse University TA Orientation Program, Syracuse, NY.
2. **Waymouth, H.** & Aksoy, S. (2019, May). *Seeing the Social in the Sciences.* Concurrent session, Syracuse University Future Professoriate Program Conference, Hamilton, NY.
3. **Waymouth, H.** (2019, April). *Teachers as Engineers: New Designs for Old Materials.* Professional Development session, Honeoye Falls – Lima Middle School, Honeoye Falls, NY.
4. **Waymouth, H.** (2019, March). *Questioning Is the Answer.* TA Professional development session for the Graduate School, Syracuse University, Syracuse, NY.
5. **Waymouth, H.** (2019, January). *Academic Language for Music Student Teachers.* Guest Lecture, Syracuse University, Syracuse, NY.
6. **Waymouth, H.,** McWhorter, C., Aksoy, S., & Cooney-Petro, E. (2019, January). *Creating a Teaching Portfolio.* TA Professional development session for the Graduate School, Syracuse, NY.
7. **Waymouth, H.,** & Petit-McClure, S. (2018, August). *Universal Design for Learning.* Mandatory session at Syracuse University TA Orientation Program, Syracuse, NY.
8. **Waymouth, H.,** Veitch, H., & Roquemore, K. (2018, May). *Quiz Me No More: Universal Design for Learning (UDL) in Assessments.* Concurrent session, Syracuse University Future Professoriate Program Conference, Hamilton, NY.
9. **Waymouth, H.** (2018, March). *Questioning is the Answer.* TA Professional development session for Syracuse University Graduate School. Syracuse University, Syracuse, NY.
10. **Waymouth, H.** (2018, February). *Academic Language for Music Student Teachers.* Guest Lecture, Syracuse University, Syracuse, NY.
11. **Waymouth, H.** (2018, February). *Vocabulary Across the Curriculum.* Professional development session, Gouverneur High School, Gouverneur, NY.
12. **Waymouth, H.** (2018, January). *Literacy Across the Curriculum.* Professional development session, Gouverneur High School, Gouverneur, NY.
13. Waters, C., **Waymouth, H.,** & Zhang, Y. (2017, November). *Creating a Teaching Philosophy Statement.* TA professional development session for the Graduate School, Syracuse University, Syracuse, NY.
14. Gagnon, T., Mothersill, S., Duquet, V., & **Waymouth, H.** (2017, October). *Returning to TA Orientation.* TA professional development session for the Graduate School, Syracuse University, Syracuse, NY.
15. **Waymouth, H.**, Mothersill, S., Zhang, Y. (2017, August). *Motivating Students*. Optional session at Syracuse University TA Orientation Program, Syracuse, NY.
16. Freeman, J., Song, Y., & **Waymouth, H.** (2017, August). *Universal design for learning*. Mandatory session at Syracuse University TA Orientation Program, Syracuse, NY.
17. **Waymouth, H.**, Catroppa, A., & Cheng, H.V. (2016, August). *Creating your teaching persona.* Optional session at Syracuse University Teaching Assistant Orientation Program, Syracuse NY.
18. **Waymouth, H.**, & Kaub, T. (2015, April). *Executive Functioning Skills*. Para-professional session at Honeoye Falls – Lima Superintendent's Conference Day, Honeoye Falls, NY.
19. Roth, D., **Waymouth, H.**, & Recktenwald, K. (2014, February). *High school decision input unit budget proposal.* Presentation to the Board of Education, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
20. **Waymouth, H.** (2013, April). *Executive Functioning Skills for Parents.* Multi-session parent

outreach program, Honeoye Falls – Lima CSD, Honeoye Falls, NY.

21. Roth, D., **Waymouth, H.**, & Nye, C. (2013, February). *High school decision input unit budget proposal.* Presentation to the Board of Education, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
22. **Waymouth, H.,** & Englert, H. (2012, July). *Response to intervention for middle and high school.* Professional development session, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
23. **Waymouth, H.,** & Englert, H. (2012, July). *Non-fiction reading strategies*. Professional development session, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
24. **Waymouth, H.,** & Englert, H. (2012, April). *Response to intervention in the high school.* Presentation to the Board of Education, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
25. Lupisella, J., Englert, H., **Waymouth, H.,** & Vitale, A. (2010, March). *Speak Community Book Discussion.* Community outreach session, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
26. **Waymouth, H.** (2010, March). *Speak Teacher Discussion*. Professional development session, Honeoye Falls – Lima CSD, Honeoye Falls, NY.
27. **Waymouth, H.** (2009, January). *Textmapping*. Optional session, Superintendent's Conference, Honeoye Falls – Lima CSD, Honeoye Falls, NY.