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# CONSENSUS MODELING AS A CULTURAL PRACTICE: A CASE STUDY FROM A SEVENTH-GRADE SCIENCE CLASSROOM

by

Sara Louise Miconi Gailey

A dissertation submitted in partial fulfillment of
the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Education

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UTAH STATE UNIVERSITY
Logan, Utah

2023

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# ABSTRACT

Consensus Modeling as a Cultural Practice: A Case Study From a Seventh-Grade Science Classroom

by

Sara Louise Miconi Gailey, Doctor of Philosophy

Utah State University, 2023

Major Professor: Sarah K. Braden, Ph.D.
Department: Teacher Education and Leadership

Reforms in science education advocate for K-12 students to engage in practices similar to professional scientists, including developing and using models and engaging in scientific argumentation with evidence. Teachers are encouraged to create classroom environments that support students in developing and employing scientific discourse and engaging in scientific practices. Engaging in these science practices requires small group collaboration which has become increasingly popular in classrooms. However, research indicates that small group collaboration does not always promote equitable participation. Furthermore, science education research in developing and using models recommends that students communicate and collaborate to refine their understanding and ideas to create consensus models. Yet, little is known about how students engage in consensus activities.

This qualitative case study uses discourse analysis to study the social processes students in small groups enact while creating consensus models. The study explores how two groups in a seventh-grade science classroom incorporate entities into their consensus models and how students are socialized to participate as a result of the instruction and peer interactions. To understand how students navigate consensus instruction, this study employs language socialization and positioning theory.

The findings indicate students used four communicative pathways to include entities in the consensus model. The four pathways exist on a continuum with group discussions offering the most equitable participation, and the greatest opportunity for students to reach consensus. On the other end of the continuum, individual students made additions to the model without discussion. Analysis of how these pathways unfold during small group interaction suggests that students' positioning of themselves and others formed social hierarchies in the group that influenced the participation patterns that emerged. The communicative pathways, along with the description of participation patterns, demonstrate that while the instructional strategy may be termed "consensus modeling," the student work may not demonstrate actual group consensus. While there may still be benefits to consensus modeling instruction, even if the models do not reflect actual consensus, more research is needed to examine the benefits and to develop instruction that mitigates inequities in small group interactions.

(226 pages)

# PUBLIC ABSTRACT


Consensus Modeling as a Cultural Practice: A Case Study From a Seventh-Grade Science Classroom

Sara Louise Miconi Gailey

Recent reforms in science education aim to involve K-12 students in practices similar to those of professional scientists. These reforms promote student collaboration and science practices including developing models and engaging in scientific argumentation with evidence. Small group work in science classrooms has increased following the reforms. However, while small group collaboration has gained popularity, research suggests that it does not always lead to equitable participation. This qualitative case study uses discourse analysis to examine how two small groups of students in a seventh-grade science class develop consensus models of a phenomenon and how students are socialized to participate in those small groups.

The results indicate that the groups used four different communicative pathways to include entities in the group consensus model. Each of the four pathways had varying amounts of participation for group members and influenced the consensus process. Analysis of how these pathways unfold during small group work suggests that students formed social hierarchies in the group that influenced participation for each group member. The results demonstrate that while small groups are assigned to create "consensus models," the final models may not demonstrate true group consensus. There may still be benefits to consensus modeling instruction, however, more research is

needed to understand the benefits and to develop instruction that promotes equitable opportunities to participate for all group members.

# DEDICATION

This dissertation is dedicated to my nonno, Renato Miconi, and my dad, Giorgio Miconi. At a young age, you both encouraged my curiosity and taught me to love learning.

# ACKNOWLEDGMENTS

I want to begin by expressing my deepest appreciation to my mentor, Dr. Sarah Braden. Without her support and guidance, this dissertation would not have been possible. Dr. Braden, I am grateful for the time and energy you have invested in me. You are truly a gifted educator and researcher. I would also like thank my committee members, Dr. Sherry Marx, Dr. Kristin Searle, Dr. Kimberly Lott, and Dr. Lauren Barth-Cohen for their support and encouragement, each of you are experts in your field, thank you for sharing your knowledge with me. I would like to recognize two other faculty members, Dr. Kit Mohr, and Dr. Ryan Knowles, both of whom have influenced my success in this doctoral journey and helped me grow as a scholar.

I want to express my gratitude to the Teacher Education faculty at Weber State University. My academic career began in your classrooms. I knew decades ago that I wanted to inspire students the way you inspired me. As I have been finishing my doctoral journey, many of you helped me muster the courage to power on. Thank you all for your calls, texts, and visits to my office, you did not let me give up.

Finally, I want to thank my family and friends for your love, support, and patience all of these years. Mom and Dad, you have been instrumental in my journey, thank you for all you have done, I love you both. To my children, Brook, Alli, and Colton, you have sacrificed so much while I have been in school. I hope you understand how important hard work and dedication are. To my husband, Clint, words cannot express how much I appreciate your support. You have encouraged me to go for my dreams and provided the support so that I could. You are my rock, thank you for believing in me.

Sara Louise Miconi Gailey

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# CHAPTER I

# INTRODUCTION

> *Science is fundamentally a social enterprise, and scientific knowledge advances through collaboration and in the context of a social system with well-developed norms.* (National Research Council, 2012, p. 27).

Science education scholars recommend that students work collaboratively as they learn science content through practices that mimic practices professional scientists use (National Research Council, 2012). The recommendation for students to learn and use science practices has led to a significant increase in small group work in science classrooms (P. S. Smith, 2020). One type of small-group collaborative learning used in science classrooms is constructing consensus models (Barth-Cohen et al., 2021; Braden et al., 2021; Passmore et al., 2017). The goal of developing consensus models is for students to engage in scientific argumentation using evidence to create a model of a phenomenon to represent a collective understanding of the scientific mechanisms causing the phenomenon. However, the social processes students engage in while consensus building in the science classroom are not well understood. Furthermore, research suggests small-group work can marginalize particular students (Braden, 2017; Cohen, 1984, 1994; Cohen & Lotan, 2014). This dissertation studies the social processes demonstrated as two groups of students collaborate to create consensus models, including how individual students are socialized to participate.

## Background of the Problem

In 2013, the national science curriculum standards, Next Generation Science

Standards (NGSS; NGSS Lead States, 2013), was released for states to choose for adoption. The previously touted National Science Education Standards (National Research Council [NRC], 1996) focused on teaching science content through inquiry to engage students in science processes. The NGSS focuses on students developing skills to understand their world, designing solutions to problems they encounter, and communicating findings within the scientific community (Krajcik, 2015). The NGSS also use inquiry, but the new standards organize the inquiry process as involving three domains established and outlined in A Framework for K-12 Science Education (NRC, 2012; henceforth referred to as the framework). Since the release of the framework and NGSS, many states have adopted the NGSS or developed standards using the three dimensions described in the framework.

3-dimensional science instruction employs three distinct sets of tools that students use at every age to learn science and engineering. These three sets of tools represent essential dimensions of science and engineering education: science and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs). By integrating all three dimensions in the classroom, students purportedly develop a deeper understanding of the world around them (NRC, 2012). The first dimension established by the framework (NRC, 2012), science and engineering practices (SEPs), includes eight practices commonly used by scientists and engineers worldwide to explore and explain phenomena and solve problems through designing and building solutions.

According to the framework (NRC, 2012), collaborative learning is essential for many science and engineering practices to ensure that students learn how to do science in ways similar to how it is practiced in scientific communities. The science and engineering practices emphasize collaborative learning and include developing and using models, planning, and carrying out investigations, constructing explanations and designing solutions, engaging in arguments from evidence, and obtaining, evaluating, and communicating information. Wieselmann et al. (2021), synthesizing the work of other scholars, concluded that small-group instruction is central and widely accepted in science education. An analysis of data from the National Survey of Science and Mathematics Education (NSSME) revealed that 87% of middle-school teachers reported using small-group work weekly (P.S. Smith, 2020). However, as Kotsopoulos (2014) warns, small group collaborative learning is not always fruitful for all students. Researchers, curriculum designers, and teachers need to be aware of the strengths and limitations of collaborative learning as it is used within specific instructional contexts. Research is needed to reveal how classroom norms influence the participation of students in science conversations and collaborative learning (NRC, 2012).

**Equity Issues in Science Education**

Science education researchers have tried to understand the root causes of inequities in learning outcomes and opportunities in science classrooms (Baker, 2016; Braden, 2017; Cohen, 1994; Kotsopoulos, 2014; O. Lee, 2003; Shah & Lewis, 2019). There has been an emphasis on teaching strategies that promote using students' experiences and cultural knowledge (Larkin, 2019) and utilizing language scaffolds to support science conversations (Braden et al., 2021; Windschitl et al., 2018). However, disparities in learning outcomes in science between and across social markers like gender, ethnicity, and socioeconomic status are not changing quickly. The National Center for Education Statistics (2021) report card for science in the United States reported only a slightly smaller score gap from 2009-2019 between male and female and White students compared to Black, Hispanic, and multiracial Grade 8 students.

Research on small-group collaborative learning in science classrooms highlights areas that continue to perpetuate inequities. Perceived academic ability and social status of group members have been shown to influence participation patterns and students' positions in small groups (Adams-Wiggins et al., 2020; Bianchini, 1997; Braden, 2017; Cohen, 1984, 1994; Oliveira & Sadler, 2008). In addition, gender stereotypes can influence how students perform leadership roles and access materials during small-group work (Wieselmann et al., 2021). Differences in cultures related to language and communication norms among multilingual and immigrant students can also influence small-group interactional patterns (Kayi-Aydar, 2014; O. Lee, 2003; Shah & Lewis, 2019).

If small-group collaborative learning is a recommended instructional practice in science education and is used frequently (P. S. Smith, 2020), understanding how students work collaboratively is important for teachers and instructional designers who aim to support equity and maximize learning. Furthermore, within the SEPs, students are encouraged and sometimes required to come to consensus during small-group collaboration. Students in small groups are often instructed to reach a consensus to design and carry out an investigation, develop a model, or construct an explanation. However, research revealing how small groups of students navigate consensus building and whose ideas are represented in the product of consensus is limited.

## Significance of the Study

This dissertation adds to the current literature on collaborative learning in science in two ways. First, by focusing on the discursive interactions that support or constrain a small group's ability to come to a consensus on an explanation and visual model of a scientific phenomenon. Although collaborative learning and consensus-building are implied in the framework and NGSS, few theorists have explored how consensus unfolds or does not in the context of collaborative learning in science. Lemke (2001) describes sociocultural perspectives in science education research as "viewing science, science education, and research on science education as human social activities conducted within institutional and cultural frameworks" (p. 296). Second, by relating the group-level processes employed while building consensus models to the socialization of individual learners, this study offers insight into how various discursive practices and patterns led to equitable or inequitable learning opportunities for the students in this study.

## Positionality Statement

As the researcher for this study, I identify as a middle-class, native English-speaking, white female with ten years of K-12 teaching experience. My interest in the social aspects of science learning is both personal, as I am a former elementary teacher, and theoretical, as I am interested in how researchers might productively apply language socialization and sociocultural learning theories to their understanding of classroom learning and the design of instruction. While observing students as a teacher, I noticed that not all students participated equally when instructed to work collaboratively. Further, predictable hierarchies emerged within groups. This concerned me. While collaborative learning can allow students to co-construct knowledge through building from individual group members' understandings, I did not see this happen. I saw one or two students' ideas representing the entire group.

My experiences as a teacher have led to my journey as a researcher to understand the nature of collaborative learning and how teachers can support the creation of equitable opportunities to participate for students working in small groups. This research project aims to build from current scholarship on collaborative learning and generate another view into the nuances that influence student interactions and highlight moments of both successful and unsuccessful collaboration.

As a graduate research assistant, I participated in multiple components of the larger project from which these data were collected. Due to my role and position on the research team, I have spent a large amount of time working with the data and becoming familiar with the participants via the data. However, I do not have relationships with the collaborating teacher or student participants. I only know the participants through what is seen and heard in the data. The lens I use to interpret phenomena comes from my own racialized and gendered experiences and identity as a white female teacher and researcher, as well as my knowledge of the project and data set.

## Study Purpose and Research Questions

Students are often tasked to work within collaborative small groups in science to learn through and use the SEPs (NRC, 2012; P. S. Smith, 2020). However, hierarchies often form within small groups in classrooms (Cohen & Lotan, 2014; Adams-Wiggins et al., 2020). One or two students might lead by assigning the others to complete tasks rather than working as a group collaboratively to exchange ideas and come to consensus. Such role designations shape the learning opportunities of the students involved. This instrumental case study has a dual focus on the communicative practices in a specific instructional context and their direct influence on the socialization of individuals through discourse, a combination typical in language socialization research (Rymes, 2008). The research questions guiding this dissertation are as follows.

1. What communicative practices do students use to negotiate the incorporation of ideas as they are instructed to build group consensus on a scientific model?
2. How are students in two small groups socialized by their teachers and peers to participate in a modeling task where they have been instructed to reach consensus?

## Summary of Research Design

This study qualitative case study uses discourse analysis techniques to explore the communicative processes students engage in and how students are socialized to participate while creating a group consensus model. The data used in this study were collected as a part of a larger research project between two institutions. The data were collected in a 7th-grade science classroom in a mid-sized city in the mountain west region of the United States. Eight students within two groups, their teacher, and a research team member were present in the data used for analysis. Data sources included audiovisual data and student work samples. There were three phases of analysis, including several iterations of coding audiovisual data and transcripts, generating frequencies of turns of talk and communicative practices, and an inductive approach of the various data segments to categorize patterns of participation and positioning.

# CHAPTER II

## LITERATURE REVIEW

This study was conducted in a seventh-grade science classroom and an instructional unit aligned to the Next Generation Science Standards (NGSS) and Utah Science with Engineering Education (SEEd) standards. The following section offers a brief overview of the national and state science standards to situate the instructional practices under investigation. The NGSS were released for state adoption in 2013 and used the tenets of *A Framework for K-12 Science Education* (NRC, 2012). The framework and NGSS standards represent a major curricular and pedagogical shift. The previous standards focused on using inquiry to facilitate learning of science content, whereas the NGSS focuses on students' developing skills to understand their world and design solutions to problems they encounter (Krajcik, 2015). The NGSS also features an inquiry-based approach rather than direct instruction (J. Smith & Nadelson, 2017). After the release of the NGSS, many states adopted the standards directly or developed standards that are aligned with the NGSS and framework (National Science Teaching Association [NSTA], n.d.).

In 2016, Utah designed the SEEd standards for Grades 6-8, with Grades K-5 and 9-12 released in 2019. The SEEd standards are similar to NGSS and use the components described in the framework (NRC, 2012) as 3-dimensional learning (3D). After a phased transition, Utah has fully implemented the SEEd standards for all Grades K-12 since the 2020-2021 academic year. The new standards were written with each of the 3-dimensions recognized within each standard along with the performance expectations students should master. With the change in standards in Utah, teachers have been tasked with changing their thinking about how science is taught in their classrooms. Instead of focusing on students memorizing content, they are expected to engage students in 'doing' science and engineering. The instructional unit taught during this study is aligned with the SEEd standards and uses 3D instruction.

## 3-Dimensions of Science Instruction

Inquiry-based instruction, which influenced the development of 3D, has long been a feature of science education. The National Research Council's new vision of science education operationalizes inquiry-based learning through three distinct sets of tools or dimensions that students use while learning science and engineering concepts. The dimensions outlined by the NRC (2012) are the science and engineering practices (SEPs), crosscutting concepts (CCC), and disciplinary core ideas (DCI). The goal is that by integrating all three dimensions within the science curriculum, students will develop a deeper understanding of the world around them and how scientists study natural phenomena. The following subsections will describe the three dimensions with the SEPs presented last, elaborating on the practices that are focal to this study (i.e., engaging in argument from evidence and developing and using models).

One dimension of science education identified by the NRC (2012) is the *disciplinary core ideas* (DCI). DCIs are most commonly associated with scientific knowledge, the main ideas, or concepts of the different scientific disciplines. The DCIs are organized into four categories established in the framework: physical science, life science, earth and space science, and engineering design, as well as detail the topics to be covered as students' progress through their education (NRC, 2012). The younger grades start with broad topics, and as they advance in grade bands of K-2, 3-5, 6-8, and 9-12, each grade band builds on the former, so students deepen knowledge acquisition for each DCI (NRC, 2012). The next dimension is *crosscutting concepts* (CCC). The seven CCCs can be applied to all of the DCIs of science. The CCCs are (a) patterns; (b) cause and effect; (c) scale, proportion, and quantity; (d) systems and system models; (e) energy and matter; (f) structure and function; (g) stability and change. The CCCs help in the sense-making of phenomena and are used to create connections between DCIs. For instance, the CCC, *cause, and effect,* is used to conceptually understand the effect of the earth's tilt on seasons (earth and space science DCI) and the effects of mixing two substances (physical science DCI).

The third dimension established by the NRC (2012) is the *Science and Engineering Practices* (SEP). The eight practices therein are used by scientists and engineers worldwide to explore and explain phenomena and solve problems through designing and building systems. The practices are (a) asking questions and defining problems; (b) developing and using models; (c) planning and carrying out investigations; (d) analyzing and interpreting data; (e) using mathematics and computational thinking; (f) constructing explanations and designing solutions; (g) engaging in argument from evidence; (h) obtaining, evaluating, and communicating information. The NR (2012) emphasizes:

> As in all inquiry-based approaches to science teaching, we expect that students will themselves engage in the practices and not merely learn about them

> secondhand. Students can only comprehend scientific practices and fully appreciate the nature of scientific knowledge itself by directly experiencing those practices for themselves. (p. 30)

Thus, the current recommendations for science education include having students develop the skills used by professional scientists. Students are tasked with developing science content knowledge through the eight identified practices. The SEPs explore and explain the disciplinary core ideas, while the crosscutting concepts provide a framework for understanding the ideas in any domain. This study's DCI is embedded in physical science and focuses on magnetic forces. Multiple CCCs can be applied to understanding magnetic forces. However, the unit was designed to highlight cause-and-effect relationships to help students develop mechanistic reasoning (Russ et al., 2008) for magnetism. Russ et al. identify entities and the activities of entities as the causal mechanisms of a phenomenon. Under this framing, mechanistic reasoning is the process where students and scientists alike engage in reasoning from evidence to understand the mechanisms influencing a phenomenon like magnetism (Russ et al., 2008). The primary SEP for the unit of instruction is developing and using models. Students were tasked to engage in discussions to develop models that helped explain the causal mechanisms associated with magnetism. A lesson description will follow in the methods section and can be found in Braden et al. (2021).

Developing and using models to explain the mechanistic reasoning of a phenomenon is the primary SEP under investigation in this study. However, in order to develop and revise models, students must also craft arguments using evidence. Furthermore, when working to develop consensus models, students would verbally articulate and negotiate their arguments and evidence in the conversation. Thus, the discourse skills students need in consensus building are content-related (e.g., how to state and support a scientific claim with observational evidence) and social (e.g., how to productively negotiate agreement/disagreement). Rather than being two separate forms of discourse, content-related and social discourses are laminated together and present simultaneously in conversations as students evaluate and respond to the ideas of others. The following section will describe the cultural and communicative practices associated with consensus in general to illuminate what students are being socialized to do through learning activities similar to the one in this study.

## Cultural Practice of Consensus

Literature focusing on consensus outside of educational contexts addresses topics like joint decision-making in professional settings (Konaté et al., 2020; Luo, 2020; Wodak et al., 2011) and reasoning processes for believing consensus (Boseovski et al., 2017; Einav, 2018; Sebastián-Enesco et al., 2020; Yousif et al., 2019). Students are assigned consensus-building tasks to practice skills and discourses necessary for consensus-building and joint problem-solving in many professional settings (Hoffmann, 2020). Many careers require groups of people to come to a consensus on ideas, problems, and solutions, including science fields. The reviewed scholarship for this section does not explicitly define consensus; its meaning is left to be inferred through the descriptions of contexts, methods, and findings. This study defines *consensus* as the agreement of an idea between a group of individuals. This definition aligns with the literature in this section and the forthcoming literature related to consensus and collaborative learning. Fiol (1994) describes the notion of consensus as applicable in two components, the interpretation of the content of an idea and the framing of communication around the idea. A group could simultaneously agree and disagree while negotiating ideas. For example, the group could agree that the interpretation of ideas is correct but disagree about how the idea is framed in communication (Fiol, 1994).

The literature on the reasoning processes for consensus illuminate that both young children and adults reason about ideas depending on who is presenting the ideas during consensus building (Boseovski et al., 2017; Einav, 2018; Fiol, 1994; Luo, 2020; Sebastián-Enesco et al., 2020). For example, Boseovski et al. describe that young children's perception of expertise influences their agreement with the presented ideas. Ideas given by someone considered an expert in their field (i.e., zookeeper) are considered accurate over a layperson's ideas, even if the ideas are the same (Boseovski et al., 2017). Sebastián-Enesco et al. (2020) indicated that young children would also agree with ideas when more people agree. Similarly, Luo presents three factors influencing a professional group's ability to negotiate consensus: social connections (i.e., friendship, family, enemy) between the listener and speaker, the perceived social power of the individual sharing the idea, and the weight of agreement from others. For example, a group member is more likely to agree with an idea if it comes from someone they hold in higher esteem, like a friend (social connection), if the idea comes from someone with more power than their own, like a manager or expert (social power) and if more people in the group agree with the idea (weight of agreement).

The reviewed literature on joint decision-making in professional settings indicates that leadership style and communication influence a group's ability to reach a consensus (Wodak et al., 2011; Fiol, 1994) and an overarching process for joint decision-making (Konaté et al., 2020). Wodak et al. describe authoritarian and egalitarian leadership styles that limit or support consensus in corporate joint decision-making. The authoritarian leadership style is established through the hierarchy of roles, enforcing consent by emphasizing their own opinion or ideas and directing the group conversations (Wodak et al., 2011). The egalitarian leadership style focuses on interpersonal communication, encouraging all group members to share and discuss ideas and consent (Wodak et al., 2011). Fiol identified that displays of confidence and certainty in ideas limit conversations to resolve differences of viewpoints on an idea and hinder a group's ability to reach a consensus. Participants demonstrated unstable support patterns for the content or framing of ideas, indicating apprehension of a social fallout when disagreeing with those that demonstrated certainty (Fiol,1994).

Research on consensus in professional settings also describes the process professional decision-making meetings should go through while negotiating consensus (Konaté et al., 2020). First, the group should prepare to meet, including developing a collective understanding of the problem. Next, the group should negotiate and confront all viewpoints and ideas; then, they should generate solutions for the problems and measure for agreement on solutions. If dissensus occurs, the group should continue negotiating and confronting ideas until they attain consensus and present their decision. The process above describes the ideal process that students are being socialized to perform (Hoffmann, 2020).

While these studies do not directly connect to education, they exhibit evidence that young children and professionals demonstrated that potential social fallout influences a person's agreement with ideas (i.e., Boseovski et al., 2017; Sebastián-Enesco et al., 2020; Fiol, 1994) and that the leadership style enacted in a group influences the ability to reach consensus (Wodak et al., 2011). Further, as described above, consensus in general, is socially mediated and culturally dependent; educators need to know about the processes of consensus, in general, to understand what we are socializing students to do through consensus-related instructional tasks. Collaborative learning offers one context in which students engage in the consensus-building situations described above. The following section explores literature pertaining to collaborative learning and consensus building in the specific context of developing a group model of a scientific phenomenon.

## Collaborative Learning and Scientific Argumentation in Consensus Model Building

Collaborative learning is a rather ambiguous term used frequently in educational research. This study uses Trimbur's (1989) definition:

> Collaborative learning may be distinguished from other forms of group work on the grounds that it organizes students not just to work together on common projects but more important to engage in the process of intellectual negotiation and collective decision making. (p. 602)

While groups of students are working toward constructing a consensus model, they must make collective decisions about representing various entities in the model. The purpose of collaborative learning in science includes giving students opportunities to make their thinking visible, to learn how to articulate their ideas, to support ideas with evidence, to critically consider others' ideas, to question, to build on each other's ideas with supporting evidence, and possibly to create a shared understanding, or a joint product (Hogenkamp et al., 2021). Ideally, students learn content and practices through collaborative interactions (Oliveira & Sadler, 2008).

To engage in collaborative learning, as defined by Trimbur (1989), students use processes of scientific argumentation (Hogenkamp et al., 2021). However, students may engage in argumentation to persuade others to believe their idea is correct and not to critically consider all ideas and support them with evidence (Felton et al., 2009, 2015). The NRS (2007) distinguishes everyday argumentation, which often aims to win through persuasiveness and power, from scientific argumentation which aims to create a shared understanding of a phenomenon based on the plausibility of ideas and evidence. However, in practice, scientific argumentation among scientists involves both the expression of ideas and evidence and methods of persuasion (Rifkin & Martin, 1997; Yuan et al., 2019). Ideally, students would use scientific argumentation while presenting ideas to one another and negotiating what to include during consensus model building. Nevertheless, given that argumentation serves social and content-related functions, investigations of how students discursively construct and refute arguments with their peers while constructing group consensus models are needed.

## Developing and Using Models

The SEP of developing and using models includes two types of models, mental and conceptual (NRC, 2012). Mental models are personal and incomplete representations that help the thinker make sense of experiences. Whereas conceptual models are "explicit representations that are in some ways analogous to the phenomena they represent" (NRC, 2012, p. 56), which can include diagrams, mathematical representations, and computer simulations. Conceptual models represent some form of mental models, and the two types of models are dependent on one another. However, in science education and this current study, developing and using models refers to conceptual models. Developing and using models in science represents students' current understanding of a phenomenon. For example, students generating a visual model to describe their current understanding of the molecular patterns of water for varying states of matter is a conceptual model. Reproducing a visual model of the solar system from a textbook does not account for the student's current understanding of the solar system and is therefore not considered as developing and using a conceptual model. Conceptual models are often generated from an initial experience of a phenomenon; students ideally refine their model as their understanding of the phenomenon increases through investigations and scientific argumentation (NRC, 2012).

Literature is abundant in scientific modeling. Most of the research on modeling focuses on how developing and using models can be productively used to help students learn science concepts (Barth-Cohen & Wittmann, personal communication, October 16, 2018; Guy-Gaytán et al., 2019; Oh & Oh, 2011; Schwarz et al., 2009; Windschitl et al., 2008). Researchers also delineate the mechanistic reasoning practices used to construct models (Barth-Cohen et al., 2021) and descriptions of how different ages of students engage in developing and using models (Forbes et al., 2015). For example, Barth-Cohen et al. describe ways middle school students used evidence to reason causal mechanisms while creating a group model. The findings indicate that the students could reason about their models in ways similar to students in undergraduate physics. In addition, multiple peer-reviewed practitioner articles describe instructional sequences for modeling, where students generate an initial model, refine the model after investigation, present refined models to others, and develop consensus models (e.g., Braden et al., 2021; Forbes et al., 2015; Kenyon et al., 2008; Krajcik & Merritt, 2012; Passmore et al., 2017; Schwarz et al., 2009).

Consensus models are conceptual models “acknowledged as valid by different social groups after discussion and experimentation” (Oh & Oh, 2011, p. 1119). Developing a consensus model in a classroom aims for students to present their initial ideas using evidence, critically compare ideas, and socially negotiate how to construct a model that explains the phenomenon (Gilbert, 2004). The literature reviewed in this section suggests that developing scientific models aids in student learning of science content and that students can engage in scientific argumentation based on evidence while creating models. Empirical studies on modeling mention developing consensus models as pairs, small groups, or as a whole class (Cheng & Brown. 2010; Guy-Gaytán et al., 2019; Pierson & Clark, 2018; Tobin et al., 2018), but there is a gap in the literature, the critical processes of negotiating ideas and arriving at consensus on the various entities in a group model is rarely discussed.

## Collaborative Nature of Consensus-Model Development

Consensus-model building is a collaborative process that requires both the social negotiation of ideas and the cognitive demands of constructing a conceptual model. The limited research on consensus building in science classrooms is divided into two approaches: science education and social contexts. Research from science education literature has explored the role of consensus building in facilitating the refinement of ideas during the model-revision process (e.g., Barth-Cohen & Wittmann, personal communication, October 16, 2018; Schwarz et al., 2009). Scholars who focus on the social context have studied the possible interactions that can occur among students (e.g., Berland & Lee, 2012; Chan, 2001; Kuhn, 1991; Mercier & Sperber, 2011), or the teachers' framings of consensus building tasks (Cohen, 1994; Garcia-Mila et al., 2013; Gijlers et al., 2013; González-Howard & McNeill, 2018).

Literature coming from science education describes the progression of developing and using models, including instruction that contains consensus building. Schwarz et al. (2009) assert that the consensus-building process helped students understand the aim of the modeling process and how to better explain and view models. Building on the work of Schwarz and colleagues, Barth-Cohen and Wittmann (personal communication, October 16, 2018) describe how students revised their models after being confronted with new evidence and ideas shared by peers while developing a consensus model. Both of these articles depict how scientific concepts are articulated in conversation over time as students revise models. However, the conversational mechanisms that shape the consensus-building process for all students in the group have yet to be described.

The first social-context strand of literature related to consensus building focuses on possible interactions that may occur, such as comparing and evaluating others' ideas (Berland & Lee, 2012; Kuhn, 1991) and persuading others of an idea (Barron, 2000; Chan, 2001; Mercier & Sperber, 2011). Berland and Lee pose that when confronted with ideas that differ from one's own, a student might reject constructing a consensual understanding even if evidence is provided, particularly when the topic is controversial (e.g., evolution). Kuhn provides a similar example of when students negotiate consensus, others' ideas are only accepted when they present evidence supporting the listeners' initial ideas. Barron (2000) and Mercier and Sperber explore student interactions during consensus building. Both authors posit that students interact in various ways depending on their goal for consensus building. For instance, if their goal is winning an argument about the causation of a scientific phenomenon, they will be less likely to accept evidence that does not support their initial idea. These studies illuminate the possible challenges that students can experience when tasked to reach consensus. However, due to the context-specific nature of these case studies and the small number of case studies related to consensus building in science, additional research is needed to add to this body of literature to reveal if these findings are idiosyncratic of particular learning environments or if they are reflective of larger patterns and processes of consensus building.

The second strand of social-context scholarship on consensus building in science classrooms focuses on how the teacher frames the instructional task requiring consensus. Research suggests that student engagement in SEPs is connected to the epistemological framing of the instructional task of consensus building (e.g., Engle & Conant, 2002; González-Howard & McNeill, 2018; Hammer & Elby, 2003; Webb, 2009). Findings from this area of scholarship correlate the interactional patterns students in small groups engage in while attempting to achieve consensus with the way teachers instruct students to complete the task. González-Howard and McNeill (2018) found that when a teacher emphasized individual language, such as using the pronouns: I or you. Students spent more time critiquing the ideas of their peers. When the teacher used more communal language like the pronouns 'we and us,' students spent more time building on one another's ideas.

Similarly, Ke and Schwarz (2019) discovered that students' ability to develop a consensus model was connected to the epistemological framing given by the teacher. Groups were less successful in developing scientifically accurate consensus models when the consensus task was presented as an end product, where only correct information should be held and time to deliberate was limited. Alternatively, when the consensus model was presented as an epistemic tool to make sense of and explain a scientific phenomenon, groups were more successful at constructing scientifically accurate consensus models (Ke & Schwarz, 2019). Building on this literature, Guy-Gaytán et al., (2019) demonstrated that inconsistent framing of the purpose of modeling by the teacher limited authentic modeling practices in the classroom. This line of research demonstrates the important role that the teacher plays in presenting consensus building and how teacher framings influence subsequent student interactions. However, how teachers shape the unfolding of consensus among small groups of students as they work together has not yet been explored in this literature. In addition to this limited scholarship on consensus activities in science classrooms, consensus processes have also been studied in mathematics education.

## Consensus Building in Mathematics

Mathematics education research has explored the consensus processes that students engage in while making joint decisions on solving math problems (e.g., Barnes, 2004; Kotsopoulos, 2014). While mathematics and science education are different in many aspects, there are similarities in collaborative group work and consensus-building goals. For instance, studies related to small group collaborative learning in math and science promote developing opportunities for students to explain and justify their ideas with their peers, consider the ideas of others, and revise understandings through discussions (Berland & Lee, 2012; Campbell & Hodges, 2020). The results from the math education research provide greater insight into the communicative moves students use during collaborative learning. These findings illuminate approaches and possibilities to studying student interactions and group functioning in other content areas, such as science.

Many of the studies in mathematics education examine how student positions relate to group function (Barnes, 2004; Campbell & Hodges, 2020; Kotsopoulos, 2014). Campbell & Hodges (2020) studied participation patterns for students in small groups, categorizing groups by the contribution level across group members. (e.g., co-construction of ideas, free for all). For instance, the contribution of ideas from individuals in groups labeled 'co-construction' were equally distributed among those group members. Alternatively, when one student's ideas were presented more often, the group was labeled 'confirming one group member.' At an individual level, Barnes and Kotsopoulos describe linguistic patterns that promote or inhibit group members' contributions by positioning one another, including how students respond to others' ideas. Alternatively, Gomoll et al. (2017) focused on nonverbal, embodied actions that create spaces for joint problem-solving in math. Leaning toward another group member and making eye contact with the speaker promoted higher levels of participation among group members, while looking away or moving communal resources limited the participation of some group members.

Tasks of consensus-building in science and joint problem-solving in math are naturally complex, and both require students to develop an understanding of the content by communicating and negotiating ideas with peers. The literature in this section provided insight into possible group participation patterns that occur during collaborative learning settings (Campbell & Hodges, 2020) and individual communicative practices that can include or exclude group members from participating (Barnes, 2004; Kotsopoulos, 2014). The scholarship in this section also suggests that small-group collaboration involves complex social and cognitive work in which students influence each other's learning (Campbell & Hodges, 2020; Gomoll et al., 2017; Kotsopoulos, 2014). While the preceding sections have described some possible mechanisms that influence participation for students in collaborative learning, the final section of this literature review discusses possible underpinnings that suggest how and why certain students experience inequities within collaborative learning contexts in STEM.

## Inequities and Identity in Science Classrooms

A socially mediated activity, like consensus building in science, is subject to inequitable opportunities to participate for group members. For students to become socialized into discipline-specific discourse and practices, students need opportunities to practice and experiment with the language and social negotiations required by the field (NRC, 2012). As mentioned in Chapter I, the NRC called for research on the social aspects of 3D learning. Research is needed to understand how diverse students can enter and become full participants in a scientific classroom community and how peer interactions contribute to this process.

### Science Talk

In a science classroom, all students come with a wealth of experiences and knowledge about science phenomena, but many use different linguistic patterns than traditionally expected in the field (NRC, 2007). Thus, in some classrooms, students must use the specialized form of science discourse to engage verbally in what is considered legitimate science talk (Brown & Ryoo, 2008; Halliday, 1989; Jensen et al., 2021). Classrooms are not neutral settings; they are influenced by cultural and communicative language norms (Foster et al., 2003). Communicative norms are influenced by context and social classifications (Archer et al., 2013). These norms are often tacit, and students are left to figure them out independently (Delpit, 1995).

Consequently, students unfamiliar with the specialized language of science can struggle to fully engage in science instruction and conversations (Brown & Ryoo, 2008).

Brown and Ryoo advocate for science content to be taught using everyday communicative practices, and after students understand the content, instruction can then focus on scientific language. Other science education scholars also recommend making and giving deliberate opportunities for all students to practice scientific discourse (Lemke, 1987), the norms and practices of science conversations explicit (O. Lee & Avalos, 2002).

To shift the expected discourse patterns of science classrooms, researchers promote using language as a means to learn rather than an object of learning (Braden, 2017; Brown & Ryoo, 2008; Jensen et al., 2021; Valdes, 2018). Jensen et al. define *equitable classroom talk* as "communication of disciplinary ideas through discourse interactions with classmates and the teacher that resonate with everyday practices and identities of intersectionally minoritized students" (p. 4). Equitable classroom talk emerges through communicative interactions when traditionally marginalized students' experiences and language norms are considered assets. Teachers support equitable classroom talk through three principles, (a) connected language interactions, (b) communal language interactions, and (c) disciplinary practices.

The first practice, connected language interactions, is defined by integrating everyday language practices of students into instructional conversations to support participation, which requires rejecting approaches to correct language usage based on grammatical conventions and focusing on the meaning of what is being said (Braden, 2017; Brown & Ryoo, 2008; Jensen et al., 2021; Rymes, 2015). The second practice, communal language interactions, requires providing students with opportunities to discuss and collaborate with peers to develop the ability to use language for social and academic purposes (Cohen et al., 1999; Jensen et al., 2021). The final practice, disciplinary practices, requires students to engage in talk around the discipline (i.e., science) to make "thinking visible through talk" (Jensen et al., 2021, p. 5 ).

Brown and Ryoo (2008) found that when separating the conceptual and linguistic components of science learning, students learning improved both conceptually and linguistically. When teachers used everyday language to ask questions, students demonstrated a greater understanding of the content; when asking questions using scientific talk, students struggled to understand the science language (Brown & Ryoo, 2008). To promote equitable, productive science talk in classrooms, Michaels and O'Connor (2012) present elements that support productive talk, including belief about students' abilities, established ground rules, predetermined guiding questions, and strategic talk moves.

A socially mediated activity like consensus building of a conceptual model of a phenomenon would benefit from students using everyday talk instead of technical, scientific jargon so that all ideas are considered throughout the process. Jensen et al. (2021) posit that equitable science classroom talk should include communal language interactions, including small group collaboration and consensus building. However, research on small group collaboration demonstrates that the types of talk students use during discussions influence the participation and status of students within the group (Adams-Wiggins et al., 2020).

**Status Hierarchies and Local Identities**

Adams-Wiggins et al. (2020) studied how students in a seventh-grade science class navigated status hierarchies while working in collaborative small groups. The findings indicated that status hierarchies were legitimated through peer interaction, and higher-status students used cultural capital to tacitly enforce status hierarchies. Adams-Wiggins et al. describe that high-status students would use technical science jargon as cultural capital to legitimate their position within the group hierarchy. Low-status students could challenge their position but often at the expense of a lower-status student (Adams-Wiggins et al., 2020).

In science classrooms, status hierarchies are often influenced by social classifications like race or gender (Adams-Wiggins et al., 2020). Cohen (1994) has demonstrated that the construction of social hierarchies in the classroom often replicates larger societal norms. Stereotypes about social classifications can lead to unwarranted judgments about an individual's competence during a task which shapes status hierarchies where women and people of color are viewed as having lower status in the group (Archer et al., 2013; Cohen, 1994; O'Barr & Atkins, 1980). Further, the status of participants in small groups influences their participation. Those with higher status in the group participate more than others with low status (Cohen & Lotan, 1995).

Status in science classrooms is often attributed to perceived ability and expertise displayed through scientific discourse (Bianchini, 1997; Engle et al., 2014). Research from the field of identity studies has focused on the intersection of specialized language development and content learning (Braden, 2017, 2019; Brown, 2004; Olitsky et al., 2010; Wortham, 2004, 2006, 2008). Wortham (2006) provides empirical evidence that demonstrates how social identification in classrooms becomes intertwined with learning, arguing that "we must acknowledge, instead, that neither reason nor power, neither social identification nor academic learning, exists in pure form. We must explore how both knowledge and power, both identity and learning contribute to fundamental human process" (p. 25). As Wortham describes, identity and learning are interconnected: when students choose to engage in academic discussions, they are also choosing to identify themselves as certain types of people. Olitsky et al. (2010) suggest that students are more likely to engage in science activities when there is an opportunity to gain social capital through specialized language use. Further, students may refrain from science talk if the context threatens their socially displayed identity. Snell and Lefstein (2018) also suggest that instructional practices where students have to present their ideas out loud can make them vulnerable to being labeled as "inarticulate" or "low ability" (p. 2), which has ramifications on classroom identities.

The way students view themselves and their place in the classroom has implications for participation and learning. Brown et al. (2005) reports that underrepresented youth could assimilate into a science class's epistemological and cultural norms but had difficulty appropriating science discourses. Through interviews, Brown (2004) gathered that students only found the discursive practices of science applicable in the classroom, suggesting a cultural conflict between everyday life and science discourses. Braden (2017, 2019, 2020, 2022) also provides multiple examples of how locally constructed science identities are demonstrated through discourse patterns, often replicating racialized and gendered stereotypes, and influencing student participation.

Brown et al. (2005) posit:

> The language of academic genres offers students a way to use language to symbolically cue their identity. Nevertheless, engaging in these discourse practices is not neutral concerning students' identity.... The negotiated role of engaging in the situationally defined discourses of science needs to be reconciled with students' emerging academic identities. Therefore, success or failure in becoming a member of a discourse community may hinge on how students are allowed to position themselves with respect to the subject matter, discourse practices, other members of the community, and so forth. (pp.781-782)

The ideas illuminated above suggest that every moment of speaking is also a moment of performing a specific identity. Identity researchers focusing on equity promote shifting the expected discourse to validate a wider range of communicative practices (Brown & Ryoo, 2008; Rymes, 2016). By participating in scientific conversations, students can simultaneously learn and shape the specialized language of science in their classroom (Braden, 2022). Challenging the traditional scientific genre to validate a wider range of communicative practices could encourage connections between everyday life and science for students (Braden, 2017).

**Identity Models in STEM Classrooms**

Patterns of various types of behavior and perceived social status are interpreted by others often as a recognizable type or model of social identity. Identity scholars present empirically defined recognizable types of classroom identities and positions through classroom discourse studies (e.g., Braden, 2017, 2019; Wortham, 2004, 2006). Often the purpose of labeling or characterizing patterns of behaviors as contextually defined local identities or positions is to document how socially mediated activities create ideological structures. Recognizing the linguistic practices that define the locally performed identities is one of the first steps to understanding how inequities in participation manifest and persist. Through understanding these identity models, researchers, teachers, and students can begin the task of challenging tacit communicative practices that perpetuate inequitable participation. The purpose of this section is to highlight the various characterizations of social behaviors that have been identified during small group instruction during STEM classrooms.

Braden (2016) describes three locally constructed identities from a ninth-grade science classroom: the science expert, the good student, and the good assistant. The science expert identity is classified through students' engagement in science content discussions, use of technical language, and how they interacted with other students. Students recognized as science experts used interactional practices including directing other students, interrupting peers, selectively ignoring peers, and verbally disagreeing with peers (Braden, 2016). The good student identity includes students asking technical questions, restating explanations from the teacher, promoting task completion, evaluating group members' behaviors in relation to the assigned task, and expressing agreement with students perceived as science experts (Braden, 2016). The good assistant identity is characterized through students performing directives from other students, asking permission from others before acting, looking for approval for their work from others, and not verbally expressing agreement or disagreement (Braden, 2016).

Wieselmann et al. (2021) identified four labels for student participation patterns during small group mathematics instruction: the differential but engaged project manager, the invisible but interested onlooker, the scholarly designated leader, and the off-task social contributor. The labels were generated from the coding classroom discourse and identifying interactional patterns for each participant. The first two labels were associated with female students while the second two labels were associated with male students. The first label is the differential but engaged project manager, the authors described this identity as task oriented and involved but did not push other group mates to agree with her. She would defer to the boys in the group and follow their directions. The second label, *invisible but interested onlooker* did not engage in discourse with the group but was rarely off task and seemed to be silently observing and was quick to assist in the task. This identity model is similar to Braden's (2016) *good assistant*. The third label was the scholarly designated leader, the student occupying this identity model displayed intelligence through talk and quick to suggest ideas. His directions and ideas were rarely questioned or challenged by peers. This identity model is similar to Braden's science expert. The third and final label was off-task social contributor, who talked frequently about everything except the project, focused on completing the task but not on ideas being presented, supported the designated leader, did not seek interaction with the girls in the group.

In addition to labeling local identity models, which reflect conglomerates of discursive positions, scholarship in this area may instead focus on labeling more fine-grained positions reflected by students' behavior. For example, Barnes (2004) identifies 14 positions that students enacted as they worked in small groups in three secondary mathematics classrooms. The fourteen positions are manager, helper, facilitator, humorist, spokesperson, expert, outside expert, critic, collaborator, in need of help, entertainer, audience, networker, and outsider. The manager and helper are task-oriented positions. The facilitator and humorist are positions that promote group cohesion. The spokesperson is the individual that speaks for the group with the teacher. The expert uses academic language and is positioned by others as having content knowledge. The outside expert does not use academic language like the expert but provides specialized expertise from outside the classroom that contextualizes the mathematical task. The collaborator works closely with others and engages in group discussions. The in need of help position either claims they do not understand or asks for help. The entertainer initiates off-task activities, while the audience position is willing to join the off-task activities or talk. The final two positions are networker, a position where a student is more concerned about other groups, and the outsider, a position where an individual either tries to join the group work and is not permitted or there is no indication of participating in the task.

Although there are variations in the terms used to classify the models of identity between each study, there are similarities in the descriptions. All three studies above have identities or positions that represent content expertise, and task orientation. Barnes (2004) and Wieselmann et al. (2021) include positions related to off-task behavior. Each of the models of identity and positions described both reflect and influence the participation of individuals within the small groups. To gain insight into the practices that reflect productive and equitable group work, researchers and teachers must identify the types of social positions that offer the greatest amount of participation across group members, and those that limit participation.

## Summary

Changes is science education have led to promoting science and engineer practices that include developing models (NRC, 2012). The modeling literature has empirically demonstrated the that developing scientific models of phenomena aid in student learning. Science education researchers have promoted instructional sequences for science modeling that include developing consensus models (Passmore et al., 2017). However, the process students exhibit when tasked to create a consensus model is not addressed in existing scholarship creating the first gap in the literature this dissertation addresses.

Small-group collaboration during consensus building has the potential to give students opportunities to engage in mechanistic reasoning and to practice articulating and revising their understandings through discourse. Yet, when there is an emphasis on using certain discourses in science classrooms, some students are discouraged from participating if their everyday language and communicative practices differ from specialized forms of science language and other forms of communication stereotypically linked to science expertise (Braden, 2017, 2022; Brown, 2004). Students need opportunities to participate in science conversations and environments that value and support everyday talk as potentially scientific to become full members of the classroom community (Brown, 2004).

Additionally, literature from the fields of language socialization and identity development posit that static inequities in STEM are the product of processes related to disciplinary socialization. Promisingly, socialization patterns can be examined and, when understood, reshaped to create more equitable outcomes in science education (Calabrese Barton & Tan, 2020). However, more research is needed to understand how students are socialized to engage in small group collaboration to create consensus models, which is the second gap in the literature addressed in this dissertation. By examining both the consensus process and student socialization while building consensus models recommendations for instruction can be made to support all students' engagement in mechanistic reasoning and scientifically rich conversations. To achieve this aim, this dissertation applies a language socialization framework and positioning theory, which are described in the next section.

## Theoretical Framework

### Language Socialization

This study's primary theoretical lens is situated within the language socialization (LS) paradigm. LS research covers a broad range of topics within social sciences but is unified by its focus on how "participants are socialized *through* language as well as *to* use language" (Baquedano-López & Kattan, 2008, p. 161). Research within the LS paradigm applies a range of theoretical frameworks, including sociocultural (Ochs & Schieffelin, 2014) and post-structuralist perspectives (Duff, 2002). A commonality amongst all LS studies is the attention to how discursive practices influence how people are encouraged or discouraged to act or speak in certain ways within different contexts (Ochs &

Schieffelin, 2014).

Because of the central importance of language for this study, I must define what language is in relation to LS and what language can do. I define language as the channel through which we learn how to be, express who we are, and co-construct meaning with others. Many LS scholars shaped my definition of language, described further in this chapter. Ochs and Schieffelin (2014) describe language as the medium in which social and cultural knowledge develops in novices or children. Gee (2010) contends that language is not just a means to communicate information but also a way to do certain things and be certain ways. Gee further describes, "saying things in language never goes without also doing things and being things" (p.2). Within this idea of language, a person can only fully understand what is said if they know who said it (the social identity presented through language) and why it was said (the social action it is accomplishing). Gee argues that in any given discursive act, a speaker is not only uttering a phrase, but there is a meaning behind the phrase and a social identity being portrayed. Similarly, in his theory of dialogism, Bakhtin (1935) describes language as not independent of the speaker but as a way for a speaker to co-create meaning with others. Bakhtin describes:

> Language is not an abstract system of normative forms but rather a concrete heteroglot conception of the world. All words have the "taste" of a profession, a genre, a tendency, a party, a particular work, a particular person, a generation, an age group, the day, and hour. Each word tastes of the context and contexts in which it has lived its socially charged life; all words and forms are populated by intentions. (pp. 676-677)

With this view of language, what a student says is not an arbitrary formulation of sounds and words; it is contextually dependent, and a listener interprets the meaning through the 'taste' being displayed. In other words, the social position a speaker holds within a group and the context itself will influence the meaning of what is said.

Bourdieu (1977) also viewed the social positions of the speaker as important, emphasizing that interlocutors do not have equal rights to speak due to the distribution of power within a group. Social positions are constituted by the individual's status and power (social capital) in the local context (Bourdieu, 1977). Social capital is attained through "actual or potential resources" (Bourdieu, 1986, p. 248), like connections or relationships with others that can advance a person's status (e.g., relatives with higher social status, friendships with specific individuals, memberships in groups). Furthermore, speakers with more social or cultural capital will have more privilege and power in a social exchange (Bourdieu, 1977; Davies & Harre, 1990; Gee, 2014). The meaning of utterances within language is influenced by who is saying them and why, along with their social position in that context. For example, the meaning of a simple phrase like 'go sit down' is interpreted by the listener according to who spoke and the context it is spoken. In the classroom context, if a teacher says, 'Go sit down,' it holds a different meaning than if a student speaks the same phrase. Furthermore, the speaker's social and cultural capital will influence the listener's interpretation. The dispersion of power within the group through the enacted social positions influences the perceptions of ideas shared amongst the group depending on who said them (Bourdieu, 1977).

Sociologist Erving Goffman (1981) also describes the roles interlocutors enact in social interaction and how those roles influence the interpretation of utterances. Goffman explains that utterances from speakers can also change the expectation for other interlocutors in social interaction. In other words, similar to LS scholars, Goffman's production format theory suggests that speakers shape and are shaped by social interactions. Goffman conceptualized the idea of production format to distinguish the different levels of participation status in social interaction. The production format has three distinct roles: animator, author, and principal (Goffman, 1981). The animator is the speaker of the words, the author is the interlocutor that scripts the spoken words, and the principal is the party whose beliefs are represented. Rymes (2015) uses Goffman's production format to understand how social contexts influence classroom interactions. Rymes describes how teachers can better understand the influences behind student utterances and the status of speakers in classroom interactions by using Goffman's production format.

Early LS scholarship looked at the role schooling played in reproducing social orders (Bernstein, 1971; Bourdieu & Passeron, 1990; Giddens, 1979; Heath, 1983). Within educational settings, LS studies attend to students' lives as they engage in institutionally organized activities, which include the re/production of larger social orders (Baquedano-Lopez & Kattan, 2008; Rymes, 2015). Students are socialized through language to engage in educational activities in certain ways and to use language in those same settings (Heath, 1983). LS researchers conduct discourse analysis using various methods, one of which is positioning theory. Positioning theory is a conceptual approach to discourse analysis that aligns with LS and allows for the examination of how language is shaped by and shapes the participation of individuals in educational settings.

## Positioning Theory

Positioning Theory (PT) relies on sociocultural learning perspectives, social constructivism, and early feminist perspectives (Harré et al., 2009). However, scholars have recently used PT in studies that apply critical theories and post-structuralist approaches (Kayi-Aydar, 2019). Rom Harré, the principal architect of positioning theory, advocates adopting a representational view of cognition to focus on the meaning-making process and what he calls 'discursive psychology' or the 'discursive turn' (Harré et al., 2003). For those using PT, learning is viewed as discursively constructed. Harré and Gillette (1994) argue that the study of the mind cannot be purely objective; rather, the mind must be viewed "as dynamic and essentially embedded in historical, political, cultural, social, and interpersonal contexts. Ostensibly, one cannot separate the mind from context and the social norms that influence an individual's discursive actions.

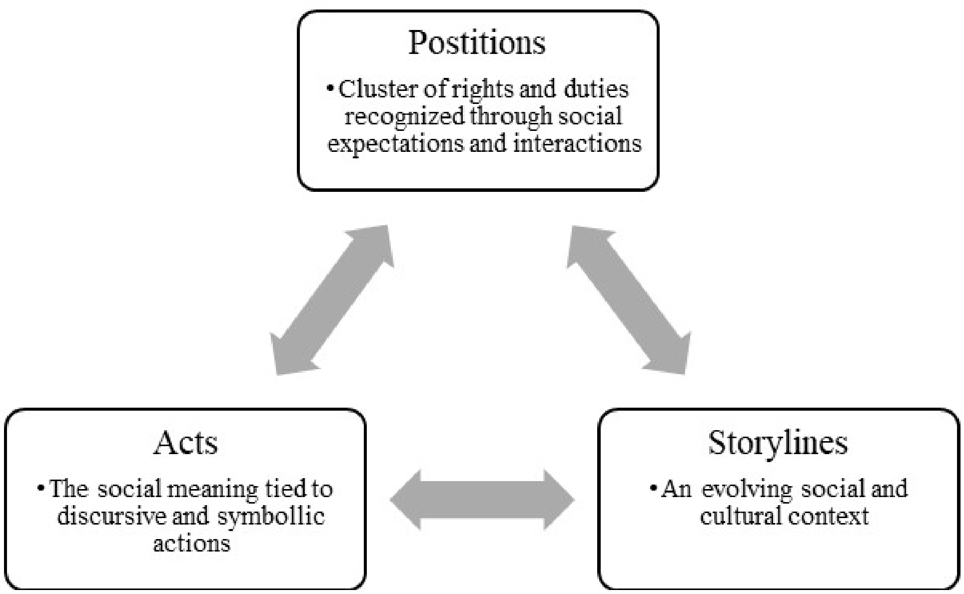
One of the essential goals of positioning theory is to "highlight practices that inhibit certain groups of individuals from saying certain things or performing certain sorts of acts or actions in discursive practices" (Kayi-Aydar, 2019, p. 2). In meeting this goal, positioning theory allows the analyst to examine how rights and duties for interlocutors are established and assigned within a social episode or across episodes. The rights and duties an interlocutor performs or expects others to perform indicate the positions assigned or assumed in that specific storyline or context. Rights are understood as actions that an interlocutor expects others to do, while duties are actions an interlocutor must do for others (Kayi-Aydar, 2019). The following section elaborates the key tenets of positioning theory.

**Positioning Triad**

Most scholars using PT describe the positioning triangle or triad to represent the interdependence of three important components of the theory: positions, acts, and storylines (Green et al., 2020; Kayi-Aydar, 2019; see Figure 1). If one component changes, the other two will be influenced (Davies & Harré, 1999). Scrutinizing all three vertices of the positioning triad affords an analysis of social interactions through discourse, listeners' interpretations, and context.

**Figure 1**

*Positioning Theory Triad*




Kayi-Aydar (2019), building on the work of Deppermann (2015), described *positions* as "semiotically structured ascriptions tied to social actions and accomplished by social practice" (p. 5). Because positions are based on social action and practice, they can and often do vary from moment to moment. However, they are contextually linked to the past experiences of the interlocutors at that moment. *Storylines* in the positioning triad (see Figure 1) are defined as the context in which the positioning occurs (Slocum & Van

Lagenhove, 2003). The storyline exists prior to and is shaped by the social episode. The storylines are created by linking past experiences with the present meaning and future opportunities for the characters involved.

Harré (2012) defines *acts* as actions (discourse and physical gestures) and the social meaning in a specific context. For instance, if someone were to say, “You look hot,” the words spoken are an action. This could mean very different things to different individuals and in different contexts. The words and the speaker’s intended meaning and the receiver’s interpretation of the meaning create an act. In this case, the phrase could be an invitation to change the thermostat or to engage in a romantic encounter.

Acts, storylines, and positions are all interdependent and influence one another (Davies & Harré, 1999). Positions are established when interlocutors interactively or reflexively present certain rights or duties that other interlocutors acknowledge or take up in the storyline (Kayi-Aydar, 2019). Interlocutors’ positions are identifiable and interpreted by the acts performed; at the same time, the acts performed are influenced by past and present storylines. The positions presented and taken up shape the development of the present and future storylines. Positioning theory offers one way to analyze how students are socialized through language by examining the intersections of communicative acts, storylines, and assigned positions (Duff, 2002; Menard-Warwick, 2008).

## Intersection of Language Socialization, Positioning Theory, and Science Education

The Framework for K-12 Science Education (NRC, 2012) promotes instructional design that engages students in the science and engineering practices that experts in scientific communities' use, with the notion that, over time, with instruction, students will learn how to successfully engage in these practices. All of the practices rely on language in speech or written form, with the goal that students are socialized into the "specialized ways of talking and writing" within science communities (NRC, 2012, p. 43). Early research (Brown et al., 2005; NRC, 2007; S. Lee & Roth, 2003) that influenced the construction of the science and engineering framework (NRC, 2012) has situated scientific literacy within a sociocultural perspective. In this sociocultural perspective, scientific learning is achieved through contextually dependent discourse.

Using LS as a theoretical approach helps social science researchers examine how novices are socialized into speaking and acting in certain ways in specific contexts like the science classroom. For example, LS studies within science education have described scientific identity development (Braden, 2017, 2019, 2022), socialization into reading science texts (Oliveira & Barnes, 2019), and content-specific language use of multilingual students (Roper, 2017; Solís, 2017). Scholars from both LS and positioning theory have used identity models to classify patterns of socialization and positioning to better understand interactions in the classroom (Barnes, 2004; Braden, 2016; Wieselmann et al., 2021).This research adds to the LS and positioning theory literature by using an analytic framework that combines these two perspectives to understand how students in small groups are socialized through language to perform certain acts and positions within specific storylines while working towards developing a consensus model.

Prior research has established that scientific consensus-building requires linguistic negotiation of ideas about natural physical phenomena. However, the social positions influencing the interpretation, uptake, or rejection of group members' ideas are often left unaddressed in research. Using PT in an LS framework, this study highlights the ideas that group members offer and take up during the consensus-building process and how the distribution of positions influences the groups' ability to obtain consensus. This approach will give analytic attention to both the communicative practices of the group and their influences on the observed participation of individual group members within the consensus-building process.

**Conclusion**

The science and engineering practices emphasized by NGSS and SEEd initiatives require students to develop the skills needed for the science and engineering fields, including engaging in argumentation based on evidence and constructing a model to develop a collective understanding of a phenomenon. Small-group collaboration has the potential to help students build the linguistic skills necessary for the consensus-building processes. However, to unpack the possible academic benefits of consensus building, attention to how students are socialized to participate during small-group interactions is needed. Specifically, how rights and duties are distributed amongst group members and whose ideas are considered during small-group collaboration need to be studied. If we understand how students are socialized to participate during consensus-building activities and the practices that constitute participation, we can work towards building more nuanced instruction to assist students in navigating the consensus process during small-group science collaboration.

# CHAPTER III

# METHODS

This study was a single, instrumental case-study. Creswell and Poth (2016) describe single instrumental case studies as appropriate when "the researcher focuses on an issue or concern then selects one bounded case to illustrate this issue" (p. 98). The study explores how students interacted when instructed to come to consensus during small-group science learning to develop a group model of a phenomenon. More specifically, this case study investigated how opportunities to participate in small groups manifested and whose ideas were heard, taken up, and represented when students collaborated on a common project. Through the analysis, I theorized about how students are socialized in small groups and why certain students' ideas are represented over others in the group model. This dissertation explores students' socialization during consensus model development in a bounded case of two small groups in a seventh-grade science classroom. The case is bounded by the people present in the classroom, location, time of instruction, and implementation of one instructional unit.

## Research Context

Yin (2018) recommends case study methods when there is no clear boundary between the phenomenon and context. In this study, the context of the study is as imperative as the participants, as the context influences the participants, just as the participants influence the context. Data used in this study were collected for a larger research project in a collaboration of researchers at two universities and two seventh-grade teachers. The unit of instruction was designed by the research team and the cooperating science teacher Dr. Samson (pseudonym). The sampling strategy for the larger project was criterion sampling (Creswell & Poth, 2016), which "seeks cases that meet some criterion, useful for quality assurance" (p. 159). The case for this study was chosen based on the teacher's criterion, Dr. Samson, because of the high efficacy of her science teaching. Data used for this study came from implementing the unit of instruction in one of Dr. Samson's seventh-grade science classrooms.

The school is located in the mountain west region of the U.S. The school has a science focus and holds Title I status. Students are admitted to the school through a lottery system. The school's demographics at the time of data collection were similar to the school district in which it was located: 47% White, 40% Hispanic, 4.6 % Multi-Racial, 4.3% African American, 2% Asian, and 2.3% Pacific Islander. In addition, 13% of the school's population were labeled as English Language Learners, 10% received special education services, and 48.9% were from families eligible for free or reduced lunch. The classroom under investigation had comparable demographics as the school at large.

**Participants**

The participants in this study were seventh-grade students, their science teacher, Dr. Samson, and a member of the research team, Dr. Brooks. At the time of the study, Dr. Samson had taught for two years as a secondary science teacher and held a Ph.D. in biology. At the time of data collection, the state had adopted new science standards aligned with NGSS. Dr. Samson expressed interest in learning instructional approaches to support student learning using the Framework for K-12 Science Education (NRC, 2012) on which the state standards were based. The research partnership between the research team and Dr. Samson was developed from conversations about a mutual interest in supporting students in scientific modeling. Dr. Brooks is listed as a participant because she engaged with the groups during the consensus modeling phase of the lesson.

Thirty students participated in the original study. They were separated into seven small groups that remained the same during the two-week duration of the instructional unit. There were class periods where different students were absent, but when they returned, they participated in the same group to which they were originally assigned. This study focuses on two of the seven groups which were selected because they had complete data sets. In addition, when they presented, Group 5 had one student who stated that he disagreed with how an idea was represented in the model, indicating an apparent lack of consensus, while students in Group 3 did not express disagreement during the presentation of their model. I wanted to examine how each group navigated developing their consensus model and to what degree each group had achieved consensus prior to presenting. Table 1 includes the names (pseudonyms) of the members of each group to be analyzed and lists their socially performed genders. When the data were collected, the research team did not explicitly request students to provide their self-identified gender pronouns. For this analysis, I will use the gender pronouns for each student used by their group members and not verbally contested by the student. Throughout data collection in the classroom, the research team witnessed no explicit conversations about students' gender identities. Thus, I rely on a socially performed gender acknowledging that this may or may not align with how students would describe their genders.

**Table 1**

*Groups and Group Members*

| Group 3 | Group 5 |
|---|---|
| Evan (M) | Rebecca (F) |
| Lindy (F) | Dylan (M) |
| Damien (M) | Landon (M) |
| Addie (F) | Emma (F) |

*Note.* F denotes female performed gender; M denotes male performed gender.

## Instructional Unit

The unit of instruction developed for this project was designed around the NGSS (2013) and the newly released seventh-grade state science standards for magnetism. With the presence of the researchers in the classroom, parts of the lesson delivery were co-taught with Dr. Samson and Dr. Brooks. The unit of instruction covered Utah Science with Engineering Education Standard: 7.1.3:

> Construct a model using observational evidence to describe the nature of fields that exist between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause-and-effect relationship between properties of objects (such as magnets or electrically charged objects) and the forces they exert. (SEEd Standards, 2019, p. 56)

The research team developed an instructional sequence based on the work of Passmore et al. (2017) and Kenyon et al. (2008). An overview of the sequence, phase, and duration of each component of the unit is provided in Table 2.

The entire unit was taught over two weeks, where classes were held every day and spanned 90 minutes. To begin, students were presented with the anchoring phenomenon of the “floating paperclip,” where a paperclip is tied to a string, and the string is taped to

**Table 2**

*Modeling with Magnetism Unit Sequence*

| Phase | Duration | Description | Day of instruction |
|---|---|---|---|
| 1 | 15 min | The anchoring phenomenon is presented, students explore the phenomenon | 1 |
| 2 | 15 min | Students create initial diagrammatic model and explanation for the anchoring phenomenon | 1 |
| 3 | 3.5 h | Students (in small groups) rotate to 8 stations where they conduct empirical investigations to gather data on magnetism and magnetic forces. During this step they are instructed to revise their initial model as new data is collected. | 1, 2, 3 |
| 4 | 130 min | Students share individual model with small group and then develop consensus model for the group around the anchoring phenomenon. | 3, 4, 5 |
| 5 | 60 min | Small groups share consensus model with class. The whole class reviews and evaluates each model in a class discussion. Following discussion, groups are advised to revise their consensus model. | 5 |
| 6 | 20 min | Individual assessment is given to each student. Students are tasked to apply their learning to a similar magnetism phenomenon | 5 |

*Note.* Full lesson description in Braden et al. (2021).

a surface like a desk. A magnet is held up just above the reach of the paperclip so that it appears to be floating due to the string's tension on the paperclip and the magnet's pull. Students explored the phenomenon themselves, then created an initial individual model and explanation to diagram the forces and entities present in the phenomenon. Subsequently, each small group rotated to eight stations to further investigate the properties of magnets and magnetic forces. Students were instructed to revise their models when they attended all the stations.

At this point in the instructional unit, each student presented their individual model to their peers in small groups. During steps 4 and 5, students were instructed on using research-based instructional strategies and scaffolds to promote equitable access to science conversations in their small groups. The scaffolds included sentence starters and templates for participating verbally in the conversation (Fisher et al., 2008). Another scaffold included talk moves (Michaels & O'Conner, 2012), where students were given questions to help guide their presentation of their individual model to the group or help them be active listeners for the peer presenting. The final instructional strategies designed to aid small-group collaboration were distributed leadership (Oliveira et al., 2014) for each step of the consensus model instruction phase and regulated turn-taking strategies (see Appendix C; Braden et al., 2021). Table 3 includes the four steps of the consensus model-building phase of instruction and the assigned leader of each step. Each student in the group was selected as an assigned leader based on the color of the workbook they were given. This instructional unit and the instructional scaffolds and strategies are fully described in a practitioner article in *Science Scope* (Braden et al., 2021).

**Table 3**

*Steps for Consensus Model Development and Assigned Leaders*

| Group | Step 1: What are the similarities and differences in our models? | Step 2: What do we agree should be in our model? | Step 3: Are we ready to draw? How should we start? | Step 4: What's our evidence for this model? |
|---|---|---|---|---|
| Group 3 | Lindy | Damien | Evan | Addie |
| Group 5 | Emma | Landon | Dylan | Rebecca |

## Data Collection

Data used for this study were collected during the collaborative project described earlier. The research team secured IRB and school-district approval before completing the consent and assent process in the classroom. Once students and parents completed and returned the forms, Dr. Samson organized the class so that 100% of the 30 students in the room consented to participate in the research. One to two members of the research team attended every class period. The following types of data were collected: Audio and visual recordings, and student work samples.

### Audio and Video Recordings

Audio and video recordings were collected, including whole-group instruction and small-group collaboration sessions. The teacher and each research team member wore an audio recorder around their necks so every interaction with students could be recorded. Eight tables were in the room during data collection, and each table had an audio recorder in the middle to capture small-group conversations. Four video cameras were placed strategically around the room to capture video data of specific tables. Due to the limited video camera availability, only some tables are seen in the video data. The audiovisual data were saved on the password-protected data-management software, Box, and an external hard drive after each data-collection session.

### Student Work Samples

Pictures of each small group's model were taken at the end of day four and then again at the end of day five. Small groups were instructed to revise their model following the whole-class discussion in which each group presented their model. After these revisions, each student was given an individual assessment asking them to apply their current understanding of magnetism to a similar but different phenomenon. Copies of each participant's assessment were collected and stored in Box and an external hard drive.

## Data Analysis

To analyze the interactions in the groups, I used discourse analysis methods grounded in positioning theory (Kayi-Aydar, 2019) and language socialization (Rymes, 2015). I studied how language-in-use is both influencing and influenced by the context of its use (Rymes, 2015). In other words, I studied how the acts (speech and physical) of group members were shaped by the instructional task of building a consensus model, as well as how those same acts shaped the outcome of the development of the consensus model. Additionally, social interactions of the two groups were analyzed through multiple iterations of coding to identify patterns and create narratives through the three phases of analysis described below.

### Phase One: Data Preparation, Corpus Building, and Initial Analysis

Phase one of data analysis began with transcribing (see Appendix B for transcription conventions) the audiovisual data that had not been previously transcribed for the initial research project. The new transcripts were created in the qualitative data analysis program Atlas.ti, which could be timestamped with the audiovisual data during transcription. The already generated transcriptions were reformatted to be imported to Atlas.ti. Once the transcripts were imported, the transcripts were timestamped so that the audiovisual data and transcripts could be coded simultaneously. While transcribing and timestamping, I marked initial moments of interest that caught my attention to revisit throughout the analysis process. This process resulted in an organized corpus of data for each group where transcripts and audiovisual data could be viewed and coded simultaneously.

I began coding the first instruction step for building the consensus model, "sharing individual models." The first round of coding involved indexing the corpus by identifying turns of talk for each group member across both groups. Every utterance was coded for the speaker, such as a student in the group, the teacher, or the researcher. While conducting the initial coding, I also created a profile describing how various ideas and entities came to be represented in the model. The profile described all 4 steps of consensus instruction (see Table 3) for each group, beginning with sharing individual models through creating the consensus model and determining evidence for the model. The profile also describes how the groups presented their consensus models to the class. The profile included extracts of transcripts and served as a narrative of the group's overall performance and was used in later analysis.

Before beginning the second iteration of coding, I generated primary process codes (Miles et al., 2020); comment, consensus, prompting, questioning, and sharing ideas. Miles et al. describe that process codes "connote observable and conceptual action in the data" (p. 66). The codes labeled the types of observable participation for each utterance. During this iteration of coding and future ones, I generated subcodes (Miles et al., 2020) to further detail and classify what was said in the primary process codes. Table

4 includes all the process codes and subcodes used to identify the communicative practices used by the participants. As coding ensued, I added the 'assigned leader' as a primary code to aid in the analysis by using it to generate code co-occurrence frequencies for each phase of model development. After coding each instructional step, I created a memo to document ideas and important moments in the data.

**Table 4**

*Codebook for Phases of Analysis*

| Process Codes (Round 1) | Subcodes (Round 2) | |
|---|---|---|
| Speaker | Addie (group 3) | Evan (group 3) |
| | Damien (group 3) | Lindy (group 3) |
| | Dylan (group 5) | Emma (group 5) |
| | Landon (group 5) | Rebecca (group 5) |
| Comment | Clarify | Correcting word choice |
| | Epistemic Stance (confusion/certainty; Rymes, 2015) | Off-task |
| Consensus | Agreement | Disagreement |
| | Asking | |
| Prompting | Student to student response | Teacher to student |
| Questioning | Student to student | Teacher to student |
| | Student to teacher | Response |
| Share Idea | | |
| Assigned leader | Addie (group 3) | Evan (group 3) |
| | Damien (group 3) | Lindy (group 3) |
| | Dylan (group 5) | Emma (group 5) |
| | Landon (group 5) | Rebecca (group 5) |
| Physical Gesture | | |

**Phase Two: Research Question One**

Phase two of the analysis focused on the first research question: What communicative practices do students use to negotiate the incorporation of ideas as they are instructed to build group consensus on a scientific model? I started by identifying if each group seemingly came to a consensus on their model during the whole-class discussion. I looked for verbal and physical markers that denote if group members agreed (e.g., head nodding when a group member presents a claim; Gomoll et al., 2017) or disagreed (e.g., a verbal challenge of their own group's model) with how their group members presented aspects of the model to the class. I refined the group profiles prepared in Phase 1 to include these additional details. When there was an apparent lack of consensus about an entity represented in the model (e.g., a disagreement over field lines), I noted the disagreement so that I could specifically examine the preceding talk to identify how that entity came to be included in the group model.

I then revisited the data coded as "share idea" from phase 1 of the analysis, starting with sharing the individual models through the entire model-building phase of instruction. I looked at the coded data to identify storylines where specific features or entities are included or excluded in the model (Campbell & Hodges, 2020). I highlighted the group profiles for moments where an idea is presented or negotiated and moments where very little might be said out loud, but a student draws on the model. By creating and analyzing data on the group profiles, I was able to track each entity added to the model through the entire process when an idea was presented (i.e., sharing of individual models or while deciding what to add to the group model), when and if it was discussed by the group, if the group came to consensus on the idea for the entity ,when it was physically added to the group model, and if group members express agreement or disagreement in the whole class discussion.

Throughout this process, I also hand-coded a printed picture of the group model to identify when the ideas for the entities on the model were presented, discussed (or not), and added to the model. The process of highlighting the moments entities were added to the model led me to notice that different group members participated for some entities differently. For instance, the group member that presented the idea was only sometimes the student that drew the entity on the model. To further explore the participation of group members involvement in consensus model development, I added another layer of analysis to aid in answering research question one. I used Goffman's (1981) notions of production roles, as discussed in Rymes (2015), to unpack whose ideas were represented in the model and to further understand the process by which students added to the group model. I was able to identify the roles of the Animator (who physically added the entity to the model), Author (who was involved with the representation of the idea), and Principal (who shared the idea being represented) of each entity in their model. Following this analysis, I identified patterns of the level of involvement from group members, which are discussed in Chapter IV.

### Phase Three: Research Question Two

The final phase of analysis for this dissertation was conducted to answer the second research question: How are students in two small groups socialized by their teachers and peers to participate in a modeling task where they have been instructed to reach consensus? The process of answering this question was more complex and fluid than the first research question. Miles et al. (2020) describe this type of analytic sequence:

> It moves from one inductive inference to another by selectively collecting data, comparing, and contrasting this material in the quest for patterns or regularities, seeking out more data to support or qualify these emerging clusters, and then gradually drawing inferences from the links between other new data segments and cumulative set of conceptualizations. (p. 6)

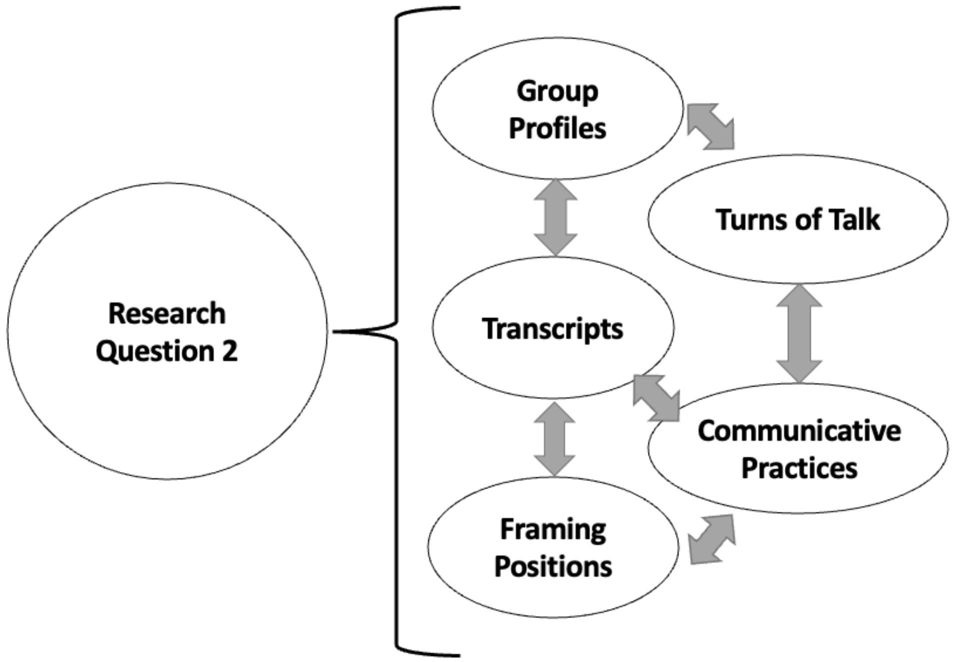
As described in this quote, I moved from one inference on student positioning to the next by comparing and contrasting various data segments and frequencies displayed in tables, transcript data, and group profiles. The analysis began with generating tables from the coded corpus to summarize and compare turns of talk (see Appendix D), types of talk (see Appendix E), and production roles (see Tables 6 and 8 later in Chapter V). I then examined these tables with the group profiles and transcripts in a dynamic process illustrated in Figure 2.

To understand the complexities of language socialization, I generated and organized data tables that report various frequencies to identify discourse patterns for each group and each group member. I began using Atlas.ti to create a code co-occurrence table to report each group/member's turns of talk. I used the assigned leader and speaker codes to generate the table (see Appendix D). I reported the totals for each student and the group for every instructional step in the consensus model-building phase of instruction.

The next table I created was another code co-occurrence table to report the frequencies of communicative practices used by each group member (see Appendix E).

**Figure 2**

*Data Analysis Phase Three Diagram*




This table compared the speaker codes and the primary communicative process codes (i.e., comment) and subcodes (i.e., comment: epistemic stance). This table allowed me to examine the frequencies of each student's various communicative practices.

The last table generated for this phase of analysis documented enacted production roles (Animator, Author, and Principal) by entity and the nature of the discourse around that entity in the model (see Appendix F). As I was creating this table, I wanted to know if there were patterns related to the assignment of roles in the group related to the type of entity being added. I used the profiles for each group and categorized each entity as being task-oriented or representing the scientific mechanisms of the phenomenon. Task-oriented entities were related to the formatting or organization of the model (i.e., Title, labels). The science mechanism entities were categorized for what they represented (i.e., arrows for force). I could analyze who occupied which roles most often, along with the nature of the entity (task-oriented or scientific), by creating this table.

The final data sources I used in the analysis for research question two were the group profile and the transcripts for each group. After creating and organizing the data sources described above, I began to look for patterns of interactions that seemingly supported or limited participation across group members, such as responding to ideas or prompting others to act (Wieselmann et al., 2021) and nonverbal communication (Gomoll et al., 2017). The analysis was fluid, and I used multiple data sources (tables, transcripts, and profiles) to identify patterns of positioning and socialization. Figure 2 provides a visual representation of the flow between the data clusters that guided the analysis of how students were socialized during the consensus-building phase of instruction. The results in Chapter V document how students came to occupy the positions related to the construction of the group consensus model and how and why other students did not come to occupy those same positions.

## Trustworthiness

The purpose of this study is to understand how students interact with one another as they engage in creating a consensus model. As described earlier in this chapter, the data comes from a larger study. Because the data were collected previously, I was unable to member check or seek participant feedback (Creswell & Poth, 2018) on my analysis from the students or teacher. Acknowledging that as a qualitative researcher, I am not separate from the analysis and my biases influence my interpretation of the data. I provided a positionality statement in Chapter I to articulate the lens I bring to this study. To further establish trustworthiness, I frequently met with another researcher to review written results and discuss my findings. The researcher asked clarifying questions, challenged assumptions, and asked for further evidence to support claims.

In addition to articulating my positionality and having the results reviewed, I actively sought negative or disconfirming evidence (Cresswell & Poth, 2018; Miles et al., 2020) to examine alternative explanations for the patterns emerging during analysis. Finally, I provide thick detailed descriptions (Miles et al. 2020) and transcript extracts to illustrate the evidence supporting the patterns that emerged in Chapter IV and V.

The theoretical framework of language socialization and positioning theory described in Chapter II directly influenced the lens I used to interpret the data. I analyzed the data by asking myself "how is this student socializing others and being socialized in this moment through language?" followed by "how does the observed socialization influence participation of group members?" concluding with the question "what evidence can I provide to support my interpretation?" "Is their counterevidence that challenges my interpretation?" The findings in both Chapters IV and V result from my understanding of the theoretical perspectives of language socialization and positioning theory described in Chapter II.

Chapter IV addresses the first research question; what communicative practices do students use to negotiate the incorporation of ideas as they are instructed to build group consensus on a scientific model? This question focuses on the cultural process of developing a consensus model. The communicative practices discussed through each pathway both shape and are shaped by students using them which is a fundamental perspective in language socialization and positioning theory. Language socialization research examines how people use language in everyday social interactions. Characterizing the pathways of communicative practices in consensus building is one way to conduct LS research because I am revealing the practices through which these students were socialized through language to use language in an instructional setting. The discussion of student socialization is addressed further in Chapter V where identity models for each group member are used to describe the patterns of communicative practices that influenced their position and participation in the group. Language socialization and positioning theory are concerned with who learners are becoming and how that is shaped by communicative practices. This study addresses the communicative pathways that influence consensus models, and then how students both socialize and are socialized to participate during consensus model building.

# CHAPTER IV

# PATHWAYS IN CONSENSUS MODEL DEVELOPMENT

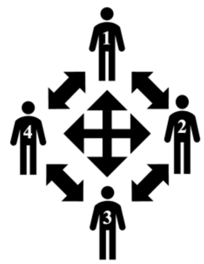
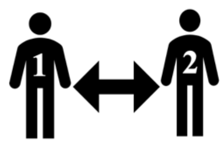
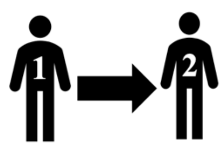
This chapter presents an analysis to answer research question one: What communicative practices do students use to negotiate the incorporation of ideas as they are instructed to build group consensus on a scientific model? The following sections present an overview of the communicative pathways students used to add various scientific and aesthetic entities to their group consensus model. Next, I will describe how each group constructed their model. The final sections of this chapter will discuss the four pathways and the associated communicative practices.

## Overview

The analysis for research question one illuminated four pathways performed by both groups for how entities became incorporated into the group models. Figure 3 showcases the four pathways with diagrams displaying levels of student involvement. The pathway that supported the most involvement from all group members is the group discussion pathway, where all or majority of the group engages in discussions around the ideas they are considering adding to their model. The pair discussion pathway is where two students discuss what should be included in the model, and then any group member draws the entity in the model as decided by the two students. The third pathway is student instruction, which is characterized by one student deciding what to add and telling another student to draw. The final pathway, single addition, is where the same student decides what and how to represent an idea and draws that idea into the model without

**Figure 3**

*Diagram of Pathways*

| Description | Who participates in discussion | Who draws entity on model |
|---|---|---|
| | Group Discussion Pathway | |
| The majority of group members participate in the conversation around the addition of the entity. Any of the group members add the entity to the model. |  |  |
| | Pair Discussion Pathway | |
| Two group members participate in the conversation. Any of the group members add the entity to the model. |  |  |
| | Student Instruction Pathway | |
| One group member decides what entity to add and instructs another student to add it to the model. The second student adds the entity to the model. |  |  |
| | Single Addition Pathway | |
| One group member decides what to add and adds the entity to the model. |  |  |

discussion. These pathways demonstrate a continuum of group member involvement. Table 5 shows the distribution of pathways used by each group.

Group 3 engaged in group discussions more often than Group 5, indicating they spent more time deciding as a group what entities to represent in their models and how to

**Table 5**

*Frequency of Pathway Usage*

| Pathway | Group 3 | Group 5 |
|---|---|---|
| Group discussion | 5 | 3 |
| Pair discussion | 1 | 1 |
| Student instruction | 2 | 2 |
| Single addition | 2 | 4 |

represent them. Group 5 had more instances of one student deciding and drawing entities in the group model, indicating that the group spent less time collaborating to decide what to include in their model. The following sections will describe how entities came to be included in each group's model to illustrate the four pathways of consensus model development. These vignettes do not capture all of the interactions and conversations that took place during the construction of the model. The vignettes offer overviews of the development of the group models. All components and entities in the group models were analyzed for the process of group consensus. The analysis included entities oriented toward explaining the scientific mechanisms and entities related to task completion that did not require conversations around scientific or mechanistic reasoning (Russ et al., 2008).

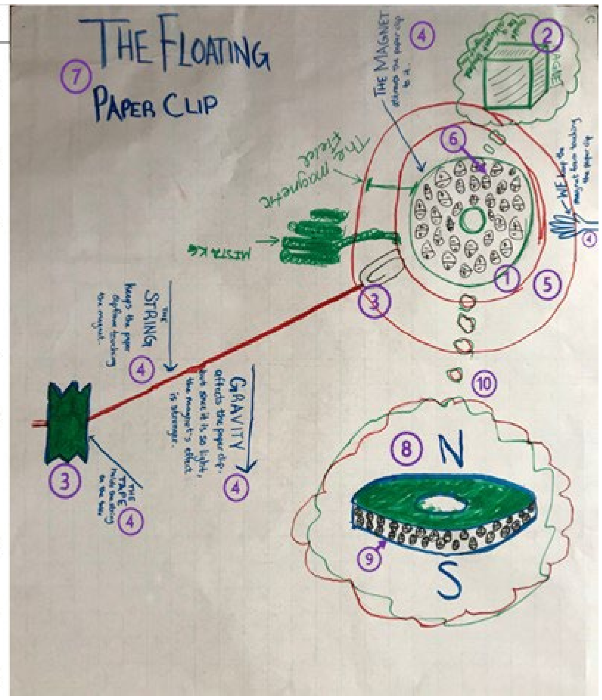
## Group 3: Group Model Construction

The consensus model conversations began during the second step in the instructional sequence. Figure 4 shows the entities included in Group 3's model, the order they were included, and the associated pathway. Damien begins step 2 by asking the

**Figure 4**

*Group 3 Model with Entity Order*

| Order | Entity | Pathway |
|---|---|---|
| 1 | Magnet | Group Discussion |
| 2 | Thought bubble with square magnet | Group Discussion |
| 3 | Paperclip, Tape, and String | Student Instruction |
| 4 | Text of forces acting on paperclip | Single Addition |
| 5 | Magnetic Field Lines | Group Discussion |
| 6 | Molecules in magnet | Pair Discussion |
| 7 | Title of Group Model | Single Addition |
| 8 | Side view and poles of magnet | Group Discussion |
| 9 | Molecules within side view of magnet | Group Discussion |
| 10 | Thought bubble around side view of magnet | Student Instruction |




group the guiding question, “what do agree should be in our model” (line 84). The group discusses some of the entities to possibly be added to their model. As shown in Figure 4, Group 3 began by deciding to add a magnet and an alternative-shaped magnet in a thought bubble (entities 1 and 2). The paperclip, tape, and string were added to the model by Addie in pencil first, and then she directed Evan and Damien to trace what she had drawn (entity 3). Addie added the text of the various forces (i.e., gravity, string, and tape) acting on the magnet without discussing it with the group (entity 4). She comments that she liked what she wrote for one of the forces and asks if anyone else wants to add a force. The group does not respond to her inquiry, and she adds all the forces written in the model. The group engages in a discussion about the addition of magnetic field lines. After the group discussion, Damien draws them on the model (entity 5). Evan and Addie converse about the molecules in the magnet, and Evan decides and draws the molecules into the model (entity 6). Addie states that the model needs a title, Lindy agrees with her, and Addie writes a title without consulting the group on the content (entity 7). Evan is checked out of class early at this point of the model development.

After Evan leaves, the group adds nothing else to the model. They move into step four of the consensus model development phase. Addie is the assigned leader for this step and begins a conversation about the evidence they have that supports what they have incorporated into their model. The teacher and researcher discuss with the group, and the conversation leads Addie to question how the molecules are represented in the model. The following day when the entire group is together again, Addie expresses her concerns with Evan, and the group engages in a conversation about the molecules in the original magnet. The group decides to add another viewpoint of the magnet and the representation of the molecules inside of the side view of the magnet (entities 8 and 9). The final entity (10) to be included in the model is a thought bubble around the additional view of the magnet. Addie directs Damien to draw the thought bubble. He is resistant at first, so Addie draws the first thought bubble. Damien then expresses that he was supposed to draw it, and Addie tells him to trace hers. Evan agrees with Addie and tells Damien that it will look better with two colors. The group finishes creating their model seconds before the class is prompted that it is time to present the group models to the class.

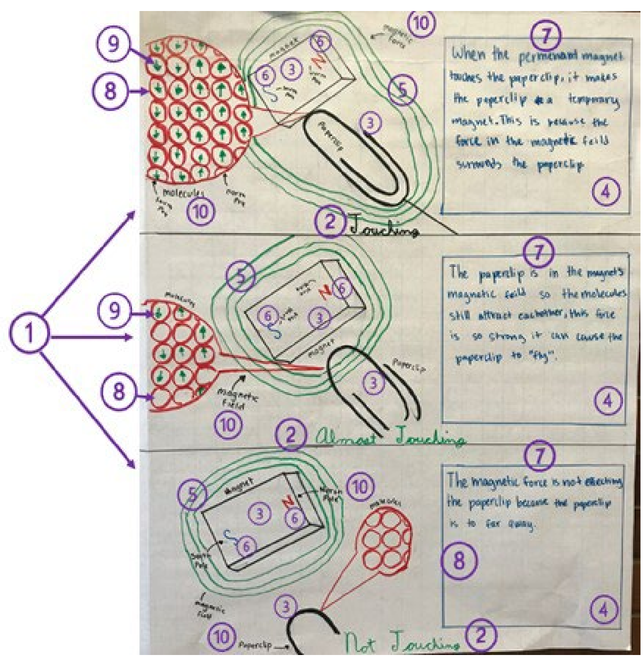
**Group 5: Group Model Construction**

Figure 5 displays the entities within the group model and the added order. The layout of three sections in the group model (entity 1) was the first idea discussed by the group. Rebecca suggests the idea, and the group does not acknowledge her suggestion. A few minutes later, the group began discussing representing the floating paper clip phenomenon in three orientations. Dylan presents a different view from what Rebecca initially suggested. Emma challenges Dylan's idea, and Landon, Emma, and Dylan then decide to use three equal sections. The group talks about the headings for each section resulting in the titles: Touching, Almost Touching, and Not Touching (entity 2).

**Figure 5**

*Group 5 Model with Entity Order*

| Order | Entity | Pathway |
|---|---|---|
| 1 | Sections showing the three orientations | Group Discussion |
| 2 | Headings for each section | Group Discussion |
| 3 | Magnet and paperclip | Pair Discussion |
| 4 | Description Boxes in each section | Single Addition |
| 5 | Magnetic field lines | Single Addition |
| 6 | North and South poles in magnet | Single Addition |
| 7 | Descriptions | Student Instruction |
| 8 | Molecules and zoom in bubbles | Single Addition |
| 9 | Arrows in molecules | Student Instruction |
| 10 | Labels for the various entities in model | Group Discussion |




Landon and Dylan state that the model must include a magnet and paperclip (entity 3). They assign Rebecca as the drawer of the magnet and paperclip. Landon then asks Dylan what shape the magnet should be. Dylan responds with square. Landon counters that the magnet be shaped like a rectangle. The two students debate about the shape. Emma asserts that it should be square. Neither Landon nor Dylan acknowledges her assertion. Dylan then agrees with Landon that it should be rectangular. Rebecca adds the magnet and paperclip to each section as a rectangle. Without consulting with the group, Emma adds text boxes to each section while Rebecca works (entity 4). While Rebecca and Emma work on the model, Landon and Dylan play a game. When Rebecca finishes drawing the magnets and paperclips, Dylan draws the magnetic field lines to the first section and prompts the group to look (entity 5). No group member gives a verbal or physical response to Dylan's prompting. Dylan continues to draw the field lines in the two other sections of the model. Next, Landon states to the group that the magnets need North and South poles; he then adds an N and S to represent the two poles (entity 6).

Following, Emma asked the group what she should write in each section inside the textbox she added for the first section. Landon gives her a suggestion, and Dylan agrees with the suggestion. Landon repeats the suggestion so that Emma can write it and then tells her what to write for the remaining two sections' textboxes (entity 7). Landon suggests that they add a thought bubble with molecules. Dylan agrees and adds that he wants to draw the arrows inside the molecules. Landon proceeds to draw the thought bubble and molecules as he described (entity 8). When Landon finishes drawing the molecules inside the thought bubble, he begins to add arrows to the molecules. Emma stops him and tells him that the arrows are Dylan's job. Landon gives Dylan the marker and tells Dylan the direction to draw the arrows inside the molecules. Dylan draws the arrows as suggested by Landon (entity 9). The final entity to be added to the model is labels for the various parts in each section (entity 10). Emma suggests that Landon write the labels, but he says no. Rebecca begins to write the labels in the first section. Dylan notices that she wrote ‘magnetic force’ where he had drawn the magnetic field lines. He corrects her, stating that it (entity 10) is a ‘magnetic field.’ The group then engages in a discussion around the terms used. Rebecca does not change the first section but writes ‘magnetic field’ for the following two sections (entity 10). The group works on their model until the end of the day. The next day the group transitions to the fourth step of the consensus model-building phase of instruction. They do not change their model before presenting it to the class.

As described above, both groups completed the assigned task of creating a group model. The groups’ ability to reach a consensus on the model varied from entity to entity. Each entity was analyzed through the discourse and actions surrounding its inclusion to understand the level of participation and involvement of group members. The following sections will define the four pathways and describe the communicative moves that characterize them. Examples from each group will be provided as illustrations.

## Group Discussion Pathway

There were eight instances between the two groups where the students engaged in a group discussion about including specific ideas and how to represent them in their models. Group 3 performed the group discussion pathway five times, while Group 5 engaged in group discussions three times. The group discussion pathway is characterized by the most engagement from various group members and promotes authentic consensus-building in some instances. The group discussion pathway promoted both task-oriented discussions and conversations related to scientific mechanisms. One simple example of the group discussion pathway that can lead to consensus building was performed by group three at the beginning of day four.

Extract 1

| | | |
|---|---|---|
| 84 | Damien: | What do we agree should be in our model? |
| 85 | Evan: | Ok. I think we should each go around and pick the part of our model that we feel the most confident in and go from there |
| 86 | Damien: | Ok |
| 87 | Lindy: | I think we should have a magnet, definitely, yeah |
| 88 | Addie: | Nice |
| 89 | Damien: | I agree with both of those decisions. |

In this storyline, Damien is the assigned leader and reads the prompting question for the second step of the consensus model building "What do we agree should be in our model?" (Line 84). Evan shares an idea related to the group process for this step that Damien accepts. Lindy shares an idea to include a magnet in the model and Addie signals agreement by saying "nice" (Line 88). Damien also signals agreement with Lindy's idea and the idea from Evan in line 89. In this example of group discussion, an idea is presented to the group by Lindy, and two group members verbally express agreement. This example displays a task-oriented interaction for the group discussion pathway. Later in the class period, the group engaged in another group discussion about what shape the magnet should be, which had more discussion related to the science mechanisms behind the entity they are representing.

Extract 2

| | | |
|---|---|---|
| 168 | Evan: | All right, so how should we start drawing our model? You should start with a magnet. |
| 169 | Lindy: | Yes, should we draw a circle, a circular one? or a |
| 170 | Evan: | I think we should do both |
| 171 | Lindy: | Both? The circular and the- |
| 172 | Addie: | Is there a difference? |
| 173 | Evan: | I don't know, I just think it's good to show both |
| 174 | Damien: | Ya |
| 175 | Lindy: | So, should we split the paper in half? |
| 176 | Evan: | Umm yeah |
| 177 | Addie: | But is it any different though? |
| 178 | Evan: | I mean not really but like a circle |
| 179 | Addie: | What if by the magnet you like put a thought bubble like a different type of magnet in a thought bubble |
| 180 | Evan: | Yeah |
| 181 | Lindy: | Do you guys agree with that? |
| 182 | Evan: | Sure |

This storyline is the first interaction after Evan becomes the assigned leader of step three when the group creates the consensus model. Evan asked how to start drawing the model and responded himself by saying to start with a magnet (line 168). As described in the previous extract, the magnet is the first entity decided by the group. Both Addie and Damien agreed to add a magnet. This group discussion led to the group identifying the magnet's shape and including a thought bubble with a differently shaped magnet inside. The shape of the magnet is significant in the model because the magnetic fields are different around a circular or rectangular magnet.

The two storylines illustrated above are examples of group 3 engaging in group discussions that led to the inclusion of macro-level entities in the final group model. Group discussions are characterized by most group members participating to some degree in the conversation and agreement in the decision of how to represent the entity. The first example in Extract 1 displays a task-oriented decision, while the discussion in Extract 2 relates to the scientific ideas they are representing. Group 3 had more instances of engaging in science reasoning conversations through the group discussion pathway (discussed further in Extracts 5 and 6).

Group 5 predominantly engaged in group discussions to complete the assigned task rather than engage in scientific reasoning. For example, Group 5 discusses their model's layout as a group. Rebecca offers a suggestion to the group about having three views. She begins by saying, "If we have our model...." Rebecca's speech is hard to hear, and the rest of her utterance is not transcribable, but she gestures with her hands while speaking to three distinct sections on the model at the top, middle, and bottom of the paper. The group members do not make any verbal or physical response to her idea at that moment, but the idea is presented again by Emma in the following storyline.

Extract 3

| | | |
|---|---|---|
| 143 | Dylan: | Alright so we should split it into three sections. Um maybe two up here and maybe one big one down here <*gestures to the poster*> |
| 144 | Emma: | That's not equal we should just do three lines |
| 145 | Landon: | Or not three lines because that would split into four sections |
| 146 | Emma: | Two lines so we have three sections |
| 147 | Dylan: | Ya let's do that |
| 148 | Landon: | So, every ten sections |

This storyline demonstrates how the idea of three sections originally presented to the group by Rebecca is addressed again by Dylan, Emma, and Landon. Dylan suggests three sections and gestures, with two sections at the top of the model and the third section being larger and at the bottom of the model. Emma expresses that sections should be equal and split with three lines. Landon corrects her, stating that three lines would create four sections (line 145). Emma corrects her original assertion by saying, “Two lines, so we have three sections” (line 146). Following this extract, Rebecca counts the line markings on the poster. Landon tells the group that each section needs ten lines to create three equal sections. Although including three views enabled the students to demonstrate their reasoning with greater sophistication, the conversation focused on how much space to give each of the three sections, not the importance of representing the phenomenon in three orientations.

This storyline about the three sections of Group 5’s model was included as the group discussion pathway because every group member contributed to some degree to the discussion and creation of the sections. Beginning with Rebecca’s initial idea and gesture, similar to the final representation, and the discussion between Landon, Dylan, and Emma. Rebecca and Landon figure out how to create equal sections using the lines already on the poster paper, and Emma draws the two lines using a ruler in the group model. Group 5’s conversation above shows that the group reached a consensus on including the three sections in the model. However, They did not converse about the scientific mechanisms while engaging in Pathway A.

**Communicative Practices that Characterize the Group Discussion Pathway**

Two types of communicative practices promoted group discussions. The first communicative practice was when a group member posed a question to the group. When a question is asked of the group, it opens the conversational floor to allow others to participate. Four of the five instances of Pathway A for Group 3 were started when a group member posed a question. Two examples have already been shown, when Damien asked what to include in the model (Extract 1, line 84) when Lindy asked what shape of magnet to include (Extract 2, line 169). Group 5 had one instance of group discussion initiated with a question posed to the group. Dylan was working on the heading for each section. He writes 'Touching' as the heading for the first section. Emma then asked the group what to title the heading of the middle section of their model.

Extract 4

| | | |
|---|---|---|
| 202 | Emma: | Wait then how are we gonna say far way? <*gesturing to the middle section*> |
| 204 | Landon: | Touching and being pulled by the magnetic force |
| 205 | Emma: | @@@ Almost touching |
| 206 | Landon: | Close by |
| 207 | Dylan: | Being pulled |
| 208 | Landon: | Just put almost touching |

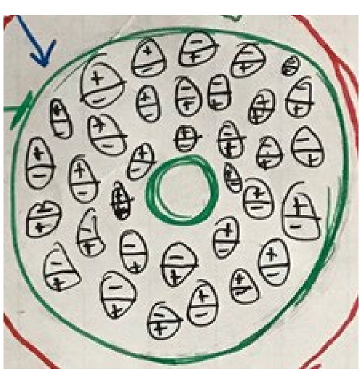
In this storyline, Emma, Landon, and Dylan discuss what heading to put for the middle section. Emma begins the discussion by asking a question (line 202). The group then starts giving ideas. Landon then tells Dylan to "just put almost touching" (line 208), an idea that was presented by Emma (line 205). Dylan then writes 'Almost Touching' as the heading for this section. The question presented by Emma seemed to open the discussion between most of the Group 5 members.

The second communicative practice that promotes group discussions is when an idea is shared, and another group member does not agree with the idea. For this communicative practice students have to be willing to share an idea or willing to vocally challenge another student's idea. This type of communicative practice promoted group discussions two of the three times for Group 5. For example, in Extract 3, Rebecca had initially offered an idea to represent three varying orientations of the paperclip in proximity to the magnet. Dylan suggests an alternative idea for how to place the three orientations (line 143). Emma challenges this idea during the group discussion (line 144), where the group ultimately decides to use the idea Rebecca suggested originally.

Group 3 had one instance of this type of communicative practice that resulted in a group discussion that required scientific argumentation about the reasoning behind the "molecules" Evan added to the original model. This decision to add the side view of the magnet. The conversation begins when Addie expresses concern with how the original magnet's molecules are represented (entity 6, see Figure 6). Evan had drawn the

**Figure 6**

*Original Drawing of Molecules*



molecules on the model before he was checked out of class early for the day before the conversation occurs. In lines 16-22, Addie tells Evan why she is uncertain about the representation of molecules in their model. At the same time as Addie expresses her

Extract 5

| | | |
|---|---|---|
| 16 | Addie: | So, we were discussing evidence and we weren't sure about how the molecules looked so then we got some bar magnets, and I was playing with them holding them like this and they stuck together. And then I flipped this one over so like. How do I explain this? So like |
| 17 | Lindy: | Like a pancake |
| 18 | Addie: | This is like the bottom. This is like the top and then I flipped it over and the bottom is here, and the top is here and they didn't stick together. So, then I was thinking that the molecules must not be how we were thinking cause like. I was thinking like south. |
| 19 | Evan: | O::K? |
| 20 | Addie | But. I don't think it's like that anymore <*rough paper noises*.> So ya. I think if you broke the magnet the other way it would stick to there so. But like it would be really. Hard to break this way |
| 21 | Evan: | #### chisel |
| 22 | Addie: | So that's why no matter which way you broke it, it's stuck together because we were only breaking it ### this way. We didn't break it on the side. So, I drew like the bottom. The bottom would be like all negatives. We would only see the negative type of atoms and then on the side ya. |

concern, Damien starts to try to erase something on the model, making the poster move on the table. The group then switches the conversation to what Damien is doing on the model. Extract 6 documents the conversation where the group negotiates the representation of the molecules in the group model.

Extract 6

| | | |
|---|---|---|
| 41 | Evan: | Just always leave your hands still. So, um I don't think we really need to fix this. I think this is fine. We just need to show it from a different angle like here |
| 42 | Addie: | But like if you were looking at that angle you would only see like the positive or negative |

43 Evan: ya that’s why we have two different angles.

44 Addie: ### what?

45 Evan: Angles.

46 Addie: Ya but that means like

47 Evan: so, we have like

48 Addie: do you see what I am saying?

49 Evan: um:: no. so if we have this:: that. I ## if we just show it like this standing up on its side. Then we have both. Then we would be able to show both things.

50 Addie: But like we have to fix that still.

51 Evan: why?

52 Addie: mmm.

53 Evan: I just don’t see a point. Like I think that’s fine

54 Addie: You’re like covering your face. What do you guys think?

55 Lindy: MMM, we are in disagreement

56 Evan: I don’t think there

57 Damien: I disagree mmm.

58 Evan: I so. I don’t think there’s anything with that I just don’t think it’s showing the whole story it’s just showing half of the story.

59 Addie: What do you guys think? Should we leave that picture or fix it, the magnets?

60 Evan: We don’t have much time.

61 Addie: We have 10 minutes

62 Lindy: Depending on how unsure we are about this we can go without, or we can go with.

63 Evan: well.. see. I think that um. So. I think that we are pretty much correct but it’s just showing it from a two-dimensional frontal view. And we need to show it from a 3-dimensional point of view.

64 Lindy: What is?

65 Evan: That is. It is showing it from a 2-dimensional view, and we need to show it from a three-dimensional view. So, we just need to add the other angle.

66 Addie: I think I kind of see what you are saying.

67 Lindy: Ya I kind of like what Evan is saying.

68 Evan: There is this but then there is also this. But that’s the <*muffled*>

69 Damien: That’s the part I am confused about. It’s negative on one side and <o*verlapping*

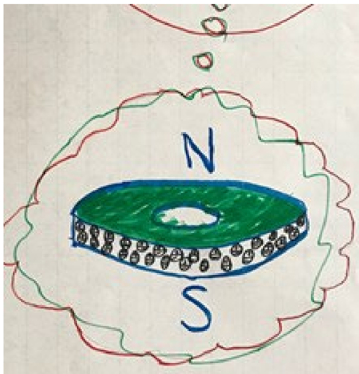
| | | |
|---|---|---|
| | | *speech>* |
| 70 | Evan: | There is this magnet |
| 71 | Addie: | If you looked at it from this perspective, then you would either only see the positive side of the atoms or the negative side |
| 72 | Damien: | Evan, I am confused on this. So why is it positive here and negative here, and negative here and positive here? Positive positive positive positive |
| 73 | Evan: | Cause I was trying to show the mixture of things but it's going to be easier to show with a second picture |
| 74 | Lindy: | We should probably start drawing |

In this storyline, Addie and Evan disagree about how the molecules are represented in the magnet. They discuss while Lindy and Damien are listening. Lindy then joins the conversation by stating that the group disagrees (line 55). Damien also says he disagrees (line 57), although what he does not agree with is unclear through the audio data. Addie asks the group what they think (line 59). Lindy indicates that she does not have an opinion (line 62). Eventually, Addie states that she understands Evan's perspective (line 66), and Lindy also agrees (line 67). Damien says he is confused twice (lines 69 and 72). Addie and Evan answer his inquiries by explaining the perspective (lines 71 and 73). Lindy then ends the storyline by prompting the group to start drawing the additional representation of the magnet (line 74). The addition to the group model is displayed in Figure 7.

As documented in multiple points in this storyline, this group discussed the concern of the representation of molecules in the magnet. Through this discussion, Addie, Lindy, and Evan decide to add the alternative view of the magnet. Every member of Group 3 participated in the discussion to some degree. Addie and Evan engaged most often. However, Lindy participated by adding to Addie's description when expressing her

**Figure 7**

*Additional View of Molecules in Magnet*




concern (Line 17). She also noted a disagreement among group members (Line 55). The observation of disagreement may have signaled her own disagreement at the time or her observation of the disagreement between Addie and Evan. Lindy then signals her agreement with Evan in Line 67, and she ends the conversation by turning the group's attention to the task of drawing (Line 74). Damien expressed his concerns about the model, demonstrating his involvement with the discussion (Lines 69 and 72).

In summary, the group discussion pathway toward entity inclusion on a consensus model promotes the highest levels of involvement from all group members and provides the closest opportunity to obtaining a full consensus from the group about adding entities into the model. Group Discussions provide more opportunities for students to negotiate the inclusion of entities. The guiding questions from the instructional design (Extracts 1 and 2) afforded students the right to share ideas with the group. When students displayed the right to challenge an idea (Extracts 3, 5, and 6), others had the duty to respond and negotiate. Although group discussions could lead to a consensus from the group, there is not enough evidence to generalize that it led to consensus in all instances it was enacted. The group discussion pathway is characterized by two different communicative practices, asking a question to the group, and challenging another group member's ideas.

## Pair Discussion Pathway

This pathway occurs when two students discuss and decide what entity to include and how to represent it. Then, the entity is added to the model by one of the two students in the discussion or another group member that did not engage in the discussion. In this pathway, two students displayed the right to engage in the decision-making, while any group member was responsible for enacting that decision. The pair discussion pathway could potentially support scientific reasoning between group members in some instances. However, in both instances in this study, the pathway was only used in task-oriented discussions. Groups 3 and 5 each performed this pathway once during the construction of the group model. Extract 7 offers an example of the pair discussion pathway from Group 5 when they discuss the shape of the magnet in their model. In this unit students interacted with circular magnets and rectangular bar magnets. The magnetic fields are arranged differently in the two types of magnets. While the shape of the magnet is relevant to students' depictions of the underlying mechanisms, this does not come up in the students' conversations.

Extract 7

| | | |
|---|---|---|
| 83 | Dylan | We should definitely draw the paperclip |
| 84 | Landon | And a magnet |
| 85 | Landon: | (after a pause) K what kind-this is the most important thing we have done all day. |

What kind of magnet should we draw in the picture?

86 Dylan: A square one.

87 Landon: I disagree I say rectangle

88 Emma: Wait what are we going to do?

89 Dylan: A rectangle is a square sir

90 Landon: Is it? What kind of magnet are we going to draw?

91 Dylan: But then again, a square is not a rectangle

92 Emma: I think we should do a square ya

93 Landon: Square yak, my neighbor is allergic to yak. She is a knitter and she bought yak yarn and she was sneezing a lot

94 Dylan: I didn’t know you could be allergic to yak.

95 Emma: Wait what type of magnet are we using?

96 Dylan: I want to say square

97 Landon Rectangle

98 Dylan: Rectangle rectangle

99 Landon: I was kidding rectangles are far superior to squares.

During the above storyline, Dylan tells the group they must include a paperclip, and Landon adds that they must include a magnet. Following these assertions, Landon and Dylan discuss what shape of magnet to include (lines 85-92). Emma asks a question (line 88) and suggests “a square” (line 92), but it is not acknowledged verbally or physically by Landon and Dylan. The two boys decide that the magnet should be rectangular, which is different than what Emma suggested. As noted, the students do not mention circular magnets which would impact how they represent micro-level entities. Rebecca draws the magnet as a rectangle after the discussion. This example includes all group members, but only Landon’s and Dylan’s comments are considered for the model. Emma’s question and suggestion were ignored until she asked what type of magnet they would use (line 94). Dylan and Landon decided on the shape. Rebecca did not engage in the discussion and only carried out what was decided by Landon and Dylan. Landon and Dylan were the two group members to engage in the discussion about the idea. Rebecca drew the magnet according to the decision that Landon and Dylan made. There is no further discussion about the shape of the magnet in this group.

### Communicative Practices that Characterize the Pair Discussion Pathway

The communicative practices promoting pair discussion, is when one student prompts an act to be performed or asks a question, another student decides how to perform the act, and then any group member will add the entity to the model according to what was decided by the two students who engaged in the discussion. The example from group 5 above in Extract 7, Landon is the assigned leader and asks the guiding question of what to include in the model. Landon and Dylan debate the shape of the magnet. Emma offers her opinion and Landon makes an off-task comment that redirects the conversation. (Extract 7, line 83). Landon prompts the act (lines 84-85) to represent the magnet. Dylan engages in a discussion about how it should be executed with Landon. In this example, Landon and Dylan display the right to engage in the discussion. The two do not verbally acknowledge Emma's suggestion. Rebecca performs the act that Landon and Dylan discussed. In this interaction, Landon and Dylan have the right to discuss and decide what to include in the model. Emma inserts her opinion but is not afforded the right at this moment for her opinion to be included in the discussion. Dylan's and Landon's lack of acknowledgement of her assertions demonstrates their ability to deny her that right, even if it is tacit. Rebecca demonstrates that it was her duty to add the magnet as decided by Landon and Dylan by drawing the magnet as a rectangle. She does not verbally disagree or draw the magnet in a different shape than what Landon and Dylan decide.

An example of the pair discussion pathway from Group 3 is when Addy tells the group, saying, “Someone can add the molecules in the magnet” (Extract 9, line 468). Addie’s act displays the right she had to prompt another member to act. After a few moments, Evan responds to Addie’s prompt, saying, “I shall start drawing molecules” (line 473). Evan assumed the assigned duty and completed the act. Addie does not tell Evan how to represent the molecules, so Evan represents them according to his ideas which Addie later challenges in step 4 of model building. The pair discussion pathway is limited in description because it is only observed one time by each group. For group 3, one of the two participating group members draws on the model. Group 5 has two students discuss and decide the entity and how to represent it and third group member draws it as directed by the deciding group members.

## Student Instruction Pathway

The involvement of two students also characterizes the student instruction pathway, the differences is that one student performs the decision-making. One student will direct other group members on what to draw in the model. This pathway differs from the pair discussion pathway because what entity to represent and how to represent it is decided by one individual. That individual will direct another group member to execute the decision. The student instruction pathway does not afford any opportunity to engage in scientific reasoning conversations within the group. It appears to be only related to task completion. One group member has the right to decide about the entity and the right to assign another member the duty to represent it on the model. There is no discussion about the entity or how to represent it in the group. Groups 3 and 5 each have two instances of this pathway leading to the addition of an entity. Group 5 provides an example of this entity in the following storyline.

Extract 8

| | | |
|---|---|---|
| 306 | Emma: | Guys what should I draw? |
| 307 | Dylan: | Whatever comes to mind |
| | Emma: | So, like the force between them <*unintelligible*> |
| 308 | Landon: | I think not touching <*unintelligibl*e> |
| 309 | Dylan: | Ya write not touching |
| 310 | Landon: | So, I would write the magnetic force is not affecting the paperclip because- it is not affecting the paperclip because of the distance between the magnets |

Above in Extract 8, Emma asks the group to tell her what to write in the text box for the not touching section of their model. Dylan tells her to write whatever comes to mind (line 307). Emma then begins to try and formulate what to write. Landon suggests that it is not clear in the audiovisual data but sounds like “I think not touching.” Dylan agrees with Landon that Emma should write “not touching” (line 309). Landon then goes on to tell Emma what to write in the section, which is what is written on the model (line 310).

A similar instance occurred in Group 3, where one student directed another student to perform an act. For example, Addie directs Damien to trace the string on the poster, which she had already drawn in pencil, saying, “you can like trace that with your color” (line 429). Damien then does as Addie directs. Moments later, the following interaction occurred that is also an illustration of Pathway C.

Extract 9

| | | |
|---|---|---|
| 466 | Addie: | Someone can draw the magnetic field. |
| 467 | Damien: | Oh! I’ll do that. Once I fix the string. |
| 468 | Addie: | And someone can draw the molecules in the magnet. |
| 469 | Damien: | Fixed it alright. What do I do? |
| 470 | Addie: | The magnetic field. Just like a circle around the magnet. |
| 471 | Damien: | Easier said than done. But wish me luck. |
| 472 | Addie: | It doesn’t have to be perfect |

In this extract, Addie prompted the group that the magnetic field needed to be drawn (line 466). Damien volunteers to do it (line 467) and then asks Addie how to add the magnetic field (line 469). Addie then directs him to draw a circle around the magnet (line 470). This interaction demonstrates that Addie’s idea of how to represent the magnetic field with a circle around the magnet is added to the model by Damien.

### Communicative Practices that Characterize the Student Instruction Pathway

The student instruction pathway is characterized by the communicative practice of one student directing another to perform a certain act. One student demonstrates the right to assign a duty to another student. In both instances of the student instruction pathway for group 5, Landon instructs others what to add to the model. Addie directs

Damien in both instances for Group 3 . In all four instances of this pathway, the students assigned the duty completed what was asked of them. There are other instances in the data of a group member telling another group member to complete a task, and the receiving group member resists the assignment of the duty. Those instances did not result in adding an entity to the group model, so they are not presented in this section but will be discussed in the next chapter.

In summary, the student instruction pathway is characterized by one student deciding how an entity should be represented in the group model and telling another student to add it. Two students are involved, but the ideas of one student are represented. The communicative move characterizing this pathway is one student directing another student how to draw or add something to the model and the student being directed to carry out the assignment as told.

## Single Addition Pathway

This final pathway provides the least amount of group involvement. There were six instances between the two groups where one student would add an entity on the model without any discussion with group members. The single addition pathway does not afford any discussions of scientific reasoning. Group 5 performed this pathway most often with four instances. Landon added entities twice without consulting his group (see Figure 5 entity 6, poles of the magnets, and entity 8, molecules in the zoom in bubbles). He verbalized that he would add things and then did. Emma and Dylan performed the other two instances in Group 5. Emma added text boxes (Figure 5, entity 7), and Dylan added the field lines (Figure 5, entity 5). Neither Emma nor Dylan made any comment before adding the entities.

Group three had two instances where one student decided and added an entity to the model (figure 4). Addie added the various forces acting on the paperclip (Figure 4, entity 4) and the title at the top of the model without consulting the group on the content of what was added (Figure 4, entity 7). When deciding what they wanted to add to the model, Addie told the group she wanted to add forces. There was no discussion on the types of forces, and she added them when they started creating the model. Another example happens when Addie tells the group they need a title, and Lindy agrees. Addie then adds a title without consulting with the group about what the title should say.

**Communicative Practices that the Single Addition Pathway**

Two possible communicative practices characterize the single addition pathway. The first practice is making a statement before adding an entity to the model. Four instances were split between the two groups where Landon and Addie commented that they would add an entity before they drew on the model. The statement does not initiate any discussion. For example, when Landon says, "We should do a North Pole and a South Pole" (line 234), and Addie states, "We can write a title, the floating paperclip" (line 517). Addie's statement does initiate a response from Lindy, but the response does not promote a discussion about what the title will be. Lindy responds, "We need a title" (line 518). Likewise, Landon states how the molecules and zoom-in bubble should look in the model. Dylan responds by saying that he will add the arrows but does not address the idea presented in Landon's statement. Landon then adds the zoom-in bubble with the molecules.

The second communicative practice for the single addition pathway is the absence of communication. This practice is only demonstrated in Group 5. Emma does not make any verbal indication that she is going to add text boxes before she draws them on the model. Similarly, Dylan does not verbally indicate that he would add the magnetic field lines to the model. After the acts were complete, other members of Group 3 did not make any comments or references to the additions made by Emma and Dylan.

The single addition pathway is characterized by one group member deciding what to represent and adding it to the model without discussion from the group. Two communicative practices were present in this pathway. The first is a statement being made before the entity is added, then the student adds the entity to the model without any discussion. The second communicative practice is silence, or the absence of verbal comments about adding an entity to the group model. Both communicative practices for the single addition pathway display that the individual student that decided and added the entity without discussion from the group had the right to do so. The group members acknowledged this right by not contesting the act being performed.

## Conclusion

This chapter aimed to identify how two groups tasked to create group consensus models came to incorporate ideas and entities in their models. Each group demonstrated various approaches to adding ideas to the model. Patterns within and between the groups led to the development of four possible pathways that characterize how ideas became included in the group models. The four pathways presented in this chapter display a continuum for both the engagement of students and the level of consensus from the group. Group discussions had the highest level of engagement from all group members. It also provided more opportunities for the groups to reach a consensus on the entity they were adding. Two students were engaged in decision-making for the group in pair discussions, which could indicate partial consensus for the group. In Extract 7, Landon and Dylan came to a consensus on the shape of the magnet. Emma did not verbalize agreement with the rectangular shape. Rebecca did not verbalize agreement, but her decision to add the magnet as a rectangle shows tacit agreement. Student instruction also shows partial agreement. The student that adds the entity to the model as directed by another group member displays tacit agreement. The single addition pathway does not signal consensus for the group on the entity provided.

Group 3 displayed more instances of the group discussion pathway, which indicates more opportunities for group consensus conversations. Furthermore, these conversations were where the group articulated their reasoning about mechanisms through discussing micro-level entities within objects like the direction of molecules (Extracts 5 and 6). Group 5 displayed more instances of the single addition pathway, indicating that the group engaged in consensus-building conversations less frequently. The single addition pathway did not afford opportunities for students to engage in discussions around the underlying mechanisms represented in their model because it involves one student drawing on the model without conversation.

There are two communicative moves that signaled the first pathway, group discussion, in both groups. The first is when a student asks a question to the group. Group 3 had more instances where the group engages in a discussion about entities in their model after a group member poses a question. Group 5 only had one instance where a question to the group initiated a group discussion. The second communicative move that promotes the group discussion pathway is when a student shares an idea about an entity and another student challenges or disagrees with the idea. Group 5 had two instances of this communicative practice leading to group discussions, while Group 3 had one. Furthermore, the pair discussion pathway was also signaled with a question for Group 3, but in this instance not all group members were afforded the right to engage in the discussion. Landon and Dylan discussed the magnet, when Emma attempted to join the conversation, her comment was disregarded, and the conversation was changed by Landon.

Both groups completed the assigned task of creating the consensus model, but the communicative pathways used during the creation signal that the model does not represent a consensus from the group. Group 3's model contained a greater number of entities that were drawn in the group model after a consensus conversation, whereas Group 5 only reached consensus on using three sections in their model, the headings for each section and labels for each entity in the model. In order to reveal how these communicative pathways came to be, the following chapter will explore how each group and its members were socialized to perform the various rights and duties associated with each pathway.

# CHAPTER V

# STUDENT SOCIALIZATION DURING CONSENSUS INSTRUCTION

This chapter presents the results related to research question two, how are students in two small groups socialized by their teachers and peers to participate in a modeling task where they have been instructed to reach consensus? Small group interactions are complicated and influenced by multiple factors including prior experiences among students and teachers. While the socialization of these students does not begin or end with their interactions in this case study, analyzing how students are socialized to participate during a particular type of instruction aimed at consensus reveals the way social positionings can influence participation and as a result, learning opportunities. As they work on their consensus models, students in both groups display momentary social positions. This chapter describes how students navigate the various social positions available during small group collaboration. I do not make larger claims about each student's longer-term identities. However, describing students' momentary identities and positionings is important because the accumulation of momentary positions constructs and reinforces classroom identities over time (Kayi-Aydar, 2019). This chapter focuses on how individual students are socialized to participate in a consensus activity and how the momentary positions enacted by group members influence the construction of the group model for a scientific phenomenon. Ultimately, the two portraits of how two groups navigate the consensus process reveal how consensus is resisted, or achieved.

As noted in Chapter III, I applied Goffman's (1981) production roles; animator, author, and principal, to reveal the roles participants can occupy while negotiating the creation of a consensus model. The production roles differ by positions. The positions students assign and enact influence who occupies certain production roles during consensus building. The storyline in this study refers to the interaction that leads to the addition of an entity to the group model. The *animator* in a given storyline is the student that physically draws the entity in the group model. The *author* in the storyline is the individual that directs the animator about what to add or how to add it. The *principal* is the student that shared the original idea or belief presented in the model. The principal in the storyline might not be involved in the conversation at the moment but shared the initial idea with the group in prior interactions. Every entity that was added to the group models had a *principal*, *author*, and *animator*. These roles could be occupied by any group member. An entity could have a different student occupy each role or the same student occupy all three roles.

Applying Goffman's (1981) production roles afforded the opportunity to demonstrate the social negotiations that framed how ideas became incorporated or excluded from the group consensus model. In so doing, I disentangle whose ideas are actually present in the group consensus model and I demonstrate how students' negotiation of momentary social positions shapes this process. While the previous chapter described the conversational pathways through which ideas became included or excluded from consensus modes, this chapter explores the social implications (positions) associated with various discursive moves.

In order to determine the types of positions for the group, I examined the frequency of talk, types of talk, and enacted production roles for each group member. An overview of the participation patterns for Group 3 will be discussed, following I provide a detailed description of the findings that support the enacted positions for each group member. The section for Group 3 will conclude with a summary. Next, I will present Group 5's findings in the same outline. Chapter V will conclude with a discussion of the role of the teacher in the socialization of students, comparison of the two groups that relates to the students' positionings to the pathways discussed in Chapter IV and to the consensus modeling process as a whole.

## Group 3: Addie, Damien, Evan, and Lindy

Group 3 consisted of four students, Addie, Damien, Evan, and Lindy. As described in Chapter IV, Group 3 had five instances of using the group discussion pathway, in their model which offered more opportunities for all students to engage in consensus conversations. The social positionings present in Group 3, demonstrate a status hierarchy often present in group work (Adams-Wiggins et al., 2020; Cohen & Lotan, 2014). Yet the status hierarchy present in Group 3 still afforded group discussions for entities in the model. Addie and Evan enact positions with higher status, while Damien and Lindy enact positions with lower status in the group.

The positions occupied by group members were identified through the following participation patterns. Lindy was the assigned leader for the first step, identifying the similarities and differences in the individual models of the group members. Damien is the assigned leader for the second step of consensus building, determining what they agree should be present in the model. Evan was the assigned leader for the third step, physically creating the consensus model. Addie was the assigned leader for the fourth step, identifying evidence for the model. The teacher assigned a leader for the presentation of the group model to the whole class, based on who was tallest in the group, Damien was assigned based on this criterion. The assigned leaders for each phase of the consensus model building had instructional cards to help them lead the group discussions for each step (see Appendix C). The practice of assigned leadership is recommended to promote equitable participation in group work (Cohen & Lotan, 2014). Cohen and Lotan also suggest using different colors of markers for each group member to use while creating a shared product, which was also used during the consensus model building steps. Addie uses a blue marker, Evan uses a black marker, Damien uses a red marker, and Lindy uses a green marker as seen in the group model (see Figure 4 in Chapter IV).

Table 6 displays the frequency each production role (Goffman, 1981) students performed in the creation of their model. The students in Group 3 each served as the animator, the person who physically drew on the model with their colored marker, for 3 entities. While this means students shared the role of physically drawing on the model equally, the students did not equally author the entities in the model. Addie enacted the positions of author and principal most often within the group meaning that her ideas were represented most often. Evan had the second highest enactment of the author and principal positions. While Evan did not enact roles as often as Addie, he was involved as the author or principal for all entities that represented mechanistic reasoning (Russ et al., 2008) for the phenomenon (see Appendix F.) Lindy was the author and principal for one entity. Damien did not enact the positions of author or principal for any entity.

**Table 6**

*Group 3 Enacted Production Roles by Group Member*

| Student | Animator | Author | Principal |
|---|---|---|---|
| Addie | 3 | 7 | 8 |
| Damien | 3 | 0 | 0 |
| Evan | 3 | 4 | 4 |
| Lindy | 3 | 1 | 1 |

To understand how the students came to enact the production roles for the entities, I examined the frequency of talk for each step of consensus building, and the types of talk performed. Addie talks most often in the group (see Appendix D) with 286 turns of talk during the construction of the group consensus model and presentation of the model. Evan has 253 turns of talk, even though his is absent for the first half of Part 4 of the consensus model development phase. Damien has 229 turns of talk, but he does not speak at all during the presentation of the group model. Lindy talked the least with 143 turns of talk. While Lindy talks the least for the group, she speaks the most during step 1 where she was the assigned leader. This demonstrates that Lindy enacted her role as the assigned leader. The frequency of talk offers one indicator in understanding the verbal participation for each group member during the steps of consensus building. For instance, Addie and Evan enact the author and principal roles most often and talk most frequently within the group which could indicate that they held positions with higher status in the group (Adams-Wiggins et al., 2020).

The assignment of situationally enacted social positions for each group member was identified through frequencies of turns of talk (Appendix D), types of communicative practices (Appendix E), and occupied production roles in the consensus model (Table 6 and Appendix B). The assignment of positions allows for the examination and classification of each student's communicative behaviors in their small group. The positions represent ideological artifacts of the social process of consensus building in a middle school classroom. The analysis revealed that students most frequently positioned themselves and were positioned by each other as the egalitarian group leader (Addie), an off-task novice (Damien), a stereotypical science expert (Evan), and a good assistant (Lindy). Table 7 details the assigned social position for each group member and the communicative practices associated with each position.

An overview of the communicative practices exhibited by each group member in conversation is displayed in Table 7. The information from the types of communicative practices indicate that certain group members engaged in the communicative moves that position others or themselves in particular ways. For instance, Addie prompts others to act more often than other group members. When prompting others, she assigns them a duty to complete and demonstrates the right to prompt others to act. Evan makes clarifying comments to the group most often and responds to questions from the teacher and other students most often. This could indicate that he has the right to discuss ideas for the group through clarifying information and responding to teacher or researcher inquiries. The information in Table 7 will be discussed further in the following sections which detail the participation of each group member and reveal how each student both socialized others and was socialized by others to perform certain rights and duties within the group. The following subsections offer illustrative examples using transcript data to further demonstrate students' positionings within the group.

**Table 7**

*Social Positions and Associated Communicative Practices*

| Communicative practices | Addie- Egalitarian leader | Damien- Off-task novice learner | Evan- Stereotypical science expert | Lindy- Good assistant |
|---|---|---|---|---|
| Commenting | • Balances displays of epistemic stance (uncertainty with moments of certainty)<br>• Corrects others' speech and word choice | • Highest frequency of off-topic comments.<br>• Many instances of expressing uncertainty or confusion. | • Frequently expresses certainty; uncertainty is combined with lengthy speech on what is known | • Does not express uncertainty often.<br>• Does not comment as much as other group members. |
| Consensus | • Asks for consensus from group members.<br>• Frequently expresses disagreement with others | • Expresses disagreement more than agreement.<br>• Does not ask for consensus | • Disagrees with peers more than agrees.<br>• Highest frequencies for both agreement and disagreement in the group | • Asks for consensus from group members.<br>• Agrees with peers' ideas more than disagrees. |
| Prompting | • Highest frequency of prompting others to act or complete a task.<br>• Low frequency in responding to prompts from peers | • Responds to prompts often, most of the time completing what was asked.<br>• Low instances of prompting others | • Balances prompting others to act with responding to prompts from others. | • Does not frequently engage in talk related to prompting others or responding to other's prompts. |
| Questioning | • Responds to questions often from peers and teachers in relation to science content and task completion.<br>• Asks peers questions at a moderate frequency usually related to science content. | • Asks other group members questions often both related to science content and off-topic questions. | • Responds to peers and teachers question most often especially when related to science content.<br>• When asking questions of peers, it is when explicitly stated by the teacher that they should ask questions | • Balances asking and responding to questions usually related to task completion.<br>• Asks the teacher or researcher questions most often, usually about task requirements. |
| Share Ideas | • Shares ideas most often. Ideas were related to task completion and science content. | • Shares ideas least often for the group, when sharing ideas, they varied from task completion, science content, and off-topic ideas | • Frequently shares ideas with the group, mostly about science content. | • Does not share ideas as much as Evan and Addie. When sharing ideas most were related to task completion. |

**Addie The Egalitarian Leader**

Addie was heavily involved in the construction of the group model, she was the author of seven entities, and principal of eight entities. She is the author and principal for the majority of the entities in the model. She also has the most turns of talk for her group (see Appendix D). She often enacts the position of egalitarian leader by prompting others to act and sharing ideas (Wodak et al., 2011; see also Table 7). Because other students generally did what Addie told them to do or suggested that they do, she both claimed and was afforded by her peers, the right to lead the group. Addie demonstrates her right to prompt others early in the model building phase by reminding Lindy that she is the assigned leader of the first step where the group compares their individual models. On multiple occasions throughout the construction of the group model Addie prompts the other group members to do something. For example, Addie assigns tasks to Damien through saying "you can like trace that with your color. I am going to start ###" (line 429). In this example, Addie drew the string that connects the paperclip to the table in the group model with pencil. She tells Damien to be the Animator of this entity by using his assigned marker color to trace what she had already done. Damien does not resist the assigned duty and traces the line affording Addie the right to assign him duties.

Another demonstration of leadership from Addie is her adherence to the directions given by the teacher and researcher. For instance, during the first step, the class had been instructed to ask questions to better understand each group member's individual models. Addie asked each of the group members questions related to their model. For example, she asked Damien, "so, with the arrows, with the like magnet cutting half, are you saying this side like attracts metal and this side like repels stuff?" (line 98) and Evan, "the river of electrons? Is that like the magnetic field?" (line 116). These questions indicate that Addie is trying to understand her peers' individual models and guide the group discussion as instructed. Addie occupies a position of leadership through performing the assigned task and engaging in conversations about the individual models, this position is accepted when her groupmates respond to her inquiries.

In addition to posing questions to her peers, Addie also demonstrates the right to challenge her peers' ideas throughout the construction of the model. For example, in Extract 2 (Chapter IV) the group is deciding what shape to draw the magnet. Evan suggests a circle and rectangle shaped magnet (line 170). Addie asks, "is there a difference?" (line 172). Evan expresses uncertainty but indicates it would be good to show both (line 173). Damien agrees, and Lindy asks about the layout of the model. Addie asks again "but is it any different though?" (line 177). The group ultimately decides to go with the magnet being circular and a square magnet being represented in a thought bubble as Addie suggests (line 179). The shape of the magnet indicates the location of the poles on the magnet which influences the physical representation of the microscopic entities and microscopic field lines the group calls "molecules" in their model.

Similarly, in Extract 5 (Chapter IV), Addie questions Evan's representation of the "molecules" in their model with, "but, I don't think it's like that anymore <*rough paper noises*>" and she then uses evidence to support her reasoning, "So ya. I think if you broke the magnet the other way it would stick to there so. But like it would be really hard to break this way" (line 20). Addie's question about the representation of the "molecules" promotes a group discussion (Extract 6, Figures 6 and 7) and ultimately change their model to include another viewpoint of the magnet in a thought bubble below the original representation. Both of these examples indicate that Addie performs the right to question Evan, and Evan's responses reinforce that right and indicate he accepted the duty to respond to her inquires. Further, the group decided on both occasions to change the model following the discussions initiated by Addie's challenges (See Figure 4, entities 2, 8, 9). Addie's right to question ideas of others influenced the creation and revision of the model through the group discussion pathway.

In addition to these prompts and questions, Addie maintains her position as leader partly by positioning others in the group through correcting their speech, and inserting her opinions when others are talking. For instance, in Extract 10, Lindy was the assigned leader for this step of the consensus modeling and begins by asking her peers the guiding question for the step (line 139).

Extract 10

| | | |
|---|---|---|
| 139 | Lindy | Okay, so our question is, what are similarities and differences in our model? Um I guess we start off with similarities being that we all had a paperclip and magnet. |
| 140 | Evan: | [yep |
| 141 | Lindy: | The difference would be, we all sort of looked at it in different perspectives, because I noticed Addie saw with- she paid attention to the stuff around it, like gravity and [ |
| 142 | Addie: | [the forces |
| 143 | Lindy: | Ya the forces around it. Damien paid attention to like [ |
| 144 | Evan: | [the directions |
| 145 | Lindy: | ya direction of the poles and all that stuff. And then, you focused on the river [ |
| 146 | Evan: | [what's causing ## |

147 Addie: [why is the

148 Lindy: You went into depth. You dived in, quite literally, like the river.

149 Evan: I know, right.

150 Lindy: Ok So, did you guys notice any differences or similarities in our stuff, I guess.

151 Evan: So, I:::noticed some similarities. Damien's magnetic juice is kind of similar to my metaphor to the river of electrons.

152 Lindy: How about you, Addie? What have you noticed that's the same, different, or that we all have?

153 Addie: Something different. Is (p.p.) I guess we all think about magnets differently because I was just kind of looking at the atoms and positives and negatives. And then, you were just thinking about magnetic field and attracting. And then Damien was thinking like half of the magnet pulls things in and half attracts and half of it repels. And then you were just thinking about electrons

154 Evan: yep

155 Addie: And why paperclips are attracted to ma[gnets

156 Evan: [ya

157 Lindy Damien, what about you? What do you think? Anything you noticed?

158 Damien: I noticed that how you and Evan kind of was simul-

159 Lindy: Sim

160 Addie: Sim-i-larity

161 Damien: simi- S I M I L A R Ity

162 Lindy: The s: im:: a:

163 Addie: Sim i:: simi:larity

164 Evan: Similar?

165 Damien: What?

166 Lindy: Sim::ilar

167 Evan: Similar

168 Damien: Ya that wha- <*other group members laugh*> cause like you guys were kind of talking about how the different um, um, power juice in the magnet depends on direction. Uh ya

169 Evan: Alright

170 Lindy: Oh, okay. @@@@

Lindy begins by telling the group differences she noticed in all of the models, starting with Addie's model "the difference would be, we all sort of looked at it in different perspectives, because I noticed Addie saw with-she paid attention to the stuff around it, like gravity and" (line 141). Addie interrupts Lindy and finishes her sentence adding "the forces" (line 142). Lindy agrees with Addie's assertion then starts to describe what she noticed in Damien's model "Ya the forces around it. Damien paid attention to like" (line 143). Evan then interrupts and completes Lindy's sentence adding "the directions" (line 144). Lindy agrees with Evan stating "ya direction of the poles and all the stuff. And then you focused on the river" Evan interrupts and finishes her sentence, as Addie also interrupts and starts to make a comment (lines 146-147). The communicative moves displayed by Addie and Evan suggest that they hold higher status, because they interrupt or finish Lindy's sentence.

Lindy holds the conversational floor by responding to Evan "you went into depth. You dived in, quite literally, like a river" (line 148). Evan agrees with Lindy, then she asks the group what differences and similarities they noticed. Evan responds first stating "so, I::: noticed some similarities. Damien's magnetic juice is kind of similar to my metaphor to the river of electrons" (line 149). Lindy then asks Addie what she noticed as similar or different in the models. Addie described the differences she noticed in the models (line 153). Evan agrees with Addie's description of his model. Addie adds "and why paperclips are attracted to magnets" (line 155). Evan agrees again.

Next, Lindy asks Damien what he noticed in their model. Damien begins to explain his ideas "I noticed that how you and Evan kind of was simul" (line 158). As

Damien is talking, he stops while beginning to say the word ‘similar.’ The group then engages in a conversation around the pronunciation of the word ‘similarity’ (lines 159-167). Damien ends the conversation by saying “ya that wha- [others laugh] cause like you guys were kind of talking about how the different um, um, power juice in the magnet depends on direction. Uh ya” (line 168). Evan responds with “alright” (line 169), and Lindy says “oh okay” as she laughs (line 170).

In the beginning of Extract 10 Addie and Evan interrupt Lindy as she is leading the group discussion. Interrupting and completing Lindy’s sentences indicate the rights that Addie and Evan appear to hold in the group. They display the right to interrupt Lindy while she is speaking, but Lindy maintains the conversational floor, she did not demonstrate the duty to step down as result of the interruptions. It was Lindy’s right as assigned leader to lead the conversation, she resists the assertions that could change who holds the conversational floor. Yet, her acknowledgement and agreement with Addie and Evan’s assertions signals they had the right to interrupt Lindy’s utterances and to share their ideas.

Addies’ correction of Damien’s speech also demonstrates her status in the group. While I assume the intended purpose of the interaction in lines 158-168, may have been to help Damien correctly pronounce a word, Damien’s ideas of the similarities and differences in the individual models were not verbally considered after the interaction. Lindy is the first group member to attempt to say the word but does not speak slowly and never finishes the word (line 159). Addie breaks down the sounds of the word and says them slowly (line 160). Damien attempts to say the word again after Addie’s first correction (line 161). Lindy then attempts to say the word again as well. Addie then says beginning of the word exaggerating the middle vowel, [I] sounds and then saying the whole word exaggerating the sounds (line 163). Evan then says “similar?” (line 164) with a raised intonation indicating a possible question. Damien did not attempt to say the word ‘similar’ again during the consensus modeling phase of instruction. Addie was not the only group member to correct Damien in this example. However, Addie corrects Damien’s word choice on a few other occasions (see Extract 11), indicating a performed right to correct others in the group.

Extract 11

| | | |
|---|---|---|
| 95 | Damien: | Okay. So, <*inaudible*> Okay so, here’s my model. Don’t judge how the paper clips look like potatoes. |
| 96 | Addie: | I love it |
| 97 | Damien: | Well, anyway, @@ in my model you can kind of see how um the magnet kind of reacts to the paper clips kind of being far away. And then like ### This one, this far away, this is kind of closer. And then like I included um arrows it was because this- I almost think the magnetic power-I don’t know- isn’t like trying to go outwards, but when it’s closer it is, because they just kind of contact. And then, my evidence plus model is like ### kind of like the paperclip, how like far away it didn’t do anything. Closer and closer you can kind of starts- almost have this connect with this and now have positive and negative electrons. And yeah. |
| 98 | Addie: | So, with the arrows, with the like magnet cutting half, are you saying that this side like attracts metal and this side like repels stuff? |
| 99 | Damien: | In a way. Like um <*stutters*> I’m almost thinking as nothing inside. Kind of like, one repels ### |
| 100 | Addie: | So, do you have like an idea of which is North, and which is South? Or do you [ |
| 101 | Damien: | [No, I have no idea. |
| 102 | Evan: | So, if this is- if these arrows are kind of like pushing out and repelling, why is the paper clip ah coming towards? |
| 103 | Damien: | Cause like what I kind of- What I mean by this drawing is like, this is sending # some magnetic things. Juice |
| 104 | Addie: | Magnetic Force |

105 Damien: Yeah, magnetic juice and then like this is connecting, but I'm not sure ###

Extract 11 shows Damien presenting his individual model to the group. Damien begins by prepositioning his model stating, "don't judge how the paperclips look like potatoes" (line 95). Addie offers positive affirmation by telling Damien "I love it" (line 96). Damien then describes his model for the group in line 97. Addie asks him a question related to his model in line 98. Damien responds but stutters at the beginning (line 99). Addie then asks him another question (line 100), Damien interrupts her question and responds with uncertainty saying "no, I have no idea" (line 101). Evan then asks Damien a question about his model "So, if this is- if these arrows are kind of like pushing out and repelling, why is the paper clip ah coming towards?" (line 102). Damien responds to Evan's question "Cause like what I kind of- What I mean by this drawing is like, this is sending # some magnetic things. Juice" In line 104, Addie says "magnetic force" to correct Damien's word choice of "juice." Damien agrees with Addie's correction but continues to use "magnetic juice" in line 105. Both of the examples from extracts 10 and 11 demonstrate that Addie is exhibiting a right to correct Damien's speech. Regardless of Addies intentions, Damien's ideas could be minimized by Addie correcting his word choice or speech. Correcting the word choice in this moment is signaling that "juice" is not a correct word to use when discussing a scientific mechanism. Addie replaces Damien's colloquial descriptions with "magnetic force." Damien continues to use the word "juice" instead of "force" for the remainder of the unit.

Extract 11 demonstrates the right Addie performed to correct Damien's word choice (line 104), but also her taking up the right and teacher assigned duty to actively listen to the descriptions provided by her peers, and to question the content of their model. The questions in lines 98 and 100 appear to be clarifying questions as opposed to questions that challenge ideas like the example in Extracts 5 and 6. Addie also provides positive support to Damien after states “don’t judge how the paperclips look like potatoes” (line 95) and she responds with “I love it” (line 96). The positive statement and clarifying questions indicate an egalitarian style of leadership (Wodak et al., 2011). While not directly observed, positive interactions like this could influence the group environment that supported more opportunities for Pathway A.

Addie influences the construction of the group model through positioning herself as a leader by exhibiting the right to assign duties to others in the form of tasks to complete in the model (Extract 9, lines 466, 468, and 470) correcting Damien’s speech (Extract 10, lines 160 and 163) and word choices (Extract 11, line 104), and challenge ideas (Extracts 2 and 4). Furthermore, Addie demonstrates an egalitarian leader position by trying to instigate group conversations related to the scientific content they are studying by asking questions about individual models as directed by the teacher and researcher (Extract 11, lines 98, and 100), and challenging ideas (Extract 2, lines 172, 177; Extract 5, line 20). She asks other students for opinions during the construction of the model (Extract 6, lines 54 and 59), and tries to keep all group members engaged in the task through assigning duties (line 429). It is through the accumulation of all of this acts and positionings that Addie is occupies the position of egalitarian leader. Her position of group leader supports consensus building by attempting to engage the group through questioning, listening to others, and directing others to share ideas or complete tasks. As leader, her communicative moves also restricted other group members participation by correcting their speech and word choice, and enacting the author, principal production roles frequently. Her position also created space for others to engage in the instructional task through telling others to perform certain acts in the model and asking questions to promote discussions.

**Damien: The Off-Task Novice Learner**

Damien was present and engaged with his peers by speaking almost as frequently as Evan and Addie. However, he often made off-task comments and did not occupy the production roles of author and principal throughout the construction of the model. Damien is the animator of three entities, where others told him what to add to the model (see Table 6). He shares the least number of ideas related to the construction of the model and has the most instances of off task talk for the group (see Table 7). Damien's frequency of off-task comments over all other communicative moves is the reason his participation style is labeled as off-task (Wieselmann et al., 2021). Throughout the instructional unit analyzed for this study Damien did not exhibit the right to assign duties to others indicating he occupied a more passive position in the group. He asked the most questions to other students, both related to the task of creating the model, and questions about off-task topics. Extract 6, Damien asks "Evan, I am confused on this. So why is it positive here and negative here, and negative here and positive here?" (line 72). An example of an off-task questions starts the interaction in Extract 12. Prior to his question, Lindy asked Addie why the group was color coding everything in the model. Damien then asked Evan the question in line 149 "What is your favorite? Green?"

Extract 12

149 Damien: What is your favorite? Green?

150 Evan: Purple

151 Damien: Magenta color

152 Addie: Blue is probably my favorite color, but it is horrible tracing

153 Damien: It's probably like blue. The word I shall not say but then like magenta

154 Addie: The word you shall not say?

155 Damien: It's Evan's favorite color

156 Addie: Why?

157 Evan: Purple?

158 Addie: Why can't you say purple?

159 Evan: I think he means black.

160 Damien: No, I can't say ##

161 Evan: You can't say purple?

162 Addie: Why?

163 Damien: It sounds really weird. But it is ####

164 Addie: Oh! You're just embarrassed to say it. Ok. That explains it. I was like wait what!

165 Damien: There is a couple words I can't say. Which are like super common words to say. It's really.

In Extract 12, Evan responds to Damien's inquiry about his favorite color by saying "purple" (line 150). Damien then responds saying "magenta color" (line 151). Addie tells the group that her favorite color is blue. Damien then tells the group that his favorite color is like blue but "the word I shall not say but then like magenta" (line 153). Addie questions his comment "the word you shall not say?" (line 145). Damien responds saying "it's Evan's favorite color" (line 155). Addie asks him "why?" as Evan asks him if he means purple (lines 156-157). Addie then asks Damien "Why can't you say purple?" (line 158). Evan then comments "I think he means black" (line 159). Damien then responds saying "no, I can't say ##" (line 160). The ending to this utterance is not clear in the audio recording, Evan then asks, "You can't say purple?" (line 161). Addie asks Damien why again. Damien clarifies "it sounds really weird. But it is ####" (line 163). Damien's utterance is not audible in the recording, however, students in the group interpreted what he said, and Addie responded to Damien's clarification saying "oh! You're just embarrassed to say it. Ok. That explains it. I was like wait what!" Damien then explains to the group "There is a couple words I can't say. Which are like super common words to say. It's really." (line 165). Evan asks a student in another group an unrelated question after Damien's comment and the storyline for the group shifts to the instructional task.

In Extract 12, Damien briefly mentions that he cannot say certain words (lines 153, 160, 163, 165). Damien's assertion that he cannot say common words could indicate why he chose to use "juice" instead of "force" in Extract 11 (lines 103 and 105) and why he struggled with the word "similar" in Extract 10 (lines 58-68). Further, Damien was the assigned leader for the group presentation and did not speak at all. As the groups were finishing their consensus models the teacher told the class that the student that was the tallest in the group would be the leader of the presentation. The group decided that Damien was the tallest. When they started their presentation, the group stood at the front of the classroom for a moment silently. Evan held the model up so his face was covered. Addie and Lindy kept looking toward Damien. Addie then whispers something to him, Damien shakes his head from side to side, indicating a possible gesture for no. Addie waits a few more seconds then starts to tell the class about the model. As the group is presenting all members glance at Damien at various moments. Damien does not say anything during the presentation but looks around the class and looks at his group as they present the consensus model. Damien's silence could be related to his statements of the words he indicated he could not say in Extracts, 10, 11, and 12. The combination of his peers correcting his speech, his comments about his ability to say specific words, and his silence during the group presentation indicate that Damien positions himself and is positioned by as a novice in the group. He does not use technical science jargon, and avoids using certain words like "similar," "force," and "purple."

Damien's position as a novice is further evidenced when he expresses uncertainty related to the construction of the group model on a few occasions. Barnes (2004) describes a similar position performed in small group work titled *in need of help,* where a student demonstrates uncertainty, asks for help, or accepts help offered by other group members. Damien's position is similar to Barnes' description, but I use the label *Novice* because/in order to highlight…. For example, in Extract 6 (Chapter IV), Addie and Evan were discussing the way the molecules in their group model were represented. Addie asks the group what they think in line 54. Damien expresses that he disagrees with something (line 57), and then clarifies "that's the part I am confused about. It's negative on one side and" (line 69). Both Evan and Addie respond to his statement. Damien then signals to Evan that he is still confused saying "Evan, I am confused on this. So why is it positive here and negative here, and negative here and positive here? Positive, positive, positive" (line 72). Evan then responds and then the interaction is concluded with an invitation from Lindy to start drawing, "We should probably start drawing" (line 74). In this example, Damien expresses uncertainty, "I am confused," asks a clarifying question "So why is it positive here and negative here…" which he specifically nominates Evan to answer. While asking a clarifying question can also be a sign of expertise (e.g., Addie Extract 5 line 20), without cooccurring with other communicative moves signaling leadership and confidence in scientific reasoning, these moves position Damien as less knowledgeable than his peers. Taken together with the criticisms Damien receives for his speech, the data analyzed demonstrate that across this unit Damien was positioned as an off-task novice.

Although the preceding analysis catalogues Damien's positions as a novice, he also resisted this position on three occasions. An example of Damien resisting negative positioning happened during the last day of working on the consensus model before the presentations to the class. All group members were working on the model when the interaction in Extract 13 occurred.

Extract 13

| | | |
|---|---|---|
| 117 | Addie: | Can I see this? There is like a faster way. |
| 118 | Damien: | What? |
| 119 | Addie: | You can do it faster. |
| 120 | Damien: | Don't worry about my speed. By the time you are done with that I'll be done with this. |
| 121 | Addie: | I'm not. |

In Extract 13, Addie tells Damien that there is a faster way to fix the drawing of the string, which Damien was working on (line 117). Damien asks "What?" (Line 118). Addie repeats that he can perform the task faster (line 119) Damien resists her right to tell him another way to complete the task by responding “don’t worry about my speed. By the time you are done with that, I’ll be done with this” (line 120). Damien often exhibits tacit agreement with Addie’s performed right to tell others to do things (Extract 9), but in this instance he resisted the positioning for being ineffective by explicitly telling her “don’t worry about my speed.” After this direct resistance Addie does not make any more comments related to Damien’s speed while working.

Damien does not claim positions of expert (explaining to his peers using jargon or offering ideas to be represented in the model; Barnes, 2004; Braden, 2016; Wieselmann et al., 2021), he actively positions himself as a non-knower by frequently expressing uncertainty, he is critiqued by his peers for his speech, he makes many off-task comments and asks his peers off task questions and did not enact the role of author or principal for any entity. Taken together, these practices indicate that Damien occupied a local social position as an off-task novice. How researchers and teachers view this social position will depend on the goals of instruction. Perhaps drawing the entities as instructed by a peer signals agreement about the underlying idea and being present and listening to peers engage in scientific argumentation (see Extract 6) is considered a successful form of apprenticeship. However, it is not clear that this is always the case. The entities that Damien draws on the model resulted from direct assignments from Addie. Which may have resulted from Addie’s desire to perform the duty assigned by the teacher and researcher that all group members should contribute to the creation of their model. As a result, there is no clear evidence that the consensus model necessarily reflects his mechanistic reasoning.

**Evan: The Stereotypical Science Expert**

Evan occupied a local social position as a stereotypical science expert during the creation of the group consensus model. Evan performed his role as science expert by using technical science related jargon, answering questions related to science content from his peers, teacher, and researcher, minimal expression of confusion, and high frequency of sharing ideas related to science content (see Table 7; Barnes, 2004; Braden, 2016; Wieselmann et al., 2021). Evan had the second highest turns of talk ($n$ = 245, see Appendix D), which was about 30 instances less than Addie. Evan left class early at the time the group was transitioning to step four of the consensus model phase of instruction where the group would talk about what evidence they had for the model. As a result, Evan missed about 20 minutes of group work time. Even with being gone he still had the second highest turns of talk. When talking Evan often clarified his ideas to the group and responded frequently to scientific related questions from group members, the researcher, and teacher. Evan asks his peers the least number of questions for the group and has the second highest amount of sharing ideas behind Addie. Evan expressed high levels of certainty regarding his ideas compared to the other peers in the group (see Appendix E).

Evan demonstrated linguistic characteristics often associated with the "stereotypical science expert" trope or identity (Braden, 2019; Cole & Zuengler, 2003). Evan uses scientific jargon when sharing ideas more frequently than any other students in Group 3. This jargon is not always used accurately, but it nonetheless functions to signal expertise in this context when interpreted along with his other behaviors. Group members express on multiple occasions that they do not understand what he is saying. For example, in Extract 15, Evan shares his individual model with the group.

Extract 15

108 Evan: All right. So::, um um one of the main four courses is electromagnetism, and magnetism is electromagnetism with no charge. And um charge is a property of electrons and so in a flowing circumstance, you're plugging something in to charge it. Uh The electrons are just carrying the charge to give to the device that you're charging, but this is uh electrons with no charge. So <*mumble*s> Okay, the thoughts are really scattered right now.

109 Evan: So, the electrons flow in sort of a semi-circle direction. Um like This is the magnet and they flow like that, and they flow the opposite direction on the opposite side. So, when you break the magnet apart, these two- these two flows are pointing against each other, causing two halves of the magnet to repel. And a similar thing happens with any magnet, whether it's broken or not. And um this- because the paper clip sort of floats in the river of electrons that's going circularly, so the river of electrons carries the paperclip towards the magnet, but it never repels the paperclip because the paperclip doesn't have a polarity of its own. And polarity is the direction of the magnetic force.

110 Evan: So, the paper clip doesn't have a polarity of its own. It's just taken by the polarity of the magnet, so it's always attracted, but other magnets have their own polarity, so they repel sometimes. Then there's copper. And copper conducts electricity, but it isn't affected by magnets and that's because it does allow electrons to move through it easily, but it doesn't float on the river. And then there's a specific story thing about how, if you have a copper pipe and you put a magnetic ball down through it, it'll go slower than putting the same magnetic ball down to the wood pipe of the same diameter at the same angle. And that's because the electrons do something because the cover that conducts electricity just doesn't attract or repel.

111 Damien: Uh:: hh I kind of lost you a couple of minutes ago.

112 Lindy: I got some of it.

113 Evan: Yeah. Like I said, my thoughts are kind of scattered.

114 Lindy: Okay so, in the beginning, I heard you were saying, and correct me if I'm wrong, you were saying the the- so you have the magnet and then the paperclip, but the reason that the paper clip, let's you push pull the magnet away, the reason it stays-goes down is because, when they're close together, that's not charging it or anything. Like the um. Like a phone

115 Evan: Okay so, it's the river of electrons that's going circular. When the paperclip is in the river of electrons, it floats on the electrons.

116 Addie: The river of electrons? is that like the magnetic field?

117 Evan: Electrons are what causes the magnetic field. So, it's a river of electrons that causes the magnet field. So, if the paperclip is in the river of electrons, it floats. But when you take the river of electrons away, it's just a paperclip.

118 *<Crosstalk, unintelligible>*

119 Damien: I was thinking of that circle thing in it.

120 Evan: That's the river- that's the direction of the river.

121 Addie: So, I didn't totally understand what you were saying, but from what I did get, and I agree with this, is that you were saying the magnet has the North or South pole, but since the paperclip doesn't have that, it can only be attracted to the magnet, it can't repel. Okay, I agree with your idea.

122 Damien: So, Evan, in this picture, you show one going one direction and one going the other. Is it possible to make this side go this way and that side go that way

123 Lindy: If you flip it? Just @ kidding @@

124 Evan: I mean, yeah. But, well, (pause) you can't change the polarity of the magnet. If you break the magnet, it seems like you change the polarity, but that's just because the two polarities, where they normally go like this and just meet in the magnet and to circle around again, now they're just going out of the magnet again and butting heads, causing them to repel. You can't change the polarity, unless it's an electron. Then you can.

125 Addie: I'm freezing right now.

In this example, Evan presents his individual model by comparing the phenomenon of the floating paperclip to electromagnetism (lines 108-110). Group members signal difficulty interpreting Evan's explanations, Damien stated "Uh::hh I kind of lost you a couple minutes ago" (line 111). Lindy expresses that she understood some of it and tries to summarize what Evan had described (lines 112 and 114). Evan then attempts to clarify his ideas (lines 115, 117, 120, and 124). Addie expresses that she didn't understand all of what he had said and then describes what she did understand (line 121). Damien asks a question of Evan's model (line 122), and Lindy answers Damien's question but signals uncertainty by laughing and saying, "just kidding" (line 123). Evan responds to the question (line 124) offering a scientifically accurate explanation of why a magnet cannot be fitted back together (like puzzle pieces) once the magnet is broken. Addie then changes the conversation by telling the group that she is cold (lines 124-125).

Evan uses terms like electromagnetism, polarity, and electrons (lines 108-110) that could be considered scientific jargon in a middle school classroom. Both Damien and Addie express confusion with his description but attempt to engage in conversations around Evan's model (lines 121 and 122). Despite Evan's expressions of uncertainty (lines 108 & 113) he follows the uncertainty with lengthy comments about what he does know (lines 109, 110, 115, & 117).

Evan's comments throughout the entire unit generally focus on his own ideas. For instance, after Addie presents her model to the group, issues the evaluation that her model is "pretty good" then goes on to tell the group evidence that supports his model. They had been instructed to ask questions of their group members' individual models. Rather than ask Addie questions or leave space for the other group members to ask her questions he tells her it is "pretty good" and talks about his own model until the class is instructed to move on to the next step. This act eliminated the opportunity for others to engage with the ideas in Addie's model.

Evan is the animator on three occasions, author of four entities, and principal of four entities (see Table 6). For three of the four instances of Evan's role as principal, the entity that was being represented had conversations related to the micro-level entities involved in the mechanism (see Appendix F). The only instance that was labeled as task-oriented is when Evan added the "molecules" to the model (see Figure 4, entity 6; Extract 9). Addie prompts the group that someone can draw the molecules (line 468) Evan then then adds the molecules without discussing their representation with the group. The addition was assigned by Addie and authored by Evan independently. The actual "molecules" represent mechanistic reasoning, however, the discussion around including the "molecules" did not include talk about the representation. This entity was challenged later by Addie (Extracts 5 and 6) which led to an instance where the group engaged in scientific argumentation around what causes magnetism.

While Evan displays expertise through using science jargon, and sharing ideas relating to science frequently, Evan's science expertise is inadvertently challenged by the teacher and researcher when they engage in a conversation related to Evan's ideas of electromagnetism being the same as magnetism. In Extract 16, the teacher approaches the group and asks the group if they were the ones that were talking about electricity and the transfer of electrons which was an idea that Evan presented in his individual model.

Extract 16

| | | |
|---|---|---|
| 349 | Teacher: | You guys were talking about electricity, like the transfer of molecules? |
| 350 | Addie: | Yeah |
| 351 | Teacher: | I have a thing you can measure it <*handheld multimeter*>, you want to check it out? |
| 352 | Evan: | Ya |
| 353 | Teacher: | You need some magnets? Or do you have some magnets? |
| 354 | Evan: | We have magnets |
| 355 | Teacher: | K, you want one on the one side, one on the other, |
| 356 | Damien: | I don't wanna do it. Evan, you want to do it? you were talking about it |
| 357 | Teacher: | K, and then you are just going to look for the number here. you want me to show you what a battery looks like? |
| 358 | Evan: | Sure |
| 359 | Damien: | @@ That is the saddest thing I have ever seen. It goes from one to zero. |
| 360 | Addie: | Like two, four. Pp. |
| 361 | Evan: | I got 23 |
| 362 | Teacher: | Oh, you're touching your own fingers, your fingers will give you a reading. |

| | | |
|---|---|---|
| | | let's try a battery, okay, you hold the plastic bit, I'll hold the battery, you hold the plastic bit. And touch that. See what kind of numbers were getting, 1500 1600? K? now I;; hold this for you, one side, other side. k, hmm. K, so do you think batteries have electricity? or are they transferring anything? |
| 363 | Evan: | Yeah |
| 364 | Teacher: | How do you know that? |
| 365 | Evan: | Because |
| 366 | Teacher: | But did the magnet show any movement of electrons? This measures movement of electrons does this have movement of electrons? |
| 367 | Evan: | Yes |
| 368 | Teacher: | Here, pick it up again. |
| 369 | Evan: | Yes, it does. |
| 370 | Teacher: | Yeah, and it's measured by volts, does this magnet have movement of elections? |
| 371 | Evan: | I think electrons are irrelevant. |
| 372 | Teacher: | Ahhh. shall we try 2 magnets see if that makes any difference? |
| 373 | Evan: | ## <*unintelligible*> |
| 374 | Teacher: | No? K prove it to me. K. thoughts? So, you're thinking maybe electrons are not the right thing? |
| 375 | Evan: | Ya I am thinking <*unintelligible*> |
| 376 | Teacher: | Ok ok awesome. I'm gonna steal this in case anybody else wants to play with it, but if you need it, it's on my desk |

In Extract 16, Evan engages in an investigation with the teacher on the transfer of electrons in magnets. The teacher brought a multimeter, which measures current and voltage, to the group and has group members place the probes on magnets (lines 351-357). The investigation demonstrates that there is no electricity flowing in magnets. Damien comments "@@ that is the saddest thing I have ever seen. It goes from one to zero" (line 359). Addie reads the results on the multimeter (line 360). Evan then reads results that were higher than Addie's stating, "I got 23" (line 361). The teacher then corrects the way Evan was holding the multimeter, indicating that the reading was from his fingers not the magnet, then she has the group touch the probes to a battery and look at the reading (line 362). She asks Evan “but did the magnet show any movement of electrons? This measures movement of electrons does this have movement of electrons?” (line 366). Evan responds with yes (line 367). The teacher directs him to pick up the probes again (line 368). Evan then says “yes, it does” indicating that the battery had higher readings of electricity (line 369). The teacher then asks Evan “Yeah, and it’s measured by volts, does this magnet have movement of electrons?” (line 370). Evan does not directly answer her question but states “I think electrons are irrelevant” (line 371). The teacher then asks if Even wants to try two magnets (line 372). Evan responds but it is not clear in the audiovisual data. However, they do not try reading two magnets with the multimeter. The teacher then responds to Evan asking him to provide evidence to support his thoughts (line 374). Evan responds but it is not clear in the audiovisual data. The teacher then tells the group that she is going to take the multimeter, but they can come get it if they would like to investigate further and then walks away from the group (line 375). In this example, the teacher challenges Evan’s idea that a flow of electrons is required to produce magnetism.

Following the investigation described above, Evan expresses his frustration with his misconception on magnetism in Extract 17.

Extract 17

| | | |
|---|---|---|
| 381 | Evan: | What was I thinking? <*no response from group members*> |
| 382 | Evan: | Well, I found the gap in my knowledge |
| 383 | Damien: | What? |
| 384 | Evan: | I found the gap ### electrons. |

| | | |
|---|---|---|
| 385 | Damien: | That hurts. |
| 386 | Evan: | What did you do? |
| 387 | Damien: | I was like- I was like we are not supposed to clap like this. It's ### |
| 388 | Addie: | You guys are just sitting there. |
| 389 | Damien: | So, we're talking about it- stuff |
| 390 | Addie: | Draw some molecules. (pause). how many markers [ |
| 391 | Evan: | [it's just like an electrical current, a force, ## electron ## a fundamental force. |
| 392 | Damien: | Dude that makes no sense. |
| 393 | Evan: | ## electrons. |
| 394 | Damien: | It's electrons [ |
| 395 | Lindy | [ you might want this |
| 396 | Evan: | <*unintelligible*> [ |
| 397 | Damien: | [Juice! |
| 398 | Evan: | It is gravity. Gravitons, but. |
| 399 | Addie: | Gravitons? Like like gravity? |
| 400 | Evan: | Who needs gravitons, gravitons are slick. |

In the above extract, Evan questions his own ability (lines 381, 382, and 384). Addie expresses frustration with Evan and Damien for "just sitting there" (line 388). Damien responds in line 389 saying "So, we're talking about it-stuff." Evan does not respond to the assertion from Addie, he continues to talk about his ideas related to electricity by listing concepts like "force," "electron," and "fundamental force" (line 391). Damien exclaims that he does not understand what Evan is saying (line 392). There is loud background noise, so the rest of the interaction was difficult to transcribe. Evan responds but the audio was not clear on everything that was said. Lindy says something presumably to Addie as they are working on the model, while Damien and Evan are talking (line 395). Evan keeps talking and Damien interrupts saying "Juice!" (Line 397).

Evan talks about gravity and then says the term Gravitons (line 398). Addie questions his comment and he responds to her saying “who needs gravitons, gravitons are slick” (line 400). Evan’s explicit comment that he “found the gap” in his knowledge (line 382) followed by his listing of potentially relevant terms without a complete explanation signify his uncertainty after having his thinking challenged by the teacher. Importantly, despite demonstrating uncertainty, his repeated uses of scientific terms (line 391) signal his local science expert status to his peers.

However, when his ideas are challenged by his peers, Evan maintains his certainty about his ideas. For example, when Addie questions the way the molecules are represented in the model in by saying “I so, I don’t think there’s anything with that I just don’t think it’s showing the whole story it’s just showing half of the story” (Extract 6, line 58), the group ends up adding an alternative view of the magnet but does not change the way the molecules are represented in the original model. Evan participates in the group as the science expert, through using technical science jargon, sharing scientific ideas often, demonstrating certainty in his ideas often, and occupying production roles of author and/or principal for all of the micro-level entities related to the scientific mechanism behind magnetism in the group model. Evan’s position in the group as the stereotypical science expert afforded him the right to share ideas frequently, disagree with peers, and respond to questions most often. As a result, his ideas were considered and represented more often than Damien and Lindy.

**Lindy: The Good Assistant**

Lindy is positioned during the consensus modeling as the good assistant for the group. Lindy's task-oriented discourse, agreement with other's ideas, and limited verbal participation characterize the good assistant position (see Table 7). Lindy was engaged during the construction of the model but did not verbally participate as often as the other members. She had the fewest turns of talk ($n$ = 143) for her group (see Appendix D). The communicative practices that characterize her participation in the group are practices are not speaking as often as others, low frequency of sharing ideas, asking questions, and prompting others (see Appendix E). For example, Lindy had the lowest frequency of off-task comments in her group, she disagreed with others the least often, and she did not verbally respond to others when they asked her to do something but would complete the assigned task. Lindy asked the teacher questions related to the requirements for the group consensus model task more frequently than her peers. She did not ask questions of her peers often and most of her questions occurred when she was the assigned leader. As described previously in Extract 10, Lindy actively tries to enact the assigned leader role by asking questions like "how about you, Addie? What have you noticed that's the same, different, or that we all have?" (Extract 10, line 152).

The assigned leadership role influenced Lindy's participation in the consensus model task more than any other participant in the study. Lindy speaks more than any other group member ($n$ = 14, see Appendix D) during Step 1, when she was the assigned leader. She does not speak nearly as often as the other group members during the other parts of consensus model building. Lindy's communicative practices during Step 1 relate to guiding the group through answering the guiding question provided in the instructions for that step of the consensus process (see Extract 10). Extract 10 presented earlier in this chapter, displays Lindy's attempts to guide the group through discussing the similarities and differences in their models. There were multiple occasions where Addie and Evan interrupted her speech with comments (lines 140, 142, 144, 146, and 147). Lindy maintained the conversational floor during these interruptions and continued to guide the group. Lindy enacted the right to lead the group because of her assigned leadership role. She does not exhibit this behavior during any other moments of instruction. Performing the assigned leadership role indicates that Lindy was aware of the expectations communicated to the class signaling that in this moment she was enacting a "good student" position rather than "good assistant." Lindy did not display the same leadership behaviors during the rest of the steps for consensus and aids Addie in making sure that the task is complete indicating a "good assistant" position.

Lindy is the animator of three entities, and the author and principal of one entity. The only entity representing her own idea is the macro-level entity of the magnet. In Extract 1 (Chapter IV), Lindy responds to Damien's question of "What do we agree should be in our model?" (Extract 1, line 84). Lindy tells the group "I think we should have a magnet, definitely, yeah" (line, 87). Addie and Damien agree with Lindy's idea (lines 88-89). The discussion in relation to the magnet does not contain conversation about the functions of the magnet (i.e., the magnetic field). Lindy on multiple occasions expresses her desire to draw the magnet, she does not communicate about mechanisms within the magnet of the macro-level invisible features of the magnetic field, which indicates that she was focused on visual representation over the micro-level mechanisms. Extract 18 contains the conversation that occurred when Lindy drew the magnet.

Extract 18

| | | |
|---|---|---|
| 96 | Damien: | You really want to draw a magnet |
| 97 | Addie: | Yeah, she can draw the magnet |
| 98 | Lindy: | I can draw a magnet |
| 99 | Evan: | I can't draw anything |
| 100 | Damien: | Neither can I |
| 101 | Evan: | I can draw a cactus. I am pretty good at eagles |
| 102 | Lindy: | I can draw anything. |

In this extract Damien asserts that Lindy really wants to draw the magnet (line 96). Addie gives permission that Lindy can draw the magnet (line 97). Lindy explains that she can draw a magnet (line 98). Evan shares that he cannot draw anything (line 99) then clarifies that he can draw cactuses and eagles (line 101). This interaction ends when Lindy positions herself as being able to draw anything (line 102). Lindy on a few occasions expresses her ability to draw (line 102). Lindy is the animator, author, and principal of the magnet (not the micro-entities inside of the magnet). In her other instances as animator, Lindy represents the ideas of Addie (see Appendix F).

Lindy does not share ideas often in the group. When she does share ideas, they are usually related to task completion. For example, in Extract 6 when the group talks about the representation of the poles in the "molecules," Lindy states "we should probably start drawing" (line 74). This idea led the group to start revising their model and ended the discussion on the molecules. Lindy's ability to guide the group to complete the model, as indicated in Extract 6 line 74, is characteristic of her position as a good assistant.

Lindy agrees with other's ideas more than she disagrees with ideas. Lindy seemed to resist sharing her opinion in one instance that could indicate the positioning of good assistant. In Extract 6 (Chapter IV), Lindy covered her face while Addie and Evan argued about the representation of the molecules in the group model. Addie says to Lindy and Damien "you're like covering your face. What do you guys think?" (line 54). Lindy completes the duty of answering Addie's question, without agreeing with either Addie or Evan by responding "mmm, we are in disagreement" (line 55). Evan then engages with Addie. Damien responds that he does not agree (line 57). Evan does not acknowledge the disagreement from Damien and goes on to express his opinion (line 58). Addie tries again to include Lindy and Damien in the conversation by asking "what do you guy's think? Should we leave that picture or fix it, the magnets?" (line 59). Evan responds to Addie before Lindy or Damien had time to respond stating, "we don't have much time." Addie then clarifies "we have 10 minutes" (line 60-61). Lindy responds to Addie's question in a way that still avoids answering the question "Depending on how unsure we are about this we can go without, or we can go with" (line 62). Evan then goes on to clarify his idea that the current model represents a two-dimensional view of the magnet, and the group needs to show a three-dimensional view (line 63). Lindy asks Evan "what is representing a two-dimensional view?" (line 64). Even responds to her question. Addie then says to Evan "I think I kind of see what you are saying" (line 66). After Addie agrees with Evan, Lindy responds "ya, I kind of like what Evan is saying" (line 67). In this storyline, Lindy performs the duty to respond to the questions posed by Addie (lines 54 and 59) to share what she thinks. Lindy answers but does not express if she agrees with Addie or Evan, rather she answers in phrases like "mmm we are in disagreement" and "…we can go without or with" (lines 55 and 62). She comments on the state of agreement or disagreement in the group but does not make any scientific claims. Lindy does not express her opinion until after Addie expresses agreement with Evan (line 66-67), where she agrees with Evan as well. In this example, Lindy occupies a good assistant position by reinforcing Addie's position as group leader. Lindy does not disagree with Addie until Addie changes her stance with Evan's idea.

Lindy appears to assist Addie in making sure the task of completing the model is completed by performing the tasks assigned by Addie and resisting expressing disagreement with Addie's idea (Extract 6). She does not speak as often, and she does not engage in off-topic conversations. Lindy does not share ideas frequently but is active in the creation of the group model. She expresses agreement more than disagreement with peers' ideas. All of these communicative practices indicate that during the instructional task of creating a group consensus model, Lindy is positioned as the good assistant.

**Summary for Group 3**

The students in group three animated entities in their model equally. On the surface this could seem like all group members participated equally in authoring the model. However, Addie participated most often in the decision making for entities added to the group model. Evan was actively involved in the addition of entities representing the scientific mechanisms of magnetism. Lindy and Damien did not enact production roles of author and principal often, but both engaged in the group discussions related to the addition of entities. Lindy infrequently discussed the mechanisms underlying the phenomenon, and more frequently discussed how the group was managing their activities to complete the assigned task. Damien's ideas were not represented in the discussion of entities and he animated entities only when directed to by Addie.

The analysis of Group 3 revealed that the members of the group positioned themselves and others in ways that influenced the creation of the group model. Even with the strategies of assigned leadership and colored markers (Cohen & Lotan, 2014) to disrupt hierarchy formation and promote equitable participation, a natural hierarchy still formed within the group. Addie and Evan displayed more instances of holding higher status positions of group leader and science expert. The assigned leadership strategy did promote increased verbal participation for Lindy, but she did not continue to participate the same way when the assigned leadership changed to another student. While all members participated equally in the physical act of adding entities, the status hierarchy in the group influenced the ideas that were represented. Depending on the goals of instruction the equitable distribution of animator could be viewed as successful. However, if the goal of instruction is to engage students in equitable representation of ideas, then additional interventions would be needed. Addie's egalitarian leadership style aided in the group engaging in the group discussion pathway frequently and scientifically rich conversations. The following section will introduce Group 5 and discuss the ways each member participates in the instructional task.

## Group 5: Dylan, Emma, Landon, and Rebecca

Dylan, Emma, Landon, and Rebecca are the students in Group 5. Group 5 demonstrated 3 instances of the group discussion pathway in their model indicating fewer group discussions about entities in their model than Group 3 (see Table 5 in Chapter IV). Group 5 engaged in the single addition pathway, frequently. Most of the entities that represent mechanisms influencing the phenomenon were added through both the student instruction pathway and the single addition pathway. In both the student instruction and single addition pathways one student decides how to represent the entity in the model, therefore there is no opportunity for the group to discuss the entity. Like Group 3, Group 5 is also characterized by a local status hierarchy. Group 5's status hierarchy did not afford group members many opportunities for the group to engage in group discussions. Landon (authoritarian leader, Wodak et al., 2011) and Dylan (secondary leader) perform positions with higher status. Emma (unacknowledged science expert) and Rebecca (good drawer) enact lower status positions.

As described for Group 3, each group member was responsible for leading the group to complete one step of the process for creating their consensus model (described in Chapter III, Table 3, and Appendix C). Emma is assigned leader for the first step, identifying the similarities and differences in the individual models. Landon is the assigned leader for the second step of consensus building, talking about what they agree should be present in the model. Dylan was the assigned leader for the third step, creating the consensus model. Rebecca was the assigned leader for the fourth step, identifying evidence for the model. Landon was assigned as leader for the presentation based on the criteria (tallest in the group) set by the teacher. The assigned leader roles did not appear to influence the participation patterns for Group 5.

Three group members performed the animator role (Goffman, 1981) equally to add entities to the model (see Table 8). Emma performed the animator role more often than the other group members ($n = 4$). Landon and Dylan authored entities more often than Emma. Rebecca did not enact the author role for any entity added to the model. Landon was principal most often ($n = 6$). His ideas were represented in the model more than double the other group members. Dylan was the principal of three entities, two of which he shared with Landon. Emma was principal of two entities, and Rebecca was

**Table 8**

*Group 5 Enacted Positions of Entities*

| Student | Animator | Author | Principal |
|---|---|---|---|
| Dylan | 2 | 7 | 3 |
| Emma | 4 | 4 | 2 |
| Landon | 2 | 8 | 6 |
| Rebecca | 2 | 0 | 1 |

principal of one entity. The discussion or addition of the entities for which Emma and Rebecca performed the principal role, were task oriented and did not include discussions relating to the scientific mechanism (see Appendix F). Landon was the principal for all of the entities representing micro-level mechanisms, north and south poles in magnets, molecules in the zoom-in bubbles, descriptions, and the arrows in the molecules (See Figure 5, entities 6, 7, 8 & 9). Dylan was the principal for the magnetic fields represented with field lines (Figure 5, entity 5). The magnetic field is a macro-level entity but invisible. The group consensus model represented primarily ideas from Landon and did not reflect group consensus.

Similar to Group 3, I examined the frequency of talk, and types of talk for each group member throughout each instructional steps of developing a consensus model. Landon speaks most often with 292 instances (see Appendix D), which is significantly more than any other group member. Dylan speaks 194 times. Emma is similar with 183 turns of talk. Rebecca speaks the least in the group with only 29 turns of talk during the construction and presentation of the group model. The frequency of talk and enacted production roles indicate the verbal participation for each group member during the consensus modeling phase of instruction. Landon enacts the author and principal roles most often and talks most frequently within the group which indicates that he demonstrated a position with higher status (Adams-Wiggins et al., 2020). Dylan speaks often and performs the author and principal roles more than Emma and Rebecca, indicating he holds a higher status position. Emma and Rebecca do not enact positions with as much status as Landon and Dylan.

To explore the situationally enacted social positions for Group 5 members, I analyzed the frequency of turns of talk (Appendix D), the types of talk used by each group member (Appendix E), and occupied production roles (Table 8). The analysis suggests that the group frequently positioned each other and themselves as authoritarian leader (Landon), secondary leader (Dylan), unacknowledged science expert (Emma) and good drawer (Rebecca). Table 9 details the social positions performed by each group member.

The overview detailed in Table 9 displays the communicative practices enacted by each group member influencing their position within the group. For example, Landon

**Table 9**

*Group 5 Social Positions and Associated Communicative Practices*

| Communicative practices | Dylan-<br>Secondary Leader | Emma-<br>Unacknowledged Science Expert | Landon-<br>Authoritarian Leader | Rebecca-<br>Good drawer |
|---|---|---|---|---|
| Commenting | • Displays the epistemic stance of uncertainty most often for the group mostly when questioned by Landon.<br>• Many instances of clarifying his ideas | • Does not express uncertainty often.<br>• Many instances of clarifying ideas. | • Frequently expresses certainty.<br>• Uncertainty is combined with speech on what is known or off-topic comments.<br>• Highest frequency in off-topic comments. | • Only makes 4 comments through the entire phase of instruction.<br>• Clarified her idea once when prompted by the teacher |
| Consensus | • Frequently expresses agreement with others (mostly Landon)<br>• Does not exhibit disagreement often. | • Expresses disagreement more than agreement. Neither at a high frequency<br>• Asks for consensus most often in group | • Frequently expresses disagreement with others.<br>• Expresses agreement on occasion<br>• Asks for consensus mainly from Dylan. | • Does not use any verbal communicative practices related to consensus. |
| Prompting | • High frequency of prompting others to act or complete a task.<br>• High frequency in responding to prompts from peers | • Low frequency of responding to prompts from others.<br>• Lower instances of prompting others compared to Dylan and Landon | • Prompts others to act or complete a task most often in the group.<br>• Will respond to prompts from peers more than Rebecca and Emma. | • Does not prompt others to act or complete a task.<br>• Responds to a prompt on one occasion. |
| Questioning | • Responds to questions often from peers and teachers.<br>• Does not ask questions of peers frequently. | • Asks other group members questions frequently both related to science content and off-topic questions.<br>• Responds to questions more than Rebecca but significantly less frequent than Dylan and Landon | • Responds to peers and teachers question most often especially when related to science content.<br>• Asks questions of peers often both related to science content and off-topic | • Balances asking and responding to questions related to task completion.<br>• Asks teacher or researcher questions unrelated to task completion or science content |
| Share Ideas | • Shares ideas related to task completion, science content, and off topic subjects less frequently than Landon and Emma. | • Shares ideas with the group often.<br>• Ideas varied from task completion, science content, and off-topic ideas | • Shares ideas most often by more than double other group members.<br>• Ideas are related to science content, task completion, and off-topic subjects. | • Shares ideas on four occasions. Mostly related to task completion. |

uses the communicative practices of sharing ideas, responding to questions from peers and teachers, disagrees with others and makes off-task comments most frequently, which indicate a position as an authoritarian leader. Rebecca does not talk often in the group, her position as "good drawer" was explicitly assigned by others. The following subsections will illustrate how these communicative practices reflect the socialization of each group member and shape the inclusion of entities into the group model.

**Landon: Authoritarian Leader**

Landon's high frequency of talk, frequency of author and principal roles, and specific communicative practices reflect and construct his high-status position in the group. He holds a production role in most of the entities represented in the model and expressed opinions about the representations of mechanisms in their model such as the direction of arrows in the molecules (see Figure 5, entity 9). Landon performs the production role of principal for six entities and author role for eight entities (see Table 8). The majority of the entities that reflect the mechanistic reasoning for the phenomenon are his ideas (see Appendix F). Appendix E summarizes the communicative practices that characterize Landon's participation. For instance, he makes clarifying comments more than other group members. He has the most off-task comments and prompts others to act most often. Landon responds to questions most often, shares his ideas twice as often as any other group member and has the highest number of interactions where he disagrees with another group member ($n$ = 18). Landon's interactions supported the inclusion of his ideas in the model and limited the participation of his peers. The following analysis demonstrate how Landon's disagreement with others shape the model construction.

Landon disagrees with his peers on many occasions, sometimes it is related to the ideas being presented for the group model (see Extracts 3 & 7) and on other occasions it seems to be a social act that does not serve the completion of the task. For example, in Extract 19, Rebecca shares her model with the group.

Extract 19

| | | |
|---|---|---|
| 72 | Emma: | K your turn. |
| 73 | Rebecca: | K so [ |
| 74 | Emma: | [Give her the paper. |
| 75 | Dylan: | Oh, my paper? |
| 76 | Rebecca: | K, so I wrote how like the magnets are like attracted to this side. |
| 77 | Emma: | Your drawing is cute. I like the zig zags. Well, ok I think we all have the same ideas like. Dylan doesn't have much of an idea |
| 78 | Landon: | Well, you can see in his drawing that he has pretty much the same thing as me. The magnetic field is going around |
| 79 | Emma: | Which is right. |
| 80 | Landon: | Or so we think. We could be dead wrong. |
| 81 | Emma: | I have learned that before. |

In Extract 19, Emma tells Rebecca that it is her turn to present (line 72). Rebecca begins to talk, when Emma interrupts and tells Dylan to give Rebecca the instructions for presenting (line 73-74). Dylan responds and then gives the paper to Rebecca, and Rebecca shares her model to the group (lines 75-76). Emma comments on Rebecca's model and then states "well ok I think we all have the same ideas like. Dylan doesn't have much of an idea (line 77). Landon disagrees with Emma's positioning of Dylan as not having "much of an idea" (line 77), instead aligning Dylan's model with his own labeling it as "the same thing as me" (line 78). Emma then agrees with Landon's assertion and evaluates the models saying, “which is right” (line 80). Landon then disagrees with her agreement to his idea stating “Or so we think. We could be dead wrong” (line 80). Emma responds telling him she has “learned that before” (line 81). After this interaction Landon tells the group that he learned about magnetism from a popular science cartoon.

In this example Landon disagrees with Emma on two occasions, the first is when she positions Dylan as not having an idea about the phenomenon. Landon repositions Dylan as similar to him. Emma agrees with Landon, and he disagrees with her again (lines 79-80). The second disagreement appears to be serving a social goal and is not about the scientific ideas in Dylan’s model. Similarly in Extract 3, Emma disagrees with Dylan about the layout of the three sections in their model stating, “That’s not equal we should just do three lines” (line 144). While speaking Emma points to three sections on the paper. Landon then disagrees with her by saying “or not three lines because that would split into four sections” (line 145). Emma agrees with his correction. Landon’s disagreement with Emma during these instances creates a division of accessible communicative rights in the group. His disagreement signals that Landon has to approve of Emma’s the right or position to be credible. Landon’s acts in these instances help to position him in a higher status leadership position, which affects the ways in which Emma’s ideas are evaluated in discussions. Emma both resists and reinforces Landon’s position. By offering agreement with him when he disagrees with her initial statement, she reinforces his position. She resists by evaluating the correctness of the entity in question as “right” (line 79).

Similar to Evan in Group 3, Landon crafts himself as the science expert in the group (Barnes, 2004; Braden, 2016; Wieselmann et al., 2021). His expertise is challenged in one interaction early in the consensus modeling task, when the researcher approaches the group as they are sharing their individual models. Extract 20 documents an interaction that occurred after Landon shared his model with the group.

Extract 20

| | | |
|---|---|---|
| 27 | Emma: | How would you represent the force? The magnetic field? |
| 28 | Landon: | Oh, um but this is the magnetic field. This is |
| 29 | Emma: | Yeah, but how would you represent it molecularly? |
| 30 | Landon: | Oh. |
| 31 | Researcher: | That is a good question |
| 32 | Landon: | Um |
| 33 | Researcher: | So, you mean like in here? Within that type of. Like in that part of the drawing. What is happening with the fields around those? |
| 34 | Emma: | Yeah. |
| 35 | Researcher: | That is a good question |
| 36 | Landon: | So, I don't know |
| 37 | Researcher: | And that is ok |
| 38 | Landon: | Ya but I forgot to say what I think happens when paperclips. I think that when it gets inside the magnetic field all of the molecules inside certain materials. Like certain metals uh come together in the same order as a magnet cause. When you think- when you like in this what we did today with the nails how if it was touching it's almost like this becomes a magnet too. So, the magnetic field becomes part of this nail. |
| 39 | Researcher: | Ok. |
| 40 | Landon: | So that it can pick it up too. So, the essentially the magnet turns things into magnets |
| 41 | Researcher: | So, is this paperclip magnet right now? Like is it magnetized? How can we tell from your drawings? |
| 42 | Landon: | So, it's not magnetized because it is not in the magnetic field. And uh I probably should have drawn the arrows much bigger. But there aren't any arrows. So, like what we said last year in solids they are kind of all still lined up there just not like um as perfectly in line and they are not all facing the same way they are just like all around. |

The class had been given direct instructions by the teacher that everyone should ask the person sharing their individual model questions related to the way they are representing the floating paperclip phenomenon. Emma was the first to ask Landon a question about his model "How would you represent the force? The magnetic field?" (line 27). Landon responds that the magnetic field is represented on a specific part of his model (line 28). Emma then asks a follow up question about how he would represent the magnetic field molecularly (line 29). It is at this point that the researcher comments that the question Emma asked was "a good question" (line 31). Landon hesitates by saying "oh" and "um" (lines 30 and 32). The researcher asks a few questions to clarify what Emma meant with her question (line 33). Emma replies that the researchers' understanding of her initial question was correct (line 34). The researcher repeats "that is a good question" (line 35). Landon then responds by saying "so, I don't know" (line 36). The researcher tells him "and that is ok" (line 37). Landon redirects the conversation by elaborating what he does know about the same topic (line 42).

In Extract 20, Emma asking Landon a question that he could not answer. The researcher was present when the question was asked, and Landon appeared hesitant to answer the question, when he paused saying "oh" and "um." Landon had to express uncertainty to the question, after the researcher indicated it was "good question" twice. Demonstrating uncertainty in front of the group and researcher, appeared to challenge Landon's status as group expert. Landon reinforced his position by explaining his reasoning (lines 38 and 40) and then linking this to a possible change in his model when he states, "I should have drawn the arrows much bigger" (line 42). This interaction ended following the comment from Landon on line 42, when the researcher told the group that the next person should share their model. Landon does not express uncertainty relating to science content in any other interactions during the creation of the group model.

Despite posing the only question that actually challenges Landon's expertise, Emma positions him as a science expert on multiple occasions after the interaction in Extract 20. For example, in Extract 4 (Chapter IV), Emma asks the group how to label the middle "far away" section of the model (line 202). Landon responds saying "touching and being pulled by the magnetic force" (line 204). Emma laughs and responds saying "almost touching" (line 205). Landon suggests "close by" (line 206). Dylan joins the discussion suggesting "being pulled" (line 207). Landon then directs Emma "just put almost touching" (line 208). Emma writes almost touching on the model after Landon directs her to line 208. Emma asks the group for help deciding what to write, and Landon makes suggestions. Emma suggests what ended up being written on the model (line 205). However, she did not add it to the model until Landon told her to "put almost touching" (line 208). Landon tells Emma what to write for another entity in Extract 8, when he tells her what to write for the description in the middle section (see Figure 5, entity 7). In both instances, Emma is positioning Landon as a science expert by asking for help and then writing what Landon says. In the first example, Emma essentially authored the heading "almost touching" but did not add it to the model until Landon directed her too. This positioning of Landon directly influenced the addition of entities in Group 5's model.

The off-task comments frequently made by Landon influence the group's ability to engage in conversations related to the science content of the unit. Extract 7 (Chapter

IV) demonstrates one instance where Landon asks the group what kind of magnet they should draw in their model (Extract 7, line 85). Dylan suggests a square magnet (line 86). Dylan and Landon argue about a square or rectangular magnet (lines 86-91). Emma joins the discussion agreeing with Dylan on drawing a square magnet (line 92). Landon then makes an off-task comment saying “Square yak, my neighbor is allergic to yak. She is a knitter and she bought yak yard and she was sneezing a lot” (line 93). Dylan then states that he did not know someone could be allergic to yak (line 94). Emma then redirects the conversation asking what type of magnet they are using in the model (line 94). Dylan says square, Landon says rectangle, then Dylan changes and says rectangle (lines 96-98). The interaction ends with Landon declaring “I was kidding, rectangles are far superior to squares” (line 99). In this instance Landon uses an off-task comment after Emma tried to join the discussion (line 93) to exclude Emma from joining the conversation. Extract 21 offers another example of how Landon’s off-task comments affect the group’s participation.

Extract 21

| | | |
|---|---|---|
| 223 | Landon: | While you guys are drawing, we are going to play a quick round of marble ball. <*The boys play marble ball while R draws and E watches her and the boys. The researcher approaches the table*> |
| 235 | Dylan: | We are waiting for the drawers to be done ##### |
| 236 | Landon: | We are doing the finer details. |
| 237 | Researcher: | ###### <*unintelligible*> |
| 238 | Dylan: | We are going to draw the molecules and stuff. <*researcher walks away, and the boys continue to play marble ball while the girls draw.*> |

The interaction in Extract 21 begins when Landon suggests that he and Dylan will play marble ball while Emma and Rebecca draw on the model (line 223). Dylan and Landon play the game they made up with marbles while Rebecca and Emma work. The researcher approaches the table. The audio recorder was placed closer to the girls so the conversation between the researcher and the boys is difficult to hear. Dylan states “we are waiting for the drawers to be done #####” (line 235). Landon adds “we are doing the finer details” (line 236). The researcher responds but it is not clear. Dylan replies “we are going to draw the molecules and stuff” (line 238). The researcher walks away from the group after Dylan’s comment. Landon’s suggestion in line 223 divided the group by the assignment of rights and duties. Emma and Rebecca were positioned with the duty to draw, while Landon and Dylan performed the right to play an off-task marble game. Landon reiterates the division of rights and duties in the group in line 236, by telling the researcher “we are doing the finer details.” The group members did not resist indicating that Landon had the position of group leader to assign the girls as the “drawers” and the boys as the “detailers.” The positionings illustrated in this example indicate that the production roles enacted by the group were influenced by the way they were socialized to participate by Landon as the drawers and detailers.

Many of the macro-level entities were added by Emma and Rebecca. Emma added the macro-level entities of the sections showing the three orientations, headings for each section and Boxes for the description of each section (see Figure 5, entities 1, 2 and 4). Rebecca added the magnet and paperclip, and labels for the various entities in the model (see Figure 5, entities 3 and 10). Landon’s participation in the group heavily influenced the development of the group model. His ideas are represented most often, and he directs the conversations through disagreeing with others, being positioned as the science expert in the group, and using off-task comments to guide participation of group members signaling an authoritarian leadership position (Wodak et al., 2011).

**Dylan: The Secondary Leader**

Dylan participated frequently in conversations during the development of their group model. Dylan held the position of animator for two entities similar to Landon and Rebecca (see Table 8). Both of the entities he drew on the model represented the scientific mechanisms of magnetic field lines, and arrows in the molecules to show direction of polarity (see Figure 5, entities 5 and 9). Dylan enacted all three production roles for the magnetic field lines in the model (entity 5). However, Landon and Dylan performed the author and principal roles for the arrows to show polarity in the molecules (entity 9). He enacted the author role for seven entities, many of which were co-authored with Landon ($n$ = 4). Dylan occupied the author and principal roles more than Rebecca and Emma but not as frequently as Landon.

Dylan had 193 turns of talk which is the second highest rate for the group (see Appendix D). Dylan expressed uncertainty more often than other group members and expressed agreement with others more often than other group members (see Table 9). Dylan responded to questions more than Emma and Rebecca but less than Landon. He does not question other students as often as Emma or Landon but does ask more questions of his peers than Rebecca. Dylan does not appear to occupy a position with as much status as Landon, however, he does perform the author and principal production roles more than Emma and Rebecca. Dylan's participation patterns demonstrate that

Dylan often occupies the position as the secondary leader. There was not a description in the literature similar enough to Dylan's behavior to draw from. The position's label is characterized by the status Dylan holds in the group—especially in relation to Landon. There are instances where Dylan is positioned as uncertain (Extract 22), and as a science expert (Extract 24 and 25). In addition, Landon and Dylan make comments that separate them from Rebecca and Emma (Extract 21).

Dylan's participation has both moments of science expertise and uncertainty. Early in the consensus model building instructional phase, Dylan expresses uncertainty while also declaring that the science content was irrelevant to learn when he shares his model in Extract 22.

Extract 22

| | | |
|---|---|---|
| 49 | Dylan: | Um so that is mine. It's pretty wacky. Um so here is the paper clip it got erased a little bit it's not magnetized right now and here is the magnet it's going like that. Yep. |
| 50 | Emma: | Is that all you have? Like you don't have a molecule or anything. |
| 51 | Dylan: | No (pause) I really don't get it so |
| 52 | Emma: | Magnets are weird |
| 53 | Landon: | Magnets are weird |
| 54 | Dylan: | I really don't see how it going to help me in my future so why should I learn about it now? |
| 55 | Emma: | Want to hear something funny? When I was little [ |
| 56 | Landon: | [What if you're going to become a magnetical engineer? What? |
| 57 | Emma: | My idea was if we put underneath the road |
| 58 | Landon: | Magnetical engineers |
| 59 | Dylan: | Magnetical engineers |
| 60 | Emma: | So, like underneath the road there was like a magnet then on the bottom of cars the roads would have like a thin thing that the car could fit through on the bottom of the car there would be a magnet, but it would be flipped around so they wouldn't attract they would make flying cars |

61 Dylan: The problem is that sometimes the magnets flip over and so the cars would like flip over

Dylan's assertion that the content is not important to learn could have influenced his participation during the consensus model development or it may simply represent a face-saving move because his model was challenged by Emma as not complex enough. In Extract 22, Dylan presents his individual model to the group. Dylan begins by showing the group his model and telling them it is "pretty wacky" (line 49). Emma asks Dylan "Is that all you have? Like you don't have a molecule or anything" (line 50). Dylan responds saying that he doesn't "get it" (line 51). Emma and Landon assert that Magnets are weird (lines 52 and 53). These comments could have been made to signal an understanding of his uncertainty from line 51. Dylan then proceeds to justify why he does not think the material is relevant for him to learn saying "I really don't see how it going to help me in my future so why should I learn about it now?" (line 54). Emma tries to change the conversation in line 55. Landon interrupts her utterance asking Dylan "what if you're going to become a magnetical engineer? What?"(line 56). Emma tries to change the conversation again in line 57. Landon and Dylan both say "magnetical engineers" and do not acknowledge Emma's comments (lines 58 and 59). After, Emma finishes her comment, telling the group an idea she had when she was younger about magnets being on cars and on the road (line 60). Dylan then responds to Emma's idea, telling her it would be a problem if the magnets flipped over (line 61). Emma does not respond before Landon changes the conversation by making a comment about a sitcom on TV.

While sharing his model, Dylan prepositions his model as "pretty wacky" (line

49). After Emma questions the depth of his model, Dylan first responds with uncertainty. He then clarifies that he does not think is important to learn which positions the content as irrelevant. The positioning of the content area could be a way for Dylan to reposition himself. If the lesson is positioned as irrelevant, then his uncertainty is attributed to the lesson or science contents' position rather than his own position as a non-knower.

Another example of Dylan being positioned as uncertain or not knowing science content is in Extract 19, where Rebecca shares her individual model with the group. After she shares her model Emma says "Your drawing is cute. I like the zig zags. Well, ok I think we all have the same ideas like. Dylan doesn't have much of an idea" (line 77). Landon resists Emma's attempt to position Dylan as uncertain by aligning Dylan's model with his own stating "Well, you can see in his drawing that he has pretty much the same thing as me. The magnetic field is going around" (line 78). In this example Emma positions Dylan as inexpert while Landon resists the positioning. Dylan does not engage in the conversation at all.

Dylan expresses uncertainty and was positioned as uncertain by Emma and expresses opinions on the content being irrelevant. However, he also demonstrates engagement in the science task in Extract 23. Landon and Emma engage in a conversation regarding evidence for their model at the beginning of the step 4 of consensus modeling.

Extract 23

17 Landon: We should write our names on it, But evidence is past knowledge from certain[

18 Emma: [Past teachers and uh

19 Landon: Certain

20 Emma: And TV

21 Landon: Entertain, certain, how do you put this? So, it doesn’t seem like

22 Emma: School bus teachers.

23 Landon: And certain, um.

24 Emma: Bus drivers.

25 Landon: Media sources, no, because that makes is seem like social, no, but

26 Emma Cause you have to ######

27 Landon: Well so what you do is like certain tv shows, Parenthesis, the Magic School Bus.

28 Emma: Okay, that would be sources not evidence. Evidence is how we ####

29 Landon: Evidence is yeah, that’s true.

30 Dylan: Let’s just, shut up about the evidence and think about this. Okay so what we are saying with this and that, Is that this as it gets further away from the magnet it gets less as strong. And so, we need to come up with evidence as to why we think that it’s getting less magnetized.

Landon and Emma engage in somewhat off-task conversation about how to include a TV show as evidence in their model (lines 17-29). Dylan does not engage in the conversation and attempts to redirect the conversation to be more on-task and demonstrates that he is thinking about the mechanisms involved in the phenomenon through telling the group they need to come up with evidence (line 30). The researcher joins the group after Dylan’s comment and engages in a discussion with Landon about the groups’ model. While they are talking Dylan gets supplies and begins to interact with the materials at his seat. Landon attempts to converse with Dylan during his investigation with the materials but is dismissed by Dylan’s short replies in Extract 24.

Extract 24

55 Landon: What are you doing?

56 Dylan: I'm testing something.
57 Landon: A theory?
58 Dylan: Yeah.
59 Landon: I have theories about everything.
60 Dylan: Fun.
61 Landon: That's a line from a TV Show. What is your theory?
62 Dylan: Here let me see that magnet.

In Extract 24, Dylan investigates an idea with a magnet, string, and paperclip at his seat. Landon asks him what he is doing (line 55). Dylan responds telling him that he is testing something (line 56). Landon then asks if he is testing a theory and Dylan indicates yes (lines 57 and 58). Landon then asserts that he has theories about everything (line 60). Dylan does not engage in the conversation and replies with a simple "fun" (line 60) without looking up from his task. Landon again tries to engage Dylan in a conversation in Line 61. Dylan does not acknowledge Landon's comment and asks for a magnet to help him with his investigation. In this moment Dylan investigates his own hypothesis to use as evidence for their model and does not engage in a conversation with Landon. Throughout the lesson Dylan engaged with Landon and reinforced Landon's position as group science leader. In this moment Dylan repositions himself as a scientist during the interaction in Extract 24 by dismissing or ignoring Landon's comments, and focusing on the investigation he is conducting. Dylan describes his investigations in Extract 25.

Extract 25

72 Dylan: Okay, so what I was testing there, is that um if this is a certain amount of distance

away from here if these still stay on, which they did, and that proves that it is still magnetized when it's like that. And the next thing I tested, if it got stronger when I put it next to right here and you could see that they were tighten together sort of and just like got tense and so that proves our theory for that.

73 Landon: Do you want to be the evidence guys?

74 Dylan: Sure.

75 Landon: So, these guys [

76 Emma: [So, I'll explain what I wrote and then Rebecca can explain the drawings.

77 Landon: And we will be the evidence guys. Uh which one do you want to talk about, do you want to talk about this, like this one.

78 Dylan: Yeah, I want to talk about < *gestures to the middle section of the poster where the paperclip is almost touching the magnet*>

79 Landon: Because this one doesn't really need explanation. <*gestures to the bottom section where them paperclip is not near the magnet*>

80 Dylan: Yeah.

81 Landon: It's just nothing happens because they are too far away.

82 Emma: Maybe it still does pull but the force isn't strong enough to move it.

83 Landon: Well, were saying it's this, the magnets, the magnets, this, it doesn't pull because they're so far away.

84 Dylan: So, what I want to present with is give evidence for what we are saying right here and here.

85 Landon: So, I'll do this, I'll talk about how station four. <*gestures to the top section of the model*>

86 Dylan: Yeah, okay.

87 Landon: And then you can talk about <*gestures to model*> [

88 Dylan: [The correlation between that one and that one.

89 Landon Yeah.

Dylan tells the group about his investigation to find evidence for the middle section of the model when the magnets and paperclip are almost touching in line 72 and demonstrates them to the group as he is talking about them. Dylan's investigations were hard to see in the video data, but it appeared that he had the paperclip attached to the string, additional paperclips, and a magnet. He describes his investigations and provides evidence for the almost touching section of their model. Landon responds to Dylan's explanation but does not engage with the science content, instead he asks Dylan if he wants to be "the evidence guys" with him (line 73). Dylan agrees, and Emma explains that she will present what she added to the model, and Rebecca will talk about the entities she added (line 76). Rebecca does not verbally acknowledge the assignment of the duty from Emma. Landon and Dylan go on to talk about which part of the model they will provide evidence for. Dylan chooses the middle section because the evidence he gathered supports that orientation of the paperclip. Landon explains that he will talk about the top section, because "nothing happens" in the bottom section (line 81). Emma challenges Landon's claim that nothing is happening saying "Maybe it still does pull but the force isn't strong enough to move it" (line 82). Landon dismisses her comment saying "Well, we're saying it's this, the magnets, the magnets, this, it doesn't pull because they're so far away." (line 83). Emma does not respond to Landon's reply to her challenge. Dylan and Landon discuss the evidence they will use for their parts.

In this storyline, Dylan displays science expertise while investigating evidence for their model and after Dylan tells the group about the investigation. Landon responds by asking him if he wants to be an "evidence guy" with him (line 73). Landon positions Dylan as equal with him by suggesting they will be "evidence guys" together. The two then discuss the evidence they will use and do not include Emma and Rebecca in the conversation. Landon and Dylan position themselves separate from Emma and Rebecca. For example, in Extract 21, while playing "marble ball," they describe the Emma and Rebecca as the drawers, and they will add the "finer details." Similarly, in Extract 25, Landon positions Dylan and himself as the "evidence guys." The division of positions in this group influences the positions that all the group members occupy. Landon and Dylan occupy the Author and Principal positions more often than Emma and Rebecca. Emma and Rebecca are assigned to entities that are related to task-completion. This clear divide in the group affects the resulting consensus model. The group does not engage in mechanistic reasoning conversations to generate group consensus on the mechanisms in their model. There were moments of potential discussion like when Dylan is describing the evidence he gathered in his investigation (Extract 25, line 82) but the off-task comments made by Landon and division of positions in the group limit these discussions.

**Emma: The Unacknowledged Science Expert**

Emma participates actively while creating the group model. She performs the animator role more often than other group members, drawing four entities on the model (see Table 8). She is the author of four entities and principal of two, both of which represent macro-level entities and are related to task completion (the heading and text boxes in each section, see Figure 5, entities 2 and 4). Emma engages in conversations often in the group and speaks almost as frequently as Dylan ($n$ = 183, see Appendix D) Emma's participation is characterized by the communicative practice of questioning others (see Table 9). Emma asks questions of her group members more than any other group member. The questions are related to the science content and related to off-task topics that Landon makes. In her interactions Emma actively tries to position herself as knowledgeable as Landon and Dylan, however, they resist her attempts to be recognized as having science expertise. The production roles Emma performs, and communicative practices indicate that Emma is often enacting a socially constructed position of unacknowledged science expert. This position was determined by Emma's continuous effort to elevate her status in the group with Landon and Dylan by positioning Dylan as uncertain and engaging in Landon's off-task conversations. Emma also asks questions about the science content and mechanisms more than other students. Landon and Dylan's reactions to Emma craft themselves as "detailers" and her as a "drawer." For example, in Extract 26, Emma is the assigned leader for the second step for the group consensus model building and Landon and Dylan interrupt her utterances.

Extract 26

| | | |
|---|---|---|
| 92 | Emma: | Ok what are the similarities and differences in our model? I noticed [ |
| 93 | Landon: | [I noticed that number |
| 94 | Emma: | I noticed they all have [ |
| 95 | Dylan: | [Arrows |
| 96 | Emma: | We all have the thing that goes around like we all think there is a magnetic force. Do we all think it is a force though? Or do we just think it is a field? |
| 97 | Landon: | It is a force |
| 98 | Dylan: | It's a force |
| 99 | Emma: | Ok it's a – |
| 100 | Landon: | It's a force field! |

Emma asks the group the guiding question for step 2 "ok what are the similarities and differences in our model?" and then begins to answer the question "I notice" (line 92). Landon interrupts her utterance and begins to answer the question (line 93). Emma repeats the beginning of her utterance saying, "I notice they all have" (line 94) when Dylan interrupts her and finishes her sentence saying "arrows" (line 95). Emma completes her thought and asks the group a question about magnetic field lines saying "we all have the thing that goes around like we all think there is a magnetic force. Do we all think it is a force though? Or do we just think it is a field" (line 96). Landon and Dylan both respond with "It's a force" (lines 97-98). Emma then starts to speak again and is interrupted by Landon, who declares "it's a force field!" (Line 100). During this interaction, Emma tries to engage and share ideas with her group, but Dylan and Landon interrupt her and do not engage in more in-depth conversations answering her questions about magnetic fields or forces (line 96). The interruptions in this interaction are similar to the interactions for Group 3 in Extract 10 where Addie and Evan interrupt Lindy. However, in the example in Extract 26, Emma was not able to keep the conversational floor. Landon and Dylan took the conversational floor when they changed the topic of the conversation to a popular movie following this interaction. After talking about the movie, Dylan prompts Emma to continue her assigned leadership role and "lead the discussion" (line 117) in Extract 27.

Extract 27

| | | |
|---|---|---|
| 117 | Dylan: | Lead the discussion |
| 118 | Emma: | Uh we don't really have any differences we all kind of agree on the same ideas |
| 119 | Landon: | Well, I noticed that only Landon's stars- probably haven't met him- has molecules. |
| 120 | Emma: | I have molecules |
| 121 | Landon: | You did? |
| 122 | Emma | Yes! I never showed anybody |
| 123 | Landon: | I only notice that |
| 124 | Emma: | Look mine has molecules |
| 125 | Dylan: | So, does mine |
| 126 | Landon: | See I notice Landon's only has large circles for particles |
| 127 | Dylan: | Ok |

| | | |
|---|---|---|
| 128 | Emma: | Mine had swirlies ok. It’s your turn like. |
| 129 | Dylan: | No, we got to finish with this. |
| 130 | Landon: | This is the same. |
| 131 | Emma: | Ok we all have the same thing that goes around- the magnetic force. This is different. We all have different drawings and a lot of us don’t know what we are drawing. |
| 132 | Dylan: | I noticed only you have molecules. <*speaking to Landon*> |
| 133 | Emma: | I draw molecules! |
| 134 | Landon: | But I was the only one that has circular molecules |
| 135 | Emma: | I had swirlies |
| 136 | Dylan: | I noticed that we both have arrows. Kind of |
| 137 | Landon: | Yes, we do. |
| 138 | Emma: | I have arrows too! |
| 139 | Landon: | We do. We do have arrows. |
| 140 | Dylan: | Wait let’s see your drawing again? <*looking toward Rebecca*> |
| 141 | Emma: | Ok Landon’s and Dylan’s are different because Landon knows what he is drawing. When Dylan doesn’t really understand. |
| 142 | Landon: | He’s like ya I just drew something. Whatever came to mind I think this is a rocket ship. Ya, I drew a tiger because obviously tigers can be enticed by the magnetic meat. |
| 143 | Dylan: | I think we all can agree that Rebecca should draw the poster. |
| 144 | Landon: | Yes. |
| 145 | Dylan: | Yep. |
| 146 | Landon: | It is decided. |
| 147 | Dylan: | Its decided. Alright. |
| 148 | Landon: | We win. |
| 149 | Dylan: | End of day |

During the interaction in Extract 23, Dylan directs Emma to “lead the discussion” Emma accepts the assignment from Dylan indicating he had the position in the group to assign that duty. During the same interaction Emma tries to position Dylan in a similar way directing him to perform the duty of moving on to step 3 (line 128). However, Dylan resists the duty of moving on stating "No, we got to finish this" (line 129) indicating that Emma did not have the same rights as Dylan. Throughout the interaction in Extract 23, Emma tries to position herself as equal with Landon and Dylan by detailing what she included in her individual model similar to Landon's model (lines 118, 120, 122, 124, 133, and 138). Landon and Dylan resist the positioning by differentiating the similarities that she claims (lines 119, 121, 126, 132, 134, 136).

Emma tries to position herself in the group as a higher status member by sharing ideas (ex. Extract 7, line 92; Extract 22, line 60) and questioning the ideas of others (Extract 20, lines 27 and 29). The positioning attempts are often resisted by Landon and Dylan by dismissing what she says (Extract 19, lines 77-81) or interrupting while she is speaking (Extract, 23). Landon and Dylan assigned her and Rebecca the duty of drawers (Extract 21, lines 223 and 235). Emma was not afforded the same opportunities to participate as Landon and Dylan. Emma demonstrated interest in the mechanisms underlying the phenomenon and asked questions that could have promoted group discussion around including certain entities, however, the leadership style Landon performed did not support these kinds of conversations.

**Rebecca: The Good Drawer**

Rebecca does not verbally engage often with the group. She only speaks 29 times for the entire consensus model building phase and presentation of the group model (see Appendix D). The only communicative practice that characterizes her verbal participation in the group is her silence (see Table 9). While she does not speak often, she is active in the construction of the group model. She is the performs the production role of animator for 2 entities and the principal of one entity (see Figure 5, entity 1). Rebecca shares the idea of three sections in their model when they first start talking about what to include in the model. The audio is not clear, to fully transcribe the utterance. However, as she is talking, she gestures to a paper and indicating three sections similar to how the sections are represented in the group model. After she shares the idea, the group does not converse about the idea. The idea resurfaces later in Extract 3 (Chapter IV) when Evan says "Alright so we should split it into three sections. Um maybe two up here and maybe one big one down here" (line 143). The group engages in the group discussion pathway, to decide how to distribute the sections on the poster, deciding to draw them as Rebecca had represented in her gesture.

Rebecca does not express her ideas often and is positioned as a "good drawer" by other group members. There were multiple instances where the students commented on Rebecca's drawings. For example, in Extract 19, Rebecca describes her model to the group saying "K, so I wrote how like the magnets are like attracted to this side" (line 76). Emma makes the comment "your drawing is so cute. I like the zig zags" (line 77), she does not ask any questions of the content being represented and changes the conversation during the same utterance saying "well ok, I think we all have the same ideas like. Dylan doesn't have much of an idea." Landon and Emma then talk about Dylan's model. Lines 76 and 77 are the only talk about Rebecca's individual model while she shared it with the group. Emma's comment on her model being "cute" and liking the "zigzags" signals that Emma assessed her model based on the appearance, not the scientific ideas it represented.

This positioning of "good drawer" comes up again in Extract 27, line 140, when

Dylan asks Rebecca to show him her model again. After looking at the model, Dylan asserts "I think we can all agree that Rebecca should draw the poster" (line 143). Landon agrees, and Dylan agrees again (lines 144-145). Landon then states, "it is decided" (line 146). Dylan repeats Landon and adds "alright" (line 147). Landon then says, "we win" (line 148). It is not apparent what he means by this comment. It could be in reference to he and Dylan deciding that Rebecca will draw the poster. Dylan ends the discussion by saying "end of day" (line 149). Dylan's assignment of the duty to draw the poster, demonstrates that Rebecca had a talent for drawing. However, the group never discusses her ideas related to the science content.

While Rebecca is quiet, she is active in the construction of the group model. In Extract 28, Emma asks the group for animator roles for their model.

Extract 28

| | | |
|---|---|---|
| 176 | Emma: | ok so who is going to draw ### |
| 177 | Rebecca: | I can |
| 178 | Emma: | ## <*unintelligible*> |
| 179 | Rebecca: | Oh. |
| 180 | Landon: | I call drawing the molecular ## |
| 181 | Emma: | You want to do the molecules? |
| 182 | Dylan: | I will draw arrows. |
| 183 | Landon: | Ya he is going to do the force. |
| 184 | Rebecca: | I can do the drawings |
| 185 | Emma: | Ya, you should do the drawings because you are good at drawing. You should do all the little details like the arrows, lighting bolts and dots. |

Emma begins the interaction by asking "ok so who is going to draw ###" (line

176). The background noise during this interaction makes the conversation hard to hear. Rebecca volunteers to draw. Emma comments and Rebecca then says “oh” (line 179). Landon then tells the group what he will add (line 180). Dylan says he will draw arrows (line 182). Landon clarifies that Dylan is going to draw the force (line 183). Rebecca then adds “I can do the drawings” (line 184). The drawings she is referring to in this comment is the magnet and paperclip. Emma agrees with Rebecca stating “Ya, you should do the drawings because you are good at drawing. You should do all the little details like the arrows, lightning bolts, and dots” (line 185). Emma positioned Rebecca as knowledgeable to do the “finer details” but Landon and Dylan claim that right in Extract 21. Rebecca volunteers to help create the model in extract 28. While she does not participate verbally, she does participate physically creating of the model.

Rebecca’s position in the group was defined by the roles and positionings assigned to her from her peers. Emma describes Rebecca’s individual model as “cute” (Extract 19, line 77). Dylan nominates Rebecca as the drawer of the model (Extract 27, line 143). These positioning confirmed the good drawer position when Landon and Dylan tell the researcher that Emma and Rebecca are the drawers (Extract 21, line 235) and Emma assigns Rebecca the duty of presenting the drawings of the magnet and paperclip during the whole class model presentations (Extract 25, line 76).

**Summary for Group 5**

Emma was an animator of four entities while the rest of the group drew two entities, which was not equal like Group 3. It would appear that from this data that Emma participated more often than the other group members. However, when looking at frequency, production roles, and communicative practices is evident that Landon participated most often in the creation of the group model. This group's participation was shaped by the positions each member performed. Landon held the position with highest status in the group, the group science leader. He maintains that position by balancing displays science expertise, with off-task comments that change the direction of conversations. Dylan is positioned as secondary leader for the group. Landon makes comments that aligns both he and Dylan while excluding Emma and Rebecca. Emma exhibits many instances to align her position in the group with Dylan and Landon, leading to her aspiring science expert position. However, these attempts are not accepted by Dylan and Landon. Rebecca verbally participates the least for the group and is positioned as the good drawer through descriptions provided by her peers during conversations.

The communicative practices and patterns for participation present in Group 5 do not support authentic consensus modeling. Landon's and Dylan's frequent involvement do not support the ideas of Rebecca and Emma to be considered often. Furthermore, Rebecca and Emma are not afforded opportunities to enact author or principal production roles for entities representing science mechanisms. There are three instances of the group discussion pathway that led to consensus of some entities in the group model. These entities are macro-level entities (see Figure 5), sections depicting three orientations (entity 1), headings for each section (entity 2) and labels for the various entities in the model (entity 10). The group discussions surrounding these entities were related to task completion not mechanistic reasoning. The sections depicting three alternative orientations of the paperclip and magnet could signal a greater mechanistic reasoning about the phenomenon. However, the conversation surrounding the addition of this entity was limited to location and size of the sections not what they are each representing.

## Role of the Teacher in Student Socialization During Consensus Model Development

The data analyzed for this dissertation comes from students' small group discussions. The teacher and researcher present in the room during this stage of the instructional unit circulated the room to monitor the group work and guide student conversations. Most of the recordings for the two groups analyzed in this study do not include teacher or researcher interactions. However, at the beginning of Phase 4 of instruction and the beginning of the class on subsequent days, the teacher and researcher share their expectations for consensus building in small groups with the entire class (see Extract 29).

Extract 29

| | | |
|---|---|---|
| 66 | Teacher: | Okay so we all have our drawings. We all have our model that we've been thinking about on our own, and I know you've been talking to each other in your groups as well, but you might have something different on your paper than what someone else has. and what were gonna work towards, and today we'll start and Monday we'll finish. We're gonna build a consensus model. So that means, you're gonna work in your table groups. Okay? To form one model that you all kind of present as your model as a group. So, let's think about that word, consensus, have you heard the word consensus before? Some people yes? Some people no? Where have you heard the word consensus before? Can you think of another example? |
| 67 | Student: | So, like an average that everyone agrees upon? |
| 68 | Teacher: | Yeah, something that everyone agrees upon. Now let's think about that, even in our everyday life. Now let's say you guys need to decide what movie you're going go to see after school, is that going to be an easy decision or a difficult decision? |

69 Students: <*unclear many students respond simultaneously*>

70 Teacher: Hmm it kind of depends on who you're going with right? But my point is that sometimes it's easy to form consensus, and sometimes there's a little bit of disagreement in the group. The reason why we're talking about this is because, as actual scientists in a lab, you're not always going to agree one hundred percent with each other about your models, about what's happening in the world, but you can agree like this is a model we can work with, then let's test it, let's revise it over time. So, the skills we are practicing here today are not just in thinking about magnetism but really about working together. How do we work together to form a consensus model that we can use to test this phenomenon? To test our ideas? So, it's okay today if you don't agree one hundred percent with your group. The purpose of these conversations is to figure out, where do we agree? Where do we disagree? Why? What evidence can we use to support our ideas?

Extract 29 documents the way the teacher framed the purpose of the consensus modeling task during whole class instruction. The teacher began by reviewing what the students have done and are going to be doing. She then asks the class what the word consensus means (line 66). One student in the class responds saying "So like an average that everyone agrees upon?" (line 67). The teacher agrees with the student and then gives an example to the class of trying to decide what movie to go see with friends (line 68). The teacher then situates the term and purpose of consensus in science (line 70). Following the transcript in Extract 29, the teacher goes over expectations for sharing their individual models with the group before they start working toward their consensus model.

Throughout Phase 4, the teacher and researcher emphasized the importance of active listening and using evidence to support their ideas as groups worked on developing their consensus models. The teacher and researcher framed the task using communal terms like "we" and "as a group" (lines 66 and 70). The communal framing of the task could potentially promote group discussions where students critically consider and build upon each other's ideas (González-Howard & McNeill, 2018). Further, the instructional framing by the teacher and researcher promoted the process of building consensus as equally if not more important than the final product of the model, which could also support consensus building (Ke & Schwarz, 2019). For example, in Extract 29 the teacher states "So, the skills we are practicing here today are not just in thinking about magnetism but really about working together. How do we work together to form a consensus model that we can use to test this phenomenon? To test our ideas?" (line 70). The instructional unit was framed to the class as a communal process and the goal was working together not just completing the task. The reviewed research suggested that both these practices support consensus building in the classroom (González-Howard & McNeill, 2018; Hammer & Elby, 2003; Ke & Schwarz, 2019). While the analysis from this study cannot confirm that the moments where the groups engaged in the group discussions pathway resulted from the teacher's framing of the unit of study, it is important to recognize and consider this framing as a potential factor. In addition to this whole class framing which may have impacted how students navigated the consensus process, there were also two instances where the teacher or researcher interacted with the students in Groups 3 and 5 and contributed to positioning students in particular ways.

**Challenging the Expert Position**

First, in extracts 16 and 17, the interaction began when the teacher came to group 3 and asked if they were the group talking about electricity (line 349). The interaction between the teacher and Evan challenges Evan's ideas about electromagnetism through asking questions and using a multimeter to test Evan's hypothesis that magnets always generate electricity. After the interaction, Evan expresses frustration with his misconception stating "well, I found the gap in my knowledge" (Extract 17, line 382). The questioning from the teacher both challenged and reinforced Evan's position as a local science expert. On the one hand, the interaction exposed Evan's lack of knowledge about the relationship between electricity and magnetism. On the other hand, Evan was the only student who articulated a hypothesis for magnetism that involved a relationship with electricity, and he was the only student in this group whose thinking inspired the teacher to recruit new equipment to test his ideas. Thus, by testing the model with the teacher, Evan displays the exact type of scientific reasoning that would indicate his science expert status to his peers. The teacher's sustained engagement with Evan's thinking puts him in league with the teacher even as he identifies a gap in his understanding.

The second example of how teacher questioning can challenge or reinforce enacted positions is presented in Extract 20. In this interaction, the members of group 5 share their individual models. The researcher approaches the group. Landon has just shared his model with the group, and Emma asks him "How would you represent the force? The magnetic field?" (line 27). Landon responds by indicating in his model where the magnetic field is (line 28). Emma then clarifies her question asking how he would represent the field molecularly (line 29). Landon hesitates and the researcher praises Emma's question. The researcher rephrases Emma's question and asks Emma if her interpretation was correct (line 33). Emma agrees and the researcher praises her question again. Landon then indicates that he is uncertain (line 36). The researcher indicates that it is “ok” to be uncertain (line 37). Landon then responds by sharing a detailed account of what he does know about a separate part of his model (line 38). The researcher engages with Landon about his comment.

The researcher’s praise and inquiry about Emma’s question, and Landon’s uncertainty challenged Landon’s position as an expert. Landon quickly regained his position through his lengthy description about what he did know in his model. These two examples of teacher interactions in small groups, with Evan and Landon, demonstrate the ways in which a teacher can challenge or reinforce the social positioning taking place in small groups. However, the direct role of the teacher during small group consensus building appears minimal compared to the student interactions. Even when the teacher attempted to validate Emma’s comments, this repositioning of expertise was not robust or sustained enough to change Emma’s position in the group. Similarly, while the teacher’s interaction with Evan disrupted his position to some extent by revealing a lack of knowledge, the way the interaction unfolded also positioned him as a student knowledgeable enough to engage with the teacher to test his ideas using scientific materials.

## Summary of How Socialization Impacted Consensus Model Construction

Entity 4, text of forces acting on the paperclip, was added to the model through the single addition pathway where one student decides and draws the entity on the group model (Figure 4, in Chapter IV). Addie enacted all the production roles for that entity which indicates the single addition pathway.

The pathways that lead to the inclusion of entities on the group models are influenced by the positions group members occupy while creating the model. Both groups had close to equal instances of group members holding the animator role for entities, at the surface this might seem like students are participating in the instructional activity equally (with Emma participating more than the others in group 5). However, through a deeper analysis, it is apparent that animators can be directed by the authors and principals of the various entities. There are multiple occasions where the animator was not afforded access to the discussions related to the ideas being represented. Furthermore, certain students held roles in the group more often than others which afforded their ideas to be represented and the right to direct others on what to add to the group model.

Group 3 was socialized through demonstrated expertise with the phenomenon. Addie occupied multiple author and principal roles in the group because of her assertiveness toward completing the model as directed by the teacher. Addie's egalitarian leadership promoted instances of the group discussion pathway, which indicated more discussions relating to the mechanisms and science content the entities are representing. Participation was not equitable for Group 3 and a local social hierarchy influenced their participation. However, the construction of their model had more consensus related talk.

Group 5 was influenced by a division of rights and duties in the group between the boys and girls. Landon and Dylan occupied the author and principal roles more often because they were self-assigned the “finer details” in the model. Emma and Rebecca were assigned the duty of being “drawers” of the model by Landon and Dylan. They held author and principal roles when the entities were considered task-oriented and not related to the “details.” The divide in rights and duties in Group 5 appears to be related power differences between gender (O’Barr & Atkins, 1980). I am not making causal claims about gender in this assumption, rather the distribution of rights and duties seems to be connected to gender. Emma frequently tries to position herself as a science expert in the group and uses communicative moves similar to Landon and Dylan. But never occupies a higher status position during the construction of their group model.

Group 3 had more instances of coming to consensus on entities than Group 5, which was shaped by the different leadership styles present in each group. Landon performed an authoritarian style leadership which negatively impacted the construction of the consensus model (Wodak et al., 2011). Addie performs an egalitarian style leadership (Wodak et al., 2011) , which offered more opportunities for Group 3 to engage in the group discussion pathway. The next chapter will elaborate on the instructional implications of the results from this Chapter and Chapter IV.

# CHAPTER VI

# DISCUSSION

This dissertation began with a quote from the NRC (2012, p. 27) "Science is fundamentally a social enterprise, and scientific knowledge advances through collaboration and in the context of a social system with well-developed norms." The findings in this dissertation exemplify the notion that scientific knowledge is shaped through collaboration. The purpose of this dissertation was to explore participation patterns and the communicative processes students use while engaged in a well-structured collaborative learning task of developing a group consensus model.

I employed an instrumental case study design to study how two small groups of seventh-grade students in a science classroom interacted to create group consensus models for a scientific phenomenon. I used discourse analysis techniques guided by the theoretical framework of LS and PT to analyze audiovisual data and student work samples. The theoretical paradigm of LS suggests individuals are socialized through language to act or speak in various ways and contexts (Baquedano-López & Kattan, 2008; Ochs & Schieffelin, 2014). To operationalize LS, I utilized PT to identify rights and duties that signal positions. Describing the enacted positions in the groups revealed the participation patterns of group members in this context.

In the previous two chapters, I have provided frequencies of communicative practices, detailed descriptions, and analysis of extracts to answer the research questions guiding this study.

1. What communicative practices do students use to negotiate the incorporation

of ideas as they are instructed to build group consensus on a scientific model?

2. How are students in two small groups socialized by their teachers and peers to participate in a modeling task where they have been instructed to reach consensus?

Chapter IV documents the processes the two small groups used to add entities to a group consensus model of a phenomenon. Chapter V explains how the students in the groups were socialized to participate in specific ways which directly influenced the processes described in Chapter IV. This final chapter will begin by summarizing the results from Chapters IV and V. The chapter then addresses the implications of the findings for researchers, curriculum designers and teachers. The final sections of the chapter will describe the limitations, and future research possibilities.

## Communicative Pathways for Consensus Model Development

Developing and using models to represent an understanding for a phenomenon is embedded in both national and state standards (NRC, 2012). Science education scholarship has documented positive learning outcomes for students when they develop conceptual models for phenomena (Guy-Gaytán et al., 2019; Oh & Oh, 2011; Schwarz et al., 2009; Windschitl et al., 2008). Many recommended instructional sequences include developing consensus models after students create an initial model (e.g., Braden et al., 2021; Forbes et al., 2015; Kenyon et al., 2008; Krajcik & Merritt, 2012; Passmore et al., 2017; Schwarz et al., 2009). This study contributes to existing scholarship by offering two portraits of the communicative processes that small groups of heterogenous learners can engage in while building consensus models. These portraits revealed that the students did not actually reach consensus when constructing their models.

The design of the instructional unit implemented in this study followed the recommended sequence for modeling (Passmore et al., 2017) and language supports to support equitable participation during small groups (Braden et al., 2021; Fisher et al., 2008; Michaels & O'Conner, 2012; Oliveria et al., 2014). There were four steps embedded in the unit to support consensus model development (see Table 3; Appendix C). The framing of the consensus building task by the teacher and researcher in this study, was aligned to support consensus building as described by Ke and Schwarz (2016) where it was explicitly stated on multiple occasions that the purpose of the consensus model task was to help students make sense of and explain a scientific phenomenon and create a shared understanding for the group. The teacher's instruction did mention the possibility that everyone would not agree with every aspect of the model but that they should create a model that was workable that they could test. The results indicated that the group consensus models did not demonstrate actual consensus for all group members. And, that there were many ways in which learners added entities to the group model without actually discussing those entities. There was consensus from some members for some entities in the models, but no holistic consensus on the group-produced model. Teachers and curriculum designers need to be aware that even if students appear to successfully produce group consensus models, this does not necessarily indicate that the ideas presented in the model were explicitly discussed and negotiated.

The two groups involved in this study used four discursive pathways to add entities to their group models. The pathways are group discussion, pair discussion (two students discuss the entity to be added), student instruction (one student instructs another to add and entity to the model), and single addition (one student decides and adds and entity to the model). The group discussion pathway supported the most participation from group members and greatest likelihood of reaching consensus, the other pathways exhibited a decrease in participation from group members to the single addition pathway which only involved one student deciding and adding to the model and had no explicit evidence of consensus from the group.

The purpose of constructing a consensus model of a phenomenon is for students to consider ideas of others and refine their ideas as new evidence is presented (Barth-Cohen & Wittmann, personal communication, October 16, 2018; Schwarz et al., 2009). Throughout the analysis it became evident that groups did not employ scientific discussions often to decide what to add to their models. The results in Chapter IV are significant as they describe the ways students created consensus models thereby providing insight into the communicative practices that support and limit consensus building. Chapter V then showed how the local identity positions the group members take up while working collaboratively directly influence the enactment of the communicative pathways used to create consensus models.

## Language Socialization of Group Members

In addition to providing insight into the communicative practices by which entities were discussed (or not) and added to the models, the findings/analysis also shed light on how individual students' local positionings reflected and created those pathways. The analysis reveals how students are socialized by each other to participate in various ways in the consensus modeling task. From an LS perspective, consensus modeling tasks offer opportunities to socialize students into the collaborative practices of scientists and other professions that require joint decision making or consensus. The results from answering research question two demonstrate how student socialization directly influences a group's ability to create a consensus model. An analysis grounded in positioning theory helped to reveal "microscopic understandings" of the groups' interactions that go beyond surface level assumptions to reveal patterns of participation for each group member (Rymes, 2015).

Both groups' patterns of participation were characterized by locally constructed status hierarchies (Adams-Wiggins et al., 2020; Cohen, 1994). The status of group members was in part dependent on the use of technical science language as cultural capital. Students with higher status also enacted more leadership behaviors. The leadership styles tacitly built and reinforced the status hierarchies. Students with higher status, in this case Addie in Group 3 and Landon in Group 5, also had higher frequencies of performing author and principal production roles in their groups (Goffman, 1981). This relates to Wodak et al.'s (2011) description of *egalitarian* and *authoritarian* leadership styles in corporate settings. These leadership styles, embodied by Addie and Landon in this study, influenced the outcome of the consensus models. Addie in Group 3 often demonstrated characteristics of an egalitarian leader, where others' ideas were encouraged and group discussions were promoted (Wodak et al., 2011) which led to more opportunities for consensus building. Landon in Group 5 demonstrated characteristics of an authoritarian leader, including high frequencies of turns of talk, disagreeing with others, using technical science jargon, and making off-task comments which negatively impacted his group's ability to reach consensus (Braden, 2022; Wodak et al., 2011).

Both groups demonstrated other positions that had higher status. Group 3 had a student enact a *stereotypical science expert* position characterized by the use of technical scientific jargon and using lengthy speech about what is known when uncertain (Braden, 2022). Group 5 had a student enact a position of *secondary leader,* where at times displayed characteristics of a science expert and also supported the communicative practices of the authoritarian leader with agreement. The stereotypical science expert and *secondary leader* did not enact the author and principal roles as often as the group leaders but had more opportunities where their ideas were considered and represented in the group models. The lower status students in both groups did not enact author and principal production roles as often. The situationally defined lower status positions in Group 3 are the *good assistant*, and *off-task novice*. The good assistant was characterized by being passive during discussions, not expressing ideas, opinions, or disagreement often (Campbell & Hodges, 2020). The off-task novice position was characterized by a high frequency of off-task comments, frequently expressing uncertainty about the science content, and often asking other group members questions about the science content and off-task topics (see Table 7). Other group members positioned the off-task novice through correcting speech and word choice. The positions enacted in both groups were significant in the construction of the consensus models.

**Connecting the Local Positions and the Consensus**

**Communicative Pathways**

The results from this study provide insight into the communicative practices that support or limit consensus building conversations. Understanding how students perform and participate during collaborative tasks can aid in targeting inequities in group work and developing supports for productive leadership while disrupting unproductive leadership and status hierarchies. Half of the entities in Group 3's consensus model was added through the group discussion pathway. As described in Chapter IV, the group discussion pathway provides the most opportunities for groups to participate in mechanistic reasoning and consensus related conversations. There was a status hierarchy in the group which influenced how the group members participated, but the egalitarian leader position promoted group discussions. For instance, the group leader would ask questions to the group to begin conversations (i.e., Extract 11, line 98), challenge ideas where she was uncertain, (i.e., Extract 2, lines 172 and 177) and ask other group members to share their ideas (i.e., Extract 6, lines 54 and 59).

Group 5 did not engage in as many group discussions as Group 3. Furthermore, the instances of the group discussion pathway did not support mechanistic reasoning because most of the instances were related to task completion not scientific reasoning. Group 5's patterns of participation and positioning also contained a status hierarchy. However, the higher status positions in this group did not perform communicative moves that supported scientifically meaningful group discussions. For example, the group leader from Group 5 used everyday patterns of argumentation of winning through power and persuasiveness, not scientific argumentation where the group would engage in conversation to create a shared understanding of a phenomenon based on evidence (see Extract 27, line 48; NRC, 2007). This pattern of argumentation directly limited the opportunities for Group 5 to engage in productive consensus related conversations. Furthermore, when other group members would attempt to engage in discussions around science content, the student occupying the authoritarian leader position made off-task comments that redirected the conversation away from the science content (i.e., Extract 7, line 93).

The types of talk students used while interacting shaped the status hierarchies in both groups, enacted positions, and participation patterns. Students that used technical science jargon were afforded more opportunities to participate and held higher status positions in the groups. While many researchers advocate for a shift in classroom science discourse patterns (Braden, 2017; Brown & Ryoo, 2008; Jensen et al., 2021; Valdes, 2018), this study provides evidence of the static and salient power of language. Students that used everyday language to present and discuss ideas were not afforded the same rights as others. For example, Damien used everyday language to tell the group his ideas, but his speech was frequently corrected. His ideas were not considered by the group suggesting that his language use, and the value assigned to technical science jargon did not align as it did for other group members. In the next section I present the implications of this study along with recommendations for researchers, instructional designers, and teachers.

## Implications

Over two decades ago, Bianchini (1997) critiqued the assumption that groupwork is a fast and easy way to ensure equity in a science classroom. Bianchini found that even with research supported interventions to support equitable participation, groupwork as an instructional practice did not provide all group members access to fully engage in science learning. Similarly, the instructional unit under study in this dissertation was designed using research-based instructional supports to promote equitable participation from group members including assigned leadership for the steps of consensus building, guiding questions, and sentence starters to foster science conversations (see Appendix C; Jensen et al., 2021; Michaels & O'Connor, 2012). Even with the supports, the students in this study did not participate equally, and it became evident that the group consensus models did not represent actual consensus from the groups. The consensus models were a representation of ideas mainly from students with higher status in the groups.

The findings of this study reveal that assigning students to create consensus models does not necessarily reflect an actual consensus for the group. Thus, when teachers use consensus modeling to support students' thinking, they must be careful to monitor group interactions to make sure groups engage in discussions around scientific reasoning not just task completion. Researchers and curriculum designers advocating for the use of consensus modeling may also want to examine how best to structure group conversations to enable more genuine consensus-related talk and evidence-based reasoning among students. While the exact processes that the two groups followed and the exact local positions occupied by individuals are unlikely to be replicated exactly in other contexts, the importance of the communicative pathways that lead to or away from meaningful discussion, and how egalitarian and authoritarian leadership roles impact group success is likely to transfer to other small group work settings.

Moving forward, researchers and instructional designers need to examine additional cases of small group consensus building to determine when and how to use consensus model instruction by examining communicative practices that lead to or inhibit students' scientific reasoning. Given that there are moments where Group 3 engaged in mechanistic reasoning while creating the consensus model, and Group 5 had some scientific discussion, consensus models have the potential to support science learning. The whole class discussion scaffolded by the teacher that followed the consensus-modeling phase of instruction was rich in evidence-based reasoning. Researchers, instructional designers, and teachers need to be aware that the completed product created by small groups does not necessarily represent consensus for the group, but it may have other instructional value. As curriculum that includes developing consensus models is created, curriculum designers and teachers should reflect on the intended purpose or objective of using small group consensus modeling. If the intended purpose is for students to develop their own understanding by considering the ideas of others and use evidence to decide on entities to add to the model, then teachers need to try a variety of interventions and supports to foster the group discussion pathway.

**Recommendations**

There is not one simple solution to supporting equitable participation during small group consensus building. Social hierarchies and student socialization are often tacit and result from larger societal norms. To disrupt the natural formation of social hierarchies, teachers, teacher educators and researchers need to look at changing the classroom culture as a whole. Teachers need to understand that these problems require a multifaceted approach. In the coming subsections I will describe instructional strategies that could potentially support consensus building and classroom management strategies to support a larger shift in understanding and challenging tacit behaviors that perpetuate status hierarchies and ways to examine how students are socialized to participate in classrooms.

### Consensus Building Instructional Supports

To support consensus building in the classroom, teachers could have students individually evaluate how much they agree or disagree with their group model. Braden et al. (2021) describes the *Consensus Continuum* where students have a physical way to express whether they agree or not. A physical sign of agreement or disagreement is not as easily dismissed as an utterance or silence. The physical sign is there for everyone to see. If a person marks disagreement, the group is provided with an opportunity to engage in the group discussion pathway. Heuristics like the consensus continuum (Braden et al., 2021) allow groups to identify what parts they agree or disagree with and why then generate evidence to support or revise ideas.

Another similar possible support could be for each group member to share which entities on their model they are uncertain about, or that the group did not come to consensus on with the whole class when they present their consensus model. Then the teacher can lead a discussion soliciting evidence from students to test the model. This support allows the teacher to control the conversation in order to focus the students' attention on scientific reasoning and avoid off-task digressions that were used as power moves in small group interactions. As evidenced in Group 5, off-task comments derailed opportunities for mechanistic reasoning conversations (Extract 7). The teacher can guide and model productive scientific argumentation if students present entities they are uncertain of in their small group consensus models.

The final instructional recommendation for teachers is to create a whole class consensus model and identify areas where students are less confident of the model and design investigations as a class to test the model (Passmore et al., 2017). The teacher could model and foster productive science talk (Michaels & O'Connor, 2012) as a whole class to scaffold expected communication patterns before assigning students to create group models (Passmore et al., 2017). All of the recommendations in the subsection require students to confront uncertainty or disagreement and generate evidence to gain a better understanding or negotiate consensus. Conversations like these promote scientific reasoning about the phenomenon in the model.

## Challenging Status Hierarchies

As demonstrated in multiple studies, collaborative learning is not a solution for equitable participation for students and group work often is characterized by the display of status hierarchies among group members (Adams-Wiggins et al., 2020; Archer et al., 2013; Bianchini, 1997; Cohen, 1994; Cohen & Lotan, 1995; Engle et al., 2014). Social status hierarchies can and do influence the level of participation among group members as demonstrated in this study. These locally created and mediated hierarchies influenced the enactment of the pathways that led to including the various entities in the group models. One method for assigned leadership (Cohen & Lotan, 2014), assigning group members to lead phases of the consensus process, was implemented in this study to attempt to disrupt status hierarchies and promote equitable participation, and it supported one student in engaging in interactions with her peers. However, there was no clear evidence to suggest assigned leadership influenced the participation for any of the other participants. One reason for this may have been the way that the instructional designers organized the consensus conversations into four phases, where each group member was assigned to lead a stage, but the individual phases did not offer the same opportunities to lead group discussions. As the unit was taught, the researchers observed this, and revised the curriculum to attempt to elicit more opportunities to engage in scientific reasoning conversations at each phase of the model building process (Braden et al., 2021).

The formation of status hierarchies appears to be heavily influenced by the use of technical science jargon. As previously described this unit of instruction had all the components for equitable science talk (Jensen, 2021). Yet, the groups still appeared to associate science expertise with technical science jargon over everyday language use. Research from science discourse studies describes the importance of students using everyday talk in developing mechanistic reasoning not just technical science jargon (Braden, 2017; 2019; 2022; Brown, 2004; Brown et al., 2005; Olitsky et al., 2010; Russ et al., 2008). Additional empirical research on supports and strategies are needed to support mechanistic reasoning in everyday talk while engaging in small group collaboration.

To disrupt status hierarchies and reshape the cultural values of the classroom to include science talk in everyday language, I recommend teachers and students regularly reflect on their behaviors. Students may be asked to consider how they enact or challenge the formation of status hierarchies. Teacher educators need to teach preservice and in-service teachers that cultural inequities exist in classroom as they do in society, and that we need to understand how they unfold in classroom discourse to start changing them. Changing a cultural phenomenon like status hierarchies will not happen with a simple solution. It will take a collection of strategies over time.

One strategy could be to use the classroom discourse analysis practices described by Betsy Rymes (2015). Rymes suggests that teachers take a critical approach to analyzing discourse patterns in their classrooms through video recordings and observations. Older students might be asked to engage in critical discourse analysis to aid in understanding how their own discourse patterns and types of talk influence (in)equitable participation in small group work. Opportunities for students and teachers to record and observe small group interactions and analyze the observation as a class could be one way to understand tacit behaviors that limit participation and identify behaviors that promote participation. If teachers and students continuously reflect on communicative practices that inhibit or support small group participation, over time the classroom culture could change.

## Limitations

This study had two primary limitations. First, given the nature of this as a case study, the exact results cannot be generalized to other contexts. As in, small groups of learners in other settings might navigate social positionings in slightly different ways and may engage differently in the communicative practices that shape consensus. While the small sample size of one iteration of a given lesson with two small groups limits of the generalizability of the specific findings, this smaller sample size allows for a more in-depth analysis of language and communicative practices, which would be untenable with a larger data set. Second, this study uses data previously collected from a larger project. While secondary analysis is not inherently a constraint, the lack of ability to gather further data, such as greater details on participant demographics and student perspectives from interviews, constrains the study and its interpretations. The participants were not given the opportunity to discuss their participation with the research team or declare characteristics about themselves, which could add depth to the claims about students gendered and ability related learning opportunities in the science classroom. Thus, the analysis focused on details revealed through existing interactions as opposed to students' reflective commentary about themselves outside of instruction. Findings related to social markers such as ability and gender are based on the analysis of how students reveal their ability- and gender-related identities in social interaction rather than participants' self-identified social markers. While this is a limitation, on the one hand, attending to social markers as they emerge as salient to speakers in interaction is also a feature of many approaches to discourse analysis. In many daily interactions, it is our perceptions of others that influence how we behave toward them. My role as analyst was to uncover how students performed or invoked aspects of their identities in interaction as they positioned each other during small-group collaboration, illuminating instances where opportunities to participate were afforded or constrained.

## Future Research

After data collection for the larger project, it was clear to the research team that participation and consensus related discussions were not equitable for all group members, even with the supports provided. The unit of instruction was revised so that each phase of the consensus building process might include opportunities for the groups to engage in scientific reasoning conversations. We also developed an instructional scaffold to aid groups in attaining consensus for the addition of entities. We have called this scaffold the "consensus continuum" (see Braden et al. 2021). As described earlier in this chapter, the consensus continuum is a card where students have to physically mark if they agree or disagree with the ideas for entities being presented. The guiding questions for the creation of the consensus continuum were, would the opinions of students that do not participate as frequently be considered if their disagreement was displayed physically? And would it promote more opportunities for mechanistic reasoning in the group if someone physically denotes disagreement? Future research could study if the instructional scaffold "consensus continuum" aids in facilitating participation from all students and increased opportunities to engage in mechanistic reasoning or science conversations.

Researchers and instructional designers need to develop and research strategies for how to shape small group interactions to facilitate more opportunities for group discussions when building consensus models. The communicative moves that support the group discussion pathway are asking questions and expressing disagreement of an idea. Supporting students in asking questions or expressing disagreement may increase opportunities for group discussions. Both groups displayed instances of expressing disagreement and asking questions but Group 5, had fewer moments where the questions or disagreements resulted in group discussions because the authoritarian style leader would redirect conversations. Group 3's leader used more of an egalitarian leadership style, asking questions, and encouraging others. I suggest that research focus on developing supports for egalitarian style leadership to disrupt practices associated with authoritarian style leadership. These practices could be to teach students how to ask and respond to questions that could support group discussions, norms that discourage changing topics when a question is asked, and student reflection of their own behaviors that inhibit group discussions. Teachers and researchers must be prepared to implement these strategies and test them over a longer time period than one unit of instruction. Reshaping classroom discourse will take time and continual effort.

This study adds to the established research on small group collaboration, indicating that status hierarchies form naturally in groups (Cohen, 1984). Interventions have been created to disrupt these hierarchies like marker colors for each group member and distributed leadership (Bianchini, 1997; Cohen & Lotan, 2014), yet they still emerge. Further research could be conducted to explore why interventions are not disrupting the hierarchies, and why the formation of hierarchies remains prevalent in group work. Research is needed to take an ethnographic look into the discourses, routines and practices displayed over time that reinforce status hierarchies. As another possible intervention, I would further suggest action research with students to examine how their own behavior influences the participation of others. Students engaging in the action research could indicate what successful consensus building looks like and sounds like in their context.

## Conclusion

This dissertation explored how students navigated consensus building during small-group collaboration in a science classroom. I used a theoretical framework of language socialization and positioning theory to understand how ideas become incorporated or excluded in the group models, and how individual groups members are socialized to participate in varying ways (Anderson & Gresalfi, 2010; Goffman, 1981; Kotsopoulos, 2014; Ritchie, 2002). The findings indicate that social functions of discourse outweighed the content related conversations including engaging in argument from evidence and ultimately the groups' abilities to create consensus models. This research contributes to science education literature by describing the communicative pathways deployed during consensus building and offers a portrait of how students' social positions influenced participation in creating the consensus model. Exploring how students were positioned while participating in consensus building illuminated the affordances and constraints of a nationally recommended instructional practice.

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# APPENDICES

# Appendix A

## Institutional Review Board (IRB) Approval

Research
UtahStateUniversity

Institutional Review Board

Exemption #1, #4
**Certificate of Exemption**

From: Melanie Domenech Rodriguez, IRB Chair

Nicole Vouvalis, IRB Director *Nicole Vouvalis*

To: ***Sarah Braden***

Date: ***December 1, 2022***

Protocol #: ***13075***

Title: ***Exploring Small Group Consensus Building***

The Institutional Review Board has determined that the above-referenced study is exempt from review under federal guidelines 45 CFR Part 46.104(d) categories #1 and #4:

> *Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special instructional strategies, and research on the comparison among instructional techniques, curricula, or classroom management methods.*
>
> *Research Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met: (i) the identifiable private information or identifiable biospecimens are publicly available; (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not have contact with the subjects, and the investigator will not re-identify subjects; or (iii) the research involves only information collection and analysis involving the investigator's use of identifiable education records when that use is regulated under FERPA*.*
>
> **All FERPA requirements must be followed in obtaining the secondary data as set out in the approved protocol (including securing either FERPA authorization if applicable). Please note, this exemption cannot be applied to federally funded research.*

This exemption is valid for five years from the date of this correspondence, after which the study will be closed. If the research will extend beyond five years, it is your responsibility as the Principal Investigator to notify the IRB **before** the study's expiration date and submit a new application to continue the research. Research activities that continue beyond the expiration date without new certification of exempt status will be in violation of those federal guidelines which permit the exempt status.

If this project involves Non-USU personnel, they may not begin work on it (regardless of the approval status at USU) until a Reliance Agreement, External Research Agreement, or separate protocol review has been completed with the appropriate external entity. Many schools will not engage in a Reliance Agreement for Exempt protocols, so the research team must determine what the appropriate approval mechanism is for their Non-USU colleagues. As part of the IRB's quality assurance procedures, this research may be randomly selected for audit during the five-year period of exemption. If so, you will receive a request for completion of an Audit Report form during the month of the anniversary date of this certification.

In all cases, it is your responsibility to notify the IRB **prior** to making any changes to the study by submitting an Amendment request. This will document whether or not the study still meets the requirements for exempt status under federal regulations.

435.797.1821 | 1450 Old Main Hill | Logan, UT 84322 | MAIN 155 | irb@usu.edu | FWA#00003308

Institutional Review Board

Research
UtahStateUniversity

Exemption #1, #4
**Certificate of Exemption**

Upon receipt of this memo, you may begin your research. If you have questions, please call the IRB office at (435) 797-1821 or email to irb@usu.edu.

The IRB wishes you success with your research.

435.797.1821 | 1450 Old Main Hill | Logan, UT 84322 | MAIN 155 | irb@usu.edu | FWA#00003308

# Appendix B

## Transcription Conventions

| Symbol | Meaning |
| --- | --- |
| . | end of intonation unit; falling intonation |
| ? | end of intonation unit; rising intonation |
| ! | raised pitch and volume throughout the intonation unit |
| °° | lower volume |
| : | Length (e.g., wha:::t! as a lengthened exclamation). Use multiple colons to indicate length |
| — | self-interruption; break in the intonation unit |
| (pp) | pause of greater than 0.5 seconds |
| @ | laughter; each token marks one pulse |
| [] | overlapping speech |
| () | uncertain transcription (e.g., "(you'll/we'll) find it later") |
| / | alternate hearings of uncertain transcription (e.g., "(you'll/we'll) find it later" if not sure which one) |
| # | unintelligible; each token marks one syllable (e.g., you know # I feel) |
| < > | transcriber comment; nonvocal noise; gesture, facial expression |

# Appendix C

# Consensus Model Instructional Steps

Goal: Build a Consensus Model

**1**

**Question: What are the similarities and differences in our models?**

*Group leader asks the question & leads discussion*
*(use prompts to ask peers to clarify ideas and add on)*

**Responses:**

- I noticed we all have ________________.
- I noticed only X has ________________.
- This is the same ______________.
- This is different ________________.

Goal: Build a Consensus Model

**2**

**Question: What do we agree should be in our model? Why?**

*Group leader asks the question & leads discussion*
*(use prompts to ask peers to clarify ideas and add on)*

**Responses:**

- I think we should include _________ because __________.
- I agree OR disagree with _________ because __________.

Goal: Build a Consensus Model

**3**

**Questions & Tasks:**

**(1) How should we start drawing our model?**
*Group leader asks the question & leads discussion*
**(2) Let's draw!**
*Everyone contributes to the model with a different color marker*
**(3) Let's review, is there anything that we talked about before that we haven't included? Anything we want to add or change to finalize our model?**
*Group leader asks the questions & leads discussion, all students make additions or changes as necessary.*

**Responses:**

- I think we should draw _________ because ________.
- I don't think we need __________ because ________.
- I think we need to add __________.

Goal: Build a Consensus Model

**4**

**Questions: (1) What's our evidence for this model?**
**(2) What could we do to collect more evidence or test this model?**

*Group leader asks questions & leads discussion.*
*Leader makes a list of evidence on the poster.*

**Responses**

- One piece of evidence is ______________.
- I'm not sure we have evidence for ___________.
- We could collect more evidence by ___________.
- We could test our model by ____________.

# Appendix D

## Turns of Talk by Group

*Group 3 Turns of Talk for Consensus Model Development and Presentation*

| | Part 0 Sharing models | Part 1 Comparing models | Part 2 What should in model | Part 3 Create the model | Part 4 Evidence for model | Presentation | Totals |
|---|---|---|---|---|---|---|---|
| Addie | 12 | 6 | 15 | 109 | **120** | 24 | 286 |
| Damien | 11 | 4 | **11** | 100 | 103 | **0** | 229 |
| Evan | 11 | 12 | 24 | **117** | 71* | 18 | 253 |
| Lindy | **11** | **14** | 10 | 47 | 58 | 3 | 143 |
| Totals | 45 | 36 | 60 | 373 | 352 | 45 | 911 |

**Evan left class early at the end of Part 3, he missed half of part 4*
***Bold** indicates the assigned leader for the part*

*Group 5 Turns of Talk*

| | Part 0 Sharing models | Part 1 Comparing models | Part 2 What should in model | Part 3 Create the model | Part 4 Evidence for model | Presentation | Totals |
|---|---|---|---|---|---|---|---|
| Dylan | 9 | 16 | 34 | **104** | 27 | 8 | 194 |
| Emma | **25** | **18** | 16 | 94 | 24 | 6 | 183 |
| Landon | 32 | 22 | **33** | 134 | 61 | **10** | 292 |
| Rebecca | 4 | 0 | **1** | 18 | **3** | 3 | 29 |
| Totals | 70 | 56 | 84 | 350 | 115 | 27 | 702 |

Appendix E

Frequency of Communicative Practices by Group

***Group 3 Communicative Practices***

| Communicative Codes | Addie | Damien | Evan | Lindy |
|---|---|---|---|---|
| Comment | **48** | **47** | **49** | **29** |
| Clarify | 17 | 4 | 30 | 13 |
| Correcting others | 8 | 1 | 3 | 3 |
| Epistemic Stance (uncertainty) | 13 | 11 | 4 | 8 |
| Off task | 10 | 31 | 12 | 5 |
| Consensus | **32** | **21** | **50** | **20** |
| Asking | 5 | 0 | 1 | 3 |
| Agreement | 8 | 8 | 16 | 10 |
| Disagreement | 19 | 13 | 33 | 7 |
| Prompting | 49 | 32 | 31 | 16 |
| Response | 13 | 24 | 18 | 7 |
| Student to student | 36 | 8 | 13 | 9 |
| Questioning | **92** | **92** | **88** | **60** |
| Response | 56 | 29 | 71 | 28 |
| Student asks student | 34 | 61 | 16 | 27 |
| Student asks teacher | 2 | 2 | 1 | 5 |
| Share Ideas | **30** | **16** | **21** | **18** |

*Note. The darker colors indicate more frequency. Bold indicates primary communicative practices.*

***Group 5 Communicative Practices***

| Communicative Codes | Dylan | Emma | Landon | Rebecca |
|---|---|---|---|---|
| Comment | 56 | 44 | 86 | 4 |
| Clarify | 25 | 22 | 36 | 1 |
| Correcting others | 0 | 0 | 0 | 0 |
| Epistemic Stance (uncertainty) | 13 | 5 | 7 | 0 |
| Off task | 18 | 17 | 43 | 3 |
| Consensus | 25 | 23 | 34 | 0 |
| Asking | 7 | 15 | 8 | 0 |
| Agreement | 15 | 2 | 8 | 0 |
| Disagreement | 3 | 6 | 18 | 0 |
| Prompting | 37 | 18 | 37 | 1 |
| Response | 15 | 4 | 10 | 1 |
| Student to student | 22 | 14 | 27 | 0 |
| Questioning | 59 | 76 | 102 | 15 |
| Response | 45 | 21 | 68 | 6 |
| Student to student | 12 | 51 | 30 | 7 |
| Student to teacher | 2 | 4 | 4 | 2 |
| Share Ideas | 17 | 20 | 45 | 4 |

*Note. The darker colors indicate more frequency. Bold indicates primary communicative practices.*

# Appendix F

## Enacted Production Roles for Entities in Group Models

*Group 3 Enacted Production Roles for Entities in Model*

| | Entity in model | Creation of Entity | | | Conversation for Entity inclusion |
|---|---|---|---|---|---|
| | | Animator | Author | Principal | |
| 1 | Magnet | Lindy | Lindy, Addie, Damien | Lindy | Task oriented |
| 2 | Thought bubble with magnet | Lindy | Addie, Evan | Addie | Scientific mechanism |
| 3 | Paperclip, string, tape | Addie, Damien, Evan | Addie | Addie | Task oriented |
| 4 | Text of Forces acting on the paperclip | Addie | Addie | Addie | Task oriented |
| 5 | Magnetic field (flow or electrons) | Damien | Addie | Evan | Science mechanism/ Task orientation |
| 6 | Molecules in magnet | Evan | Evan | Addie, Evan | Task oriented |
| 7 | Title on model | Addie | Addie | Addie | Task oriented |
| 8 | Side view of magnet and poles | Addie | Addie, Evan | Addie, Evan | Scientific mechanism |
| 9 | Molecules in alternate view of magnet | Evan | Evan Addie | Addie, Evan | Scientific mechanism |
| 10 | Thought bubble around sideview of the magnet | Damien, Lindy | Addie, Evan | Addie | Task oriented |

*Group 5 Enacted Positions for Entities in Group Model*

| | Entity in model | Contribution of Entity | | | Conversation on Entity Inclusion |
|---|---|---|---|---|---|
| | | Animator | Author | Principal | |
| 1 | Sections showing the three orientations | Emma | Landon Dylan | Rebecca | Task oriented |
| 2 | Headings for each section | Emma | Landon Dylan Emma | Emma | Task oriented |
| 3 | Magnet and paperclip | Rebecca | Landon Dylan | Landon | Task oriented/ Scientific |
| 4 | Description Boxes in each section | Emma | Emma | Emma | Task oriented |
| 5 | Magnetic field lines | Dylan | Dylan | Dylan | No discussion |
| 6 | North and South poles in magnet | Landon | Landon | Landon | Task oriented |
| 7 | Descriptions | Emma | Landon | Landon | Scientific mechanism |
| 8 | Molecules and zoom in bubbles | Landon | Landon | Landon | No discussion |
| 9 | Arrows in molecules | Dylan | Landon Dylan | Landon Dylan | Scientific |
| 10 | Labels for the various entities in model | Rebecca | Dylan | Landon Dylan | Task oriented |

# CURRICULUM VITAE

## SARA L. M. GAILEY

## EDUCATION

**PhD** Utah State University, Education, — Expected Summer 2023
Specialization: Curriculum and Instruction
Concentration: Cultural Studies
*Dissertation:* Exploring small group consensus building in a seventh-grade science classroom.
Chair: Dr. Sarah K. Braden

**MEd** Weber State University, Curriculum and Instruction — 2018
*Project:* Experiences of mentors and teacher candidates: Using co-teaching models during student teaching.
Chair: Dr. Louise Moulding

**BS** Weber State University, Elementary Education — 2012
Graduated Cum Laude
Science Concentration

**State Licensure and Endorsements**

- K-6 Elementary Education Professional License
- English as a Second Language (ESL) Endorsement

## UNIVERSITY TEACHING EXPERIENCE

**Weber State University**, Ogden, UT — July 2021 - Present
**Instructor**, Teacher Education

Undergraduate Courses

EDUC 3145: Educational Psychology and Classroom Management — Fall 2021, Spring 2022, Fall 2022, Spring 2023
The focus of this course is the fundamental theories and philosophies, concepts, processes, and applications related to human behavior, teaching and learning, interpersonal relationships, and classroom management.

EDUC 1010: Exploring Teaching — Fall 2021, Spring 2022
Students will explore the exciting world of teaching, examine what it means to be a teacher, and participate in field observations. This course is designed to introduce students to personal and professional

experiences within the educational community.

EDUC 3210: Integrated Level 2 Practicum — Spring 2023

The purpose of this practicum is to provide students with opportunities to design and implement integrated instruction in the elementary grades. Instruction will focus on integrating the arts, healthy lifestyles, and literacy. Students are required to spend at least 40 hours in an assigned classroom.

EDUC 4210: Integrated Elementary Level 3 Practicum — Fall 2021, Spring 2022

The purpose of this practicum is to provide students with opportunities to design and implement integrated instruction in the elementary grades. Instruction will focus on instruction of core subjects including language arts, mathematics, science, and social studies.

<u>Graduate Courses</u>

MED 6030: Advanced Educational Psychology — Fall 2021, 2022

This course is designed to provide an in-depth understanding of behavioral, cognitive and brain based psychological theories. The focus will be how this knowledge can impact and inform educational decisions and practices.

MED 6603: Positive Instructional and Behavior Supports for Schools — Spring 2022

This course includes systematic processes of sustainable and continuous school and classroom improvement. Concepts include climate and culture, process of change, building teacher and leadership capacity, development of effective leadership practices, and strategic planning that supports continuous school improvement.

MED 6313: Social Studies Methods for Elementary Teachers — Fall 2022

Explores new concepts in curriculum and methods of social studies instruction in the elementary schools.

**Utah State University**, Logan, UT — Jan 2019 to April 2022

**Graduate Student Instructor/ Adjunct Instructor** Teacher Education and Leadership

<u>Undergraduate Courses</u>

TEAL 3660: Educational Psychology for Teachers — Spring 2020, Fall 2020, Spring 2021, Fall 2021, Spring 2022

This course covers principles and practices for development of conditions for effective learning for. The course is required for prospective teachers in Early Childhood Education, Special Education, and Elementary Education.

ELED 1010: Orientation to Elementary Education — Spring 2019, Fall 2019, Fall 2020

Students assess themselves as prospective teachers by examining the attributes of effective teachers, practicing classroom relationship skills, and learning about the conditions and stresses of teaching. Students complete observations in an approved elementary classroom.

## K-12 Teaching Experience

**Ogden School District,** Ogden, UT 2012- 2021

*District Office 2020-2021*

**Elementary Science Specialist**

- Mentored teachers across the district in science instruction
- Collaborated with other content area specialists to design professional development for content integration.
- Created curriculum maps and gathered instructional resources aligned to the Utah SEEd standards for elementary grade teachers.

*Ogden Online Elementary 2020-2021*

**5th Grade Teacher**

- Taught all content areas to 5th grade students in a fully online environment.
- Instruction included multiple synchronous meetings daily on a video conferencing platform.
- Created engaging and rigorous synchronous and asynchronous lessons using various instructional platforms (e.g., Nearpod, Google classroom, Flipgrid).
- 5th Grade Lead for the school leadership team.

*Shadow Valley Elementary 2013-2020*

**Environmental Science Specialist**

- Taught environmental science lessons to grades K-6th,
- Mentored in-service teachers in science instruction.
- Created and maintained the portfolio for the school's environmental state designation.
- Advised special interest student groups (e.g., Green Ambassadors, STEM League, Science Club)
- Collaborated with community partners in science education research and service.
- Served on the school leadership team.

**6th Grade Teacher**

- Performed necessary duties for elementary teachers.
- Served as the 6th Grade Lead for the school leadership team.
- Advised the school STEM league.

**ESL Teacher/ Coordinator**

- Ensured equitable learning opportunities, interventions, and scaffolds were used for students with an ESL designation in grades 4- 6.

*Lincoln Elementary 2012-2013*

**3rd Grade Teacher**

- Performed duties necessary for elementary teachers.

## RESEARCH EXPERIENCE

**Utah State University**, Logan, UT 2018 to 2020
**Research Assistant**, Advisor: Dr. Sarah Braden

- Studied qualitative research methods and analysis
- Collaborated in research publications between two institutions

**Utah State University**, Logan, UT 2018 to 2020
**Graduate Student Researcher**

- Participated in the Qualitative Research Virtual Lab (QRVL)
- Studied qualitative research methods and analysis
- Conducted qualitative research
- Collaborated in developing research publication
- Presented findings from QRVL at conferences

## PEER REVIEWED PUBLICATIONS

**Gailey, S. M.,** & Knowles, R. T. (2021). Exploring preservice teachers' civic education beliefs with Q methodology. *Teaching Education*, 1-21.

Barth-Cohen, L., Braden, S., Young, T. & **Gailey, S.** (2021). Reasoning with evidence while modeling: Success at the middle school level. *Physical Review Physics Education Research, 17*(2), 1-18.

Braden, S., Barth-Cohen, L., **Gailey, S.** & Young, T. (2021). Modeling magnetism with the floating paper clip: Cultivating and leveraging visual literacy and talk moves to support diverse learners. *Science Scope, 44*(6), 84-92.

## PUBLICATIONS IN PROGRESS

Marx, S., Lavigne, A., Hawkman, A., Braden, Andersen, J., **Gailey, S**., Geddes, G., Jones, I., Si, S., & Washburn, K., (Accepted). "I didn't quit. The system quit me." Examining why teachers of color leave teaching. *Urban Education*.

## PEER REVIEWED CONFERENCE PROCEEDINGS

Young, T., Barth-Cohen, L., Braden, S., **Gailey, S.** (2021). Middle grade students reasoning about temporary magnetism. Physics Education Research Conference Proceedings [Virtual Conference] doi:10.1119/perc.2021.pr.Young

Young, T., Barth-Cohen, L., Braden, S., **Gailey, S.** (2020). A case of successful learning about magnetism through the use of evidence. Physics Education Research Conference Proceedings [Virtual Conference], edited by S. Wolf, M. B. Bennett, and B. W. Frank, doi:10.1119/perc.2020.pr.Young.

## REFEREED CONFERENCE PRESENTATIONS

Kiekel, J., Helmsing, M., Fisher-Maltese, C., Pham., S.T.H., **Gailey, S.,** Ward, E., Yates, K., Berson, I., Berson, M. (2023) The role of wonder across the curriculum: Conversations of supporting equitable learning opportunities. Inquiry Initiative Session at the Annual Meeting for Association of Teacher Education (ATE). Jacksonville, FL.

**Gailey, S.,** & Garavito Martinez, A., (2022) Uncovering Perceptual Bias Through Contextual Factors Assignments**.** Paper presentation at The Annual Summer Conference for the Association of Teacher Education (ATE). Nashville, TN.

Garavito Martinez, A., **Gailey, S.,** Alexander, M., Mower, D. (2022) Perpetuating Fallacies: Do contextual factors assignments expose deficit thinking? Paper Presentation at Critical Questions in Education (CQiE) Conference. Charleston, SC.

**Gailey, S**., & Knowles, R.T. (2021) Exploring preservice teachers' civic education beliefs using Q methodology. Paper presentation at The Annual Conference of American Educational Research Association (AERA) (online).

**Gailey, S**., & Knowles, R. T. (2020) Exploring preservice teachers' civic education beliefs with Q methodology. Research presentation at the College and University Faculty Assembly of the National Council for the Social Studies (online).

Young, T. G., Barth-Cohen L. A., Braden, S. K., **Gailey, S.** (2020). Creating explanatory and predictive models of magnetism in the middle-grades. Contributed presentation at the 2020 American Association of Physics Teachers (AAPT) Annual Conference. Grand Rapids, Michigan (online).

Young, T. G., Barth-Cohen L. A., Braden, S. K., **Gailey, S.** (2020). "Thinking like a physicist" in the middle-grades: Promising results from 7th-grade students studying magnetism. Poster presented at the 2020 American Association of Physics Teachers (AAPT) Annual Conference. Grand Rapids, Michigan (online).

Marx**,** S., Braden, S., Hawkman, A., Lavigne, Jones, I., A., Andersen, J., **Gailey, S.**, Geddes, G., Si, S., & Washburn, K. (2020) Examining why teachers of color leave the teaching profession. The Annual Conference of American Educational Research Association (AERA). ONLINE SYMPOSIUM DUE TO CORONAVIRUS

Hawkman, A., Marx, S., Braden, S., Lavigne, A., Andersen, J., **Gailey, S**., Geddes, G., Jones, I., Si, S., & Washburn, K. (2020) Race reflections in qualitative research: Positionality and race/ism in a collaborative research group. The Annual

Conference of American Educational Research Association (AERA). ONLINE SYMPOSIUM DUE TO CORONAVIRUS

Washburn, K., Braden, S., Marx, S., Hawkman, A., Lavigne, A., Andersen, J., **Gailey, S.**, Geddes, G., Jones, I. & Si, S. (2019). "Examining why teachers of color leave the teaching professions." Workshop conducted at the annual meeting of the National Association for Multicultural Education (NAME), Tucson, AZ.

Barth-Cohen, L., Braden, S., & **Gailey, S.** (2019). "Modeling magnetism: Tools to support revision of scientific models." *National Science Teachers Association, Area Conference, Salt Lake City, UT.*

Marx, S., Braden, S., Hawkman, A., Lavigne, A., Andersen, J., **Gailey, S**., Geddes, G., Jones, I., Si, S., & Washburn, K., (2019) Why teachers of color leave the teaching profession: An exploration through journey maps- *International Congress of Qualitative Inquiry (ICQI), Champaign, IL*

Geddes, G., Si, S., **Gailey, S.**, Anderson, J., Jones, I., & Washburn, K., (2019) Faculty Mentors: Marx, S., Braden, S., Hawkman, A., & Lavigne, A. Exploring why teachers of color leave the profession- *USU Student Research Symposium Poster Presentation Logan, UT*

## PROFESSIONAL TRAININGS

Cain, R., & **Gailey, S.** (November 2021 - March 2022) SEEd Standard Implementation Training. Ogden School District.

Braden, S., Barth-Cohen, L., **Gailey, S**. & Young, T. (2019, September). Modeling magnetism & supporting multilingual learners in 3d science instruction. Ogden School District.

Olsen, C., & **Gailey, S.** (2019, 2020) K-2 phenomenal science- Empowering students as scientists in the classroom. Ogden School District

Olsen, C., Jolley, B., & **Gailey, S.** (2018) 3-Demensional science- A new approach to teaching and learning. Weber State University

**Gailey, S.** (2017) Teaching 21st century skills using STEM. Shadow Valley Elementary

**Gailey, S.,** & Olsen C. (2017) Using claim, evidence, and reasoning to assess student learning. Shadow Valley Elementary

**Gailey, S.** (2016) Tools for a successful parent teacher conference. New Teacher Training at Shadow Valley Elementary.

## PROFESSIONAL SERVICE

**Weber State University Storytelling Festival**
Chair, 2023-present
Co-Chair, 2022-2023
Steering Committee 2021- 2022

**Teacher Education Admission and Retention Committee**
**Weber State University**
Committee Member, 2023- Present

**Child and Family Studies Referral and Retention Committee**
**Weber State University**
Teacher Education Member 2022- Present

**Teacher Education Relevant Assessment Team**
**Weber State University**
Committee Member, 2021-Present

## K-12 PROFESSIONAL SERVICE

**Elementary Science Advisory Team**
Committee Member, Utah State Board of Education, 2021- 2022

**Mentor Teacher**
Mentored teacher candidates from multiple higher institutions, 2014-2020

**Common Interim Assessment Development**
Committee Member, Ogden School District, 2017- 2018

**State Summative Assessment Cluster Development in Science**
6$^{th}$ Grade development team, Utah State Board of Education, 2017

**Science Curriculum Mapping for 4-6$^{th}$ Grades**
Committee Member, Ogden School District, 2017

**Weber State Charter Academy**
Board Member/ Parent Representative, Ogden, UT, 2013-2015

## TEACHING GRANTS

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|---|---|
| STEM Action Center Organization Grant ($3000) | 2018 |
| Ogden Foundation Impact Grant ($1000 each year) | 2013-2020 |
| Ogden Foundation Mini Grant ($300 each year) | 2013-2018 |

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| Ogden Foundation Innovative Grant ($2,500) | 2016, 2018 |
| Donors Choose STEM grant ($500) | 2017 |

## HONORS, AWARDS AND RECOGNITION

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|---|---|
| Undergraduate Honors Award- Weber State University | 2009-2012 |
| Professor's Honor Roll- Weber State University | 2012 |
| Apple for the Teacher Nominations | 2015, 2016, 2017 |
| Achieving Excellence in Teaching | 2017, 2018, 2019, 2020 |