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Gender Dynamics in Small Group within a Student-Centered Physics Course: An Exploratory Single Case Study

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GENDER DYNAMICS IN SMALL GROUP WITHIN A STUDENT-CENTERED PHYSICS COURSE: AN EXPLORATORY SINGLE CASE STUDY

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ABSTRACT

The underrepresentation of women in STEM more generally and in physics specifically has been well established (e.g., Hyater-Adams, Fracchiolla, Finkelstein, & Hinko, 2018; Johnson, Ong, Ko, Smith, & Hodari, (2017); Lock & Hazari, 2016), and the field remains challenged by the negative consequences of this underrepresentation. Women's limited access to STEM jobs is one of such consequences. A number of curricular and pedagogical innovations have shown success in better supporting student learning, and some such as SCALE-UP or (Studio Physics which is similar to SCALE-UP but with more space capacity) have been found to narrow the learning gaps between men and women. SCALE-UP is an acronym for student-centered active learning environment for undergraduate physics. Both SCALE-UP and Studio Physics are considered to be a designed learning environment and pedagogical innovation which redefines teaching or the role of an instructor as well as students in the class and course (Beichner, Saul, Abbott, Morse, Deardorff, Allain, & Risley, 2007).

Although there is extensive work on Studio Physics as an innovative pedagogical approach that shows promise in supporting learning for diverse students across gender, race, and ethnicity (Beichner et al., 2007), more research is needed to understand this innovative classroom and pedagogy from the angles of gender dynamics in a small group, with the goal of exploring gender equity in small groups within the classroom. In pursuit of this question, previous studies in this context have relied on documenting learning gains (e.g., Gaffney, Richards, Kustusch, Ding, & Beichner, 2008). For this, instructors and researchers use students' pre and posttests scores obtained through instruments such as the conceptual survey on electricity and magnetism (CSEM). Unfortunately, this approach can mask a number of underlying problems in terms of whose voice is heard in the classroom and whose ideas are taken up in small group work—

questions that are often at the heart of recent work focused on equity in STEM classrooms. The benefits of fostering equitable participation in sense-making entails that students across gender (focus of the research presented here) will be supported to adequately prepare for subsequent courses and positioned for career opportunities in STEM (White & Cottle, 2011).

The research reported here centered on a purposefully selected small group consisting of one woman and two men. I explored the woman's experiences in the small group. This exploratory single case study (Merriam, 1998) had a two-fold purpose — to identify and describe patterns in gender dynamics, and to understand what meanings students ascribed to the gender interactions. Using socio-cultural theory and discourse analysis as theoretical lenses, I analyzed interactions of the heterogenous group across 20 episodes of discourses, and interviewed the participants in a focus group. In my analysis of discourses, I searched for findings in the forms of emergent themes that reveal gender dynamics while in a focus group interview, I had the goal of knowing the meanings they ascribed to the interactions.

In relation to gender dynamics, these findings suggest that the woman (Kay) orchestrated all the active positive gender interactions occurring in this group and she did this by fostering collaborative work in the small group during discourses. The TA was effective in supporting positive gender interactions, but was not successful at alleviating negative gender interactions that were occurring. In contrast, the men were asymmetrically involved in both the positive and negative gender interactions, and subtle negative gender dynamics were the predominant form of negative gender interaction. Also, the subtle negative gender interactions occurred in association with the active positive gender interactions; the former almost always after the latter in order of association.

Multiple factors explain this sequence of association;

- the order of non-verbal and verbal discourses in an episode
- how David took up his peers' contributions
- Isaac's role as Kay's Ally, and
- the timing and type of instructional move by an instructor.

In addition, participants differed in the meanings they attributed to — presentation of small group work to whole class, learning, the verification lab, and how they framed the discourses. However, they agreed on the importance of the tools they used, the role of the TA, and their own roles as spontaneous. The participants were generally productive in their epistemological framing of the tasks. The different meanings are important because they deepen the insights into the gender dynamics and offer new ones into the participants' physics identities and epistemological framing as it relates to the discursive participation and tasks. In this way, this work offers possible interconnections among gender dynamics (with implications for gender equity), epistemological framing, and physics identity.

CHAPTER 1

INTRODUCTION

Ample research has documented the underrepresentation of various groups in STEM; specifically, racial/ethnic minorities and women (e.g., Hutardo, Newman, Tran, & Chang, 2010; Merner, 2014; Sax, Kanny, Jacobs, Whang, Weintraub, & Hroch, 2016). This underrepresentation is even more critical in physics (Lock & Hazari, 2016; Malcom, 2006; Merner, 2014, 2015; Sax, Lehman, Barthelemy, & Lim, 2016). In this study, I focused on the underrepresentation of women, who earn only 20% of the total physics bachelor's degrees awarded in the United States (US) (Lock & Hazari, 2016). Although the experiences of all women in physics are not the same due to the influences of certain factors (e.g., ethnicity, race, gender, class), it is important to recognize that regardless of their specific demographic and identity affiliations, all women are "statistically underrepresented" (Traxler & Brewe, 2015, p. 2) in physics. How might this underrepresentation be overcome? Some scholars and researchers suggest a turn to curricula and/or pedagogical innovation or reform-based teaching and learning (Beichner et al., 2007; Freeman, Eddy, McDonough, Smith, Okorafor, Jordt, & Wenderoth, 2014; Guillermo & Humberto, 2018; Hysken, Olivery, McElmurry, Gao, & Avis, 2019). Others hold the view that the social construction of physics as a masculine domain must be challenged and dismantled, even within a reform-based curriculum and/or pedagogy. In other words, the male gendering of physics is a problem that needs to be dismantled (Barton & Yang, 2000; Carlone, 2003; Hazari, Cass, & Beattie, 2015; Sabella, Mardis, Sanders, & Little, 2017). What is gender?

Even though this research is about gender dynamics and not gender, I acknowledge the complexities of gender as a *category* (Harding, 1986; Traxler et al., 2016). Therefore, for my research, I adopted the conceptualization of gender as performance (e.g., Traxler et al., 2016) as a way to frame gender dynamics in a heterogeneous group of one woman and two men. I focus on the social interaction that occur in one small group consisting of one woman and two men. In this sense, I was guided by a socio-cultural framing of gender performance which focuses on "how people are positioned or position themselves in society due to their identities" (Wilson & Kittleson, 2013, p. 806) in one gender category or another or several gender categories. In subsequent sections of this chapter, I described the underrepresentation of women in physics (both in the discipline within education and the field), consequences and influential factors of underrepresentation, overcoming barriers to underrepresentation in physics, sense-making, a brief introduction to studio physics, and then the research questions. I used studio physics interchangeably with SCALE-UP — student-centered active learning environment for undergraduate physics (SCALE-UP).

The Problem of Underrepresentation of Women in Physics

The demographic makeup of the United States is changing — there is more and more diversity (Lim, Haddad, Butler, & Giglio, 2013). However, this diversity is scarcely reflected in the physics community. For example, when one examines physics bachelor's degrees awarded between 2014 and 2016, five thousand nine hundred and forty-three (5943), that is, 74% were earned by White Americans, but only five hundred and fifty-one (551, ~8%) were earned by Asian Americans, followed closely by five hundred and eighteen (518, 7%) earned by Hispanic Americans, with another notable drop off when one examines that of African Americans who earned two hundred and fifty three (253, ~3%) of the total (Czuiko, Ivie, & Stith, 2008; Freeman et al., 2014; Huang, Taddese, & Walter, 2000; Merner, 2015). Women, too, are not equitably represented in physics bachelor's degrees awarded and the underrepresentation of women is even more critical for women of color. Between 2002 and 2012, Black women and Latinas made up only 2% of graduating physics majors (Johnson et al., 2017). Clearly, the number of women graduating with a physics degree is not reflective of the representation of this group in the wider US population, nor even that of those attending college (Huang et al., 2000; Lim et al., 2013).

Underrepresentation of women in physics programs continues as one examines patterns in graduate degrees earned and physics faculty employment. For instance, between 1976 and 2016, women earned only 20% of all doctoral degrees awarded in physics. Similarly, across the entire United States, there are scarcely 100 Hispanic and African American female physics and astronomy faculty. According to the US population records, in 2010, women represented 51% of the population, but they hold only 24% of STEM jobs, while men hold 76% of those jobs (Landiver, 2013; Szelényi, Denson, & Inkelas, 2013). This trend is even more acute when one looks specifically at physics, where women constitute only 19% of the entire field's workforce (CEOSE, 2013).

Consequences of Underrepresentation of Women in Physics

The underrepresentation of women in physics has been well established (e.g., Hyater-Adams, Fracchiolla, Finkelstein, & Hinko, 2018; Johnson et al., 2017; Lock & Hazari, 2016), and the field remains challenged by the negative consequences of this underrepresentation. These consequences are democratic in/equality, global competitiveness, and challenge to epistemological diversity.

Gender equity is important for democratic equality. Mindful of the risks (e.g., national economic insecurity) of gender inequity, the National Science Board argued that all "student[s] in America deserve the opportunity to achieve [their] full potential" (1986, p. v). How can every student who might have the interest and aptitude in STEM realize this opportunity when some of them (especially women) are prevented from completing an undergraduate program in the STEM fields?

In a similar vein, how can the nation be globally competitive if its citizens, especially minoritized groups (including women) are not positioned for economic opportunities in order to meet their own needs as they contribute to the nation's economy? Success of such groups in STEM hopefully is one pathway to economic security for the individual as it is the STEM disciplines that create the most of "new enterprises, new jobs, and the betterment of the national standard of living" (NSB, 2010, p. 1). Underrepresentation then hurts the social and economic prosperity of the individuals and groups in the demographic minority within STEM because it narrows job opportunities for these sections of the populations when they are hindered from persisting in STEM majors.

In the global economy, innovation in science and technology is thought to be a primary driver, "catalyzing the creation of new industries, spawning job growth, and improving the quality of life in the United States and throughout the world" (NSB, 2010, p. v). But in order for innovation to be put to work, individuals have to possess the knowledge, skills, and creativity needed to chart new pathways. These individuals are the building blocks of innovation (White & Paul, 2011). For the purposes of my research, I argue that since there is no evidence that substantiate any claim that men have superior cognitive capacity compared to women, it is important to consider equity and issues that pertain to equity. Without the realization of the talents or full possibilities in the next generation of Americans who constitute her potential STEM innovators, the long-term prosperity of the nation is called into question.

In addition, epistemological diversity is another area where it is possible to see the negative consequences of underrepresentation of minorities — and this has consequences for the field itself. Harding (2017) argues that a field where only a monolithic group of experts are dominant deprives the wider community of alternative perspectives, perspectives which may prove to be valuable in the knowledge construction efforts of that field. Because there is need for epistemological diversity within any knowledge production effort (Harding, 2017), physics suffers due to narrow inputs given the homogeneous backgrounds of its participants; white males dominate. Thus, the narrow nature of who is allowed to participate in physics does a disservice to the wider field.

Overcoming Barriers to Underrepresentation in Physics

What can be done about the problem of underrepresentation of women in physics? There are some possible insights into this question as one examines physics education research situated both in the K-12 arena and beyond. Works from these contexts suggest that in order to break barriers to underrepresentation in physics, there is need to challenge established social, historical, and cultural biases to students' participation in physics. According to Sabella and colleagues, (2017), overcoming barriers to students' success in physics calls for instructional approaches and curricula that leverage students' identities in order to support their learning process. In one particularly insightful study, Carlone (2003) focused on understanding patterns in student participation, interest and emerging science identities of a small group of girls in high school physics class. Challenging the established social and historical constructions of physics as academic, rigorous, and elitist, Carlone (2003) explored whether a reformed physics curriculum makes for a more inclusive and interesting science for girls. In this study, the reformed physics curriculum was a different kind of school science which promoted alternative and (broadened) meaning of what it means to "do science" and be a "science person," one that focused on many of the recent emphasis on constructing conceptual knowledge through active participation in sense-making.

In order to alleviate the underrepresentation of women in physics, there is need to broaden their participation by "[promoting] new ways of participating in physics and being a physics student" (Carlone, 2003, p. 325). Curriculum and pedagogical reforms such as *Active Physics* (Eisenkraft, 1998), are research-based approaches (Carlone, 2003). These approaches use research findings from other fields [e.g., behavioral sciences, education (curriculum and instruction)], and socio-cultural studies in order to design courses, learning environments and pedagogies that take who students are (their identities) into consideration. All these fields are important for conceiving and implementing what it means to learn science content.

Active Physics (Eisenkraft, 1998, 2010) is one reform approach to physics teaching and learning that has persisted for decades. It challenges the conceptualization of what it means to learn physics as it leverages students' differing ethnic and gender identities (African American and Hispanic girls) as valuable pathways to making sense of natural phenomena. Similarly, a student-centered pedagogy built on resources framework (Hammer, 2000) considers the understandings and insights that students bring from their day-to-day experiences to the science classroom as important. Such approaches show that science teaching can be constructed to value and build upon the perspectives of students in the classroom. However, questions have emerged that challenge if reform efforts in physics are successful in making the study of physics a more equitable endeavor (Carlone, 2004). Do reform-based approaches broaden women's participation in physics? Also, do all students perceive the opportunities for participation as equitable? The answers to such questions can be complicated. As Carlone (2003; 2004) described, *Active Physics* both contested and promoted the business-as-usual approaches to teaching and learning physics. This simultaneous contestation and promotion mean that the ways in which such student-centered approaches to physics work to support the learning of those traditionally marginalized in physics classroom are complicated.

Carlone's (2003; 2004) work helps us understand this complexity. She does this by helping us understand that classrooms are learning contexts (Enderle, Southerland, & Grooms, (2013), characterized by historical, social, and political processes that frame students' knowing and doing of science. It is important to highlight the context because "contexts … shape concepts and give them deeper, complicated and connected meanings" (Barton & Yang, 2000, p. 876). In other words, the social organization of the classroom (for example) influences the science identities students develop, and what science means for the participants — (e.g., ideal pursuit to be accepted without questioning) (Carlone, 2003). By this unquestioning acceptance of science as an ideal pursuit, Carlone means that students are to accept the canonically established knowledge of science; they are not to contest or differ from such repertoire of knowledge.

Classrooms constitute a context where practices take place and they are also layered with structures. Some practices (e.g., memorization of facts by students) and structures (e.g., teacher as the gate-keeper of knowledge while students are recipients — authority structure) have become typical in traditional science classrooms. Within this structure for example, what counts as knowledge must be endorsed by the teacher and the text (Brickhouse, 1994). When certain practices and structures (Carlone, 2003) force students to uncritically accept what it means to do science or be a scientist, without engaging them through their own sense-making, students do not have opportunities to draw on their day-to-day or cultural experiences to learn science. This is a problem because it does not give room for students' generative thinking that draws on multiple resources (e.g., personal and cultural experiences) to make sense of phenomena and so enrich the process of learning in diverse small groups. Such constraint which is often subtly or even manifestly forced on students entails power (Schenkel & Barton, 2020).

Drawing on Delpit's (1998) conceptualization, Barton and Yang (2000) described and challenged the *culture of power* — a set of values, beliefs, ways of acting, and being that unevenly elevate certain groups of people over others. This elevation is real in the sense of more control over other people, societal values, money and other economic resources. In the US, people who have been typically positioned and elevated over others are mostly white, upper and middle class, male and heterosexual (p. 874). The culture of power is no less present in physics than other science fields. They argued that culture of power advances the idea that science is an objective way of knowing pursued only by a privileged intellectual elite. This objective way of knowing is characterized by boring repetitive tasks, and denigration of students' knowledge and ideas. Also, a vision of physics which maintains established social structures that favor intellectual elites, privileges the ideas of mainstream students and denigrates those of non-mainstream students, narrows or constrains ways of doing science. In addition, such a vision has implications for how students engage in physics and the identities they develop (Hazari et al., 2015). It does not carry many students along but leaves them behind (Brickhouse, 2001; 2003). Mindful of this, it becomes important to explore the efforts made to overcome or alleviate this situation which hinders student learning.

Researchers and pedagogical innovators continue to devise new approaches for teaching and learning with the goal of improved experiences and learning outcomes for students. Student-centered approaches involve student-centered instruction and student-centered learning. Examples of student-centered approaches include Studio Physics (Beichner et al., 2007), problem-based learning (Hmelo-Silver, 2004; Hysken et al., 2019), and case-based learning

(Guillermo & Humberto, 2018). Student-centered approaches require that teachers and students take on roles that align with the approach. For instance, teachers must go beyond acting merely as transmitters of information to facilitators in the learning process for students, while students also shift from passive to active players in the learning process. According to Freeman and colleagues (2014), students must be supported to actively engage in the learning process. Guillermo and Humberto (2018) highlight five features or key areas for characterizing student-centered approaches. They include balance of power, role of the instructor/teacher, responsibility for learning, purpose and process of evaluating student learning.

There have been many positive outcomes emerging from the implementation of student-centered approaches to learning in physics classrooms. For example, mobile learning built around a mobile app technology is one form of student-centered approach to learning mathematics and physics. Students have received this adoption positively, and instructors reported the effectiveness of this method as a means to promote student-centered approach to learning (Cukierman, Agüero, Silvestri, González, Drangosch, González, & Dellepiane, 2018). Similarly, research on studio physics has reported improved conceptual understanding for students, and reduced failure rates for women and minorities in studio physics as well as in later classes (Gaffney, Richards, Kustusch, Ding, & Beichner, 2008).

As promising as the description of pedagogical innovations in physics appear, some of the prospects and assumptions related to innovative pedagogical contexts are yet empirically unexplored while there is no consensus on others. Scholars have nuanced positions on the affordances and constraints of student-centered contexts for all students' learning, especially women as minorities in STEM. According to Delpit (1988), student-centered approaches can exacerbate inequities because underrepresented students [including women] expect teaching to be more direct and explicit. Similarly, in a study on high school science, Brown (2004) found that "in some instances, participation in the cultural practices of science classrooms created intrapersonal conflict for ethnic minority students" (p. 810). Complicating things even further, several scholars in the fields of science education (e.g., Bransford, Brown, & Cocking, 2018; Granger, Bevis, Saka, Southerland, Sampson, & Tate, 2012; Tal & Tsaushu, 2017) and mathematics education (Laursen, Hassi, Kogan, & Weston, 2014) present evidence suggesting that student-centered approaches lead to student learning outcomes that are improved and more equitable, specifically from the standpoint of gender differences and sense-making in small groups.

Sense-making entails that students have opportunities to generate, use, and extend scientific knowledge within communities of practice (Haverly, Barton, Schwarz & Braaten, 2018; NRC, 2012). Although attending to sense-making in small groups within a research-based student-centered context is promising, there is a need to empirically explore the context in terms of equity. I pursue this exploration by focusing on the small group in studio physics. A deeper understanding of what happens in sense-making classrooms in "physics education … is important if we are to envision a truly alternative physics education" (Carlone, 2003, p. 310). Extant literature suggests that attention to small group sense-making shows promise for dismantling masculinity as the major barrier to women's participation in physics (Berge & Danielsson, 2012; Due, 2014; Pettersson, 2011). There are three dimensions that are involved in sense-making. So, In the next two subsections, I will present 3-dimensional learning, drawing on literature in the K-12 setting which describe alternative vision of physics instruction such as contained in the Next Generation Science Standards (NGSS). This body of literature is important because, though studio physics existed long before the NGSS, the latter offers a relevant 'lens' to make sense of classroom discourses in studio physics. Afterwards, I briefly introduce studio physics.

Current conceptualizations of learning in science classrooms center on student sense-making. The Framework for K-12 science education (Krakcik, Codere, Dahsah, Bayer, & Mun, 2014) is a very important resource for current emphasis on science teaching and learning. One of the shifts advocated by this Framework is sense-making framed as three dimensions of learning; disciplinary core ideas, cross-cutting concepts, and science and engineering practices (Framework; BOSE, 2012, NRC, 2012, NASEM, 2018).

Moving Beyond Gains Scores Toward Sense-Making for Science in Physics

Researchers, especially in physics education research have given a great deal of attention to describing the gender achievement gap by computing differences in learning gains over time for girls/women and boys/men in physics classrooms and courses. Opinions are polarized as to the importance of focusing attention on the gender achievement gap. For example, Lubienski (2008) has referred to this focus on achievement gap as “gap gazing.” This focus only tells a partial story of students’ learning in physics and their sense of what it takes and means to be a physics person. Besides urging a deficit model of students’ learning, capability, and preparation, it limits opportunities for students to context the culture of physics and work to reconstruct who they meaningfully are and how much they learn in science. Though such computations are relatively easy for evaluating student’s learning, they promote inequity in science learning; if we do not consistently take a closer and critical look at the gender interactional dynamics that help or hinder student’s participation in sense-making. Equitable participation in sense-making hopefully gives girls and women opportunities to disrupt socio-historical norms that limit their participation in the classroom and physics community. Also, they will be able to contest the culturally imposed normative ways of being competent in physics and being a competent physics person (Danielsson, 2012; 2014). We need to deepen our insight into equity-mindedness of pedagogical innovations by drawing on visions of science learning that place premium on equity.

The NRC (2012) developed and provided a new vision for science education, with a solid foundation based on science and learning research on what K-12 students should be able to do and learn. According to this vision, learning entails integrating three dimensions and is geared towards students' development of proficiency in science. These dimensions are big ideas, cross-cutting concepts and engagement in science practices. In order for students to be proficient in science, learning has to be centered around sense-making (according to the framework), but not captured in current conceptualizations and evaluation of learning in research focused on studio physics.

Sense-making encapsulates both "what" students are learning and their "ways of understanding" or/and explaining phenomena (Rosebery & Warren, 2008). It requires that teachers or instructors support and guide students through dilemma and uncertainties while creating opportunities for students to construct an understanding of the world (Braaten & Sheth, 2017). When students participate in sense-making, they work individually in interaction (i.e., with resources) and as a group to construct their understanding of the world (Maskiewicz & Winters, 2012).

Students' perspectives on what it means to do science/be a science person are important for equitable learning. For example, in work conducted by Carlone (2011), a group of African American and Latina girls were found to resist framing of competence in science because a "smart science student" was commonly associated with students from dominant cultural backgrounds in a science classroom. Instead, these girls determined their own criteria of smartness that were not dictated by the dominant groups but instead were aligned with current conceptualizations of equity that fosters student meaningful learning. These group of African American and Latina girls developed similar levels of scientific understanding and expressed positive attitudes about learning science (Carlone, 2011). Thus, in a classroom focused on students' sense-making, dominant cultures are no longer the only accepted or valid vehicles for sense-making. A movement towards approaching science as sense-making shifts power and position which have been historically reserved for mainstream groups in science learning over decades (Bang, Brown, Calabrese Barton, Roseberry, & Warren, 2017), shaping students' opportunities to learn (Harvely, Calabrese Barton, Schwarz, & Braaten, 2019; Stroupe, 2014).

Studio Physics: An Introduction

The challenge of preparing students for success in STEM bachelor's degree programs and positioning them for careers in/or related to the fields (e.g., physics) requires efforts that go as far back as the middle school/first year of high school (Tyson, Lee, Borman, & Hanson, 2007). It is important to recognize that the battle extends to the undergraduate level (PCAST, 2012). The introductory undergraduate level may be the last formal opportunity some students may have to be supported to develop proficiency in science and to pursue STEM career. There is extensive work on studio physics that shows promise in supporting diverse students' learning, including minoritized groups across gender and race (Beichner et al., 2007). Studio physics is also called (SCALE-UP). Advancement in studio physics led to the student-centered active learning environment for undergraduate physics (SCALE-UP) in the sense that studio physics was designed for up to 50 students but SCALE-UP extends the number for up to 80 students. The point here is about the capacity of the classroom space and the number of facilitators suitable for the class sizes. However, for my work, I use the terms “studio physics” and “SCALE-UP” interchangeably.

Studio physics is both a designed learning environment and pedagogical innovation which redefines the work of teaching or the role of an instructor as well as students in the class and course (Beichner et al., 2007). In studio physics, instructors and teaching assistants have the role of facilitating learning for students in their small groups. Occasionally, the instructor briefly lectures with the goal of motivating students and helping them grasp the big picture. In their small groups and sometimes in whole class discussions, students solve problem sets and carryout hands-on activities in the form of verification labs. It is through engaging in these activities that sense-making is facilitated.

Students’ successful learning experiences in studio physics has often been measured as achievement or learning outcomes on pre/post-tests (Furtak & Ohno, 2001; Gaffney et al., 2008; Hoellwarth, Moelter, & Knight, 2005; Kohl & Kuo, 2012). Some of the instruments used are the Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992) and the DIRECT—Determining and Interpreting Resistive Electric Circuit Concepts Test (Beichner, 2008; Engelhardt & Beichner, 2004). Though these results speak to the promise of the studio physics approach to foster the physics learning of a broader subset of students, this work leaves much unexamined in relation to students’ construction of knowledge in a small group and gender dynamics.

Assessment of student learning in the studio physics literature typically employs normalized learning gains. Normalized learning gain is a ratio of the difference between the post-test score and the pre-test score, and the difference between the maximum possible score or total number of test items and the pre-test score (Barrera-Garrido, 2012). Even though research using this metric for success suggests there are many positive learning outcomes for students (across gender and demographic groups) in studio physics (Beichner, et al., 2007; Cummings, 2008; Cumming, Marx, Thornton, & Kuhl, 1999; Kohl & Kuo, 2012), these findings have been problematized. For example, Madsen, McKagan, and Sayre, (2013) highlight gender differences on students' performances on concept inventories, reporting that women always have lower average pretest scores than men and, in most cases, lower posttest scores as well. Thus, even while women experience learning gains in the studio format, scholars highlight differences in learning outcomes as lingering gender gap in physics (Henderson, Stewart, Stewart, Michaluk, & Traxler, 2017). Multiple reasons have been put forward in attempt to explain the gender differences in scores (e.g., gender difference in background preparation) (Hazari, Tai, & Sadler, 2007) and how to alleviate the gender gap (e.g., changing the wording of "male-oriented" questions). However, no one to date have explored the ways in which gender dynamics might shape patterns of sense-making by students, how they participate in discursive interactions or frame tasks in studio physics, and their perspectives on equity in small group sense-making. However, the role of gender and equity in shaping students' physics learning in other STEM contexts have been frequently explored (e.g., Sax et al., 2016).

In order to explore patterns in gender dynamics in a small group sense-making in studio physics, I employed Vygotsky's socio-cultural theory (Vygotsky, 1978), and discourse analysis (Gee, 2011) as the theoretical and analytic frameworks for my research. My focus of attending to discourses in a small group in studio physics is to provide insight into gender dynamics at play in such a group so that instructors in this context may be able to provide strategic support for the development of science proficiency of all their students.

Research Questions

The primary purpose of this exploratory research was to identify and describe patterns in gender dynamics in a select heterogeneous group of one woman and two men, as first step towards understanding equity of participation in sense-making in an introductory physics course. within SCALE-UP. The participants constitute a unique small group — the woman (Kay) participant being highly aware of her agentic voice, one of the men (Isaac) somewhat aware of gender equity, and the other man (David) less aware of gender equity concerns. Secondly, I desired to understand what meanings students ascribed to the gender interactions within a select small group. I argue that this exploration is important for understanding how gender dynamics may influence the experiences of the woman in discursive interactions. Understanding women's experiences in physics classrooms is important for improving their persistence in physics, alleviating gender inequity in physics classrooms, physics as a field, and improving the success of women in physics courses. It is my hope that informed by an in-depth understanding of gender dynamics in the heterogeneous small group, instructors and TAs can more effectively support positive gendered interactions and alleviate negative ones in such a heterogeneous group of women and men in Introductory Physics within studio classrooms.

Thus, this research was guided by the following questions:

1. What patterns of gender dynamics centered around the woman's participation emerge within a heterogenous small group in a student-centered/reform-oriented approach to physics instruction?
2. What meanings do the small group participants assign to these dynamics?

CHAPTER 2

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

For quite some time, the attention of administrators, researchers, faculty/instructors, and policy-makers has been drawn to optimizing student learning experiences and achievement in undergraduate education in the sciences (Sunal, Wright, & Bland-Day, 2004). Gender inequity has emerged as a centrally important aspect of such attempts at optimization. This is because gendered learning experiences in STEM influence student outcomes and persistence, especially in relation to participation of women (Nissen & Shemwell, 2016). Though issues of gender and equity in physics in particular and science in general attracted the attention of researchers as far back as the late 1970s/1980s (e.g., Alexopoulou & Driver, 1997; Gould, 1997; Keller, 1997; Rossiter, 1982), recently, there has been a resurgence of interest. Indeed, recently, issues of gender and equity have begun to garner more attention in physics (Götschel, 2011; Madsen, McKagan, & Sayre, 2013; Lewis, Stout, Pollock, Finkelstein, & Ito, 2016; Rosa & Mensah, 2016), with the underrepresentation of women as one of the ongoing points of conversation (Götschel, 2011; Madsen, McKagan, & Sayre, 2013; Lewis et al., 2016; Rosa & Mensah, 2016). The research described here continues in this line of investigation as I examined gender dynamics in a reform-based approach to physics instruction in an introductory undergraduate course.

In this chapter, I present socio-cultural theory as my theoretical framework in this exploratory research to understand gender dynamics in sense-making within the select small group. I review literature on discourse analysis, gender and physics, then, equity in physics/STEM. Finally, I will review literature on physics learning in studio physics centered around electricity and magnetism.

Theoretical Framework

For my theoretical framework, I drew on socio-cultural theory to explore students' sense-making as they engaged in discourses and use tools to advance their work in a heterogeneous small group. Socio-cultural theory of learning originated in the work of Levi Vygotsky (Aimin, 2013; Newman, 2018) who described learning as a social process framed by society and culture. It is important to note, however, that Vygotsky also acknowledged the place of the individual in this social process. In Vygotsky's socio-cultural theory, the social interaction comes before the individual as social interaction is key to the individual's learning. Learning takes place both within the social interaction and on the individual level. The culture and history of institutions and societies provide a context which frame social interactions. It is the interaction within the group that shapes what and how the individual learns (e.g., new strategies, skills, and understanding of the world).

As Vygotsky (1979) described, individuals need to participate in social interactions (e.g., in a broad range of activities) such that group work influences the individual's efforts to internalize the results of those interactions. Given that social interaction is fundamental to learning, learners and learning events are understood to be immersed within social interactions that bound the learning events or activities. This learning process takes place within a *space* where the individual has potential which needs to be supported by the group and more knowledgeable others (e.g., teachers or instructors) in order to realize such potential (Nufaida, 2018) (i.e., student sense-making of natural phenomena). Even though Vygotsky's work began with young learners, it has been used to account for learning in other groups — particularly when the learning is thought to include socialization into practices (Lave & Wenger, 1991; NRC, 2012). Vygotsky's socio-cultural theory includes the role of more knowledgeable others, but for the purposes of this research, I focused on the role of the participants in the group (the social level) and the TA in as far as the small group's interaction involved the TA in relation to the experiences of the woman.

According to Tudge and Scrimsher (2003), social interaction is not a one-way event but is a dialogical (between the individual and the group) interaction, with multiple dimensions. These interactions involve words but can also include other tools. These tools include can include writings, models, diagrams, drawings, mathematical and symbols (Leontiev, 1981). In classrooms in the 21st century, discursive practices such as explanation of ideas by students to their peers in small and whole groups are used in social interactions to learn while computers, white boards, calculators, graphs, sketches, and models are some of the tools with which learners co-construct these explanations to build their knowledge.

Students' discursive practices and how they use tools in the learning process are understood to be shaped by culture and society. For example, reform-based approaches to teaching and learning physics require that students model or explain the natural world, following the example of how physicists work (Brewe, Sawtelle, Kramer, O'Brien, Rodriguez & Pamela, 2010) in order to make sense of natural phenomena and develop competence. Amidst others, competence in the physics classroom includes the following; students need to understand concepts, make observations, predict outcomes, model phenomena, draw on the *cultural funds* (Kiyama & Rios-Aguilar, 2017) of their personal communities, and subject their knowledge claims to the scrutiny of the classroom community. These practices and use of tools (both physical and conceptual) may appear to be gender-neutral but extant literature highlights the fact that students do not only engage in doing physics but in doing gender as well in order to demonstrate their competence in a predominantly masculine physics culture (Due, 2014;

Pettersson, 2012). Thus, at least in part, social interaction between the individual and the group involves culturally laden discursive practices and use of tools. One way that the culture of physics has been constructed as masculine is the assumption that masculinity is analytic and hands-on in knowledge-building whereas femininity is descriptive or narrative (Due, 2014; Pettersson, 2012).

The practices and ways of using tools go beyond students' mere memorization of a body of knowledge as described in the transmission model, instead, according to Vygotsky, learners internalize new understanding and skills immersed in a cultural context. However, Cobb and Yackel (1996) offered a critique of the idea of internalization in Vygotsky's socio-cultural theory. According to them, internalization in Vygotsky's theory is a transmission model which presents students as engaging with cultural meanings that are passed on from prior generations. The duo seems to suggest that transmission of information is a cognitively passive process. However, that understanding is being challenged. Tekkumru-Kisa, Stein, and Schunn (2015) developed a framework for analyzing cognitive demand of tasks in the learning of (science) content. In their framework, even the least cognitively demanding level tasks require some sort of effort, however little, by the learner. Other tasks, in contrast, which are designed to anchor student learning are much more cognitively demanding of students such as making connections among ideas in order to explain a phenomenon. What is important for this discussion is that even memorization, which is the lowest level of cognitive demand is not a passive process, rather, it is an active process as the learner needs to invest time and effort to understand and recall information. This suggests that all internalization requires active learning. Vygotsky's socio-cultural theory emphasizes the role of social interaction between more knowledgeable others and the learner to optimize learners' efforts allowing them to advance in the zone of proximal development. This social interaction suggests active learning.

In order to strive for a modern interpretation of Vygotsky's social interaction and internalization, Scott and Palincsar (n.a) propose an alternative model — the participation model of cultural development. This model is also known as guided participation (Lave & Wenger, 1991; Rogoff, 1990). The implication of this model is that learning is understood to be an act of transformation, but not a transformation that is achieved by merely transmitting information to the learner. Rather, it is a transformation of the learners' potentials within the zone of proximal development and an internalization of what is learned consequent upon the learners' participation in social interaction. Both of these are key to the process of learning.

This position communicates a tension between transformation and internalization. This debate on transformation versus internalization is a deeper search into how the interaction between the individual and the group accounts for the individual's learning. In other words, how does the individual in the group learn? Current conceptualizations of learning or learning theories may be helpful in taking a perspective that meaningfully sheds light on the debate. New visions of science teaching and learning such as those found in the *Framework for K-12 Science Education* (NRC, 2012) shed further light on students' responsibility to be actively involved in science and engineering practices. Tools are important for engagement in the practices in order to make the most of socio-cultural practice and thus develop proficiency in science.

My research here is not based on constructivism as a theory of learning, however, I believe that exploring some common ground between socio-cultural theory and social constructivism may be helpful for making sense of how transformation differs from or is similar to internalization. This common ground consists in the understanding that the individual does not learn by merely participating in group activity and memorizing the repertoire of knowledge built by experts in a given discipline over time. Rather, in the face of social interaction, in order for the individual to personally learn, such an individual must actively construct an understanding by negotiating, clarifying, evaluating, and extending what the group learns. In other words, critical reasoning and reflection (Driscoll, 2005) are important. So, the learner does not merely take in information but takes apart, rebuilds and advances new information to learn, asks questions to clarify understanding and apply the new information, while needing to evaluate what s/he had learned so far, what needs to be learned and re-learned. Through all these processes, the learner needs to step back and think through not just on what is being learned but on the process of learning as well.

Transformation plays a part in the individual's learning. One can appreciate this by viewing this suggestion through the lens of disciplinary engagement. A learner is supported to productively engage in learning within a discipline (content) area when s/he is given authority but held accountable to peers and the discipline as well (i.e., disciplinary norms). Also, in order to deal with uncertainties such as problems with no known or definite path (problematizing content), the learner is given resources (Engel, 2011; Engel & Conant, 2002a; Forman & Ford, 2014). For my work, the knowledge-base and practices that have accumulated in the physics community over time are normative aspects of what students need to learn, and competence in this knowledge-base is important for learning in the studio physics classroom. These knowledge-base and competence are part of the culture of the community [physics] within which students participate in sense-making.

Taken together I understand learning as a process shaped by both the cultural meanings and practices that have accumulated over years and the individual student's participation within this repertoire of knowledge. In order to understand how gender dynamics plays a role in shaping students' participation in physics discourses, I take a socio-cultural lens in this research.

Socio-cultural theory and science learning. Taking "a socio-cultural perspective on science education means viewing science, science education, and research on science education as human social activities conducted within institutional and cultural frameworks" (Lemke, 2001, p. 296). This means that science is open to cultural influences both from human beings who participate in science as a field of human endeavor and the institutions of society such as agencies of government as political institutions. Social interaction and gender equity are some of the current issues focused on by science educators who employ socio-cultural perspectives in their work.

Social interaction is key and necessary for learning, with social organizations or institutions (i.e., family, school, classroom, research laboratory, etc.) as some of the influential factors in the process of learning. Collectively, these socializing agencies also influence the norms within which sense-making takes place. For example, students bring prior knowledge into what/how they learn in classrooms and they make use of experiences from outside the classroom as well as prior courses in their schooling to learn new concepts and make sense of new phenomena in some new or advanced way. These experiences from outside the classroom come from sources such as their families, field trips, and political events. These sources influence how students negotiate social interactions and social interactions enact norms of the learning context which over time become the community's culture (Lemke, 1991).

How does a socio-cultural perspective apply to understanding discursive interactions in a small group of a woman and two men within studio physics? Through learning, the learner becomes/is made part of a culture — enculturation (Scott & Palincsar, n.a), and this includes physics learning. Students competence in the physics classroom includes talking, behaving, and using tools in ways that are considered normative or accepted in physics and the physics classroom. One implication of this enculturation is that for a discipline that is masculine in its culture, students who do not identify with this dominant gender are constrained to conform to the masculine culture in order to be recognized as competent in physics. For example, the head-physicist in a plasma physics lab in the USA presented his definition of competence in plasma physics as follows: "Here in the lab, you do labor [manual work] …. That means to get greasy and dirty, to lie under machines and to lift heavy things" (Pettersson, 2011, p. 57). Based on the larger society's construction of what is masculine, this lab was seen as a site for masculine work. Within the definition of competence in this plasma physics lab under consideration, a woman will be understood as doing the work suitable for men in order to establish her physics competence.

Researchers in science education have used socio-cultural perspectives to examine interactions among learners (e.g., Gonsalve, 2014; 2014; Lemke, 2001; Nagel, 2012; Nissen & Shemwell, 2016; Patchen & Smithenry, 2014; Rosa & Mensah, 2016; Warren & Rosebery, 2011; Tan & Calabrese Barton, 2008), not only to highlight what content they learn, but who they become as learners. For instance, in a physics classroom, students do not only learn content but are socialized into physics — what physicists do, how physics think, the approaches they employ in problem-solving, the kinds of questions they ask (as part of conducting inquiry). So, physics identity development should be integral to what it means to learn physics (Hazari et al., 2015).

Socio-cultural theory is suited for my work as it is useful and appropriate for understanding the interaction across gender (gender dynamics) between the individual and the small group within studio physics. It is my hope that using the socio-cultural theory to explore gender dynamics in small group work within studio physics will add to our understanding of how such dynamics influences discourses and shapes students' experiences, especially the experiences of the woman. Socio-cultural theory offers us a perspective on design and discourse in science [physics] classrooms (Adams, 2015). Since studio physics is a designed environment and innovative pedagogy which foregrounds learning as participation in small group/whole classroom physics discourses, socio-cultural theory is an appropriate lens for my work.

Discourses and discourses. Scholars conceptualize the term discourse in nuanced ways. For Weedon (1987), discourse refers to ways of constituting knowledge, the social practices, forms of subjectivity, the associated power relations and the social practices. In Weedon's view, there is the inherently social dimension in knowledge-building and peculiarities in how power and knowledge are connected. In other words, discourse is part and parcel of social processes (Fairlough, 2001). This relation between power, knowledge and discourse as an inherently social process implies that there is nothing neutral in discourse. That is, there is no discourse without a goal. Rather, discourse performs functions, especially of a social and political nature. For example, According to Wodak and Meyer, (2009), discourse sustains and reproduces the status quo, producing and reproducing unequal power relations between groups of people. Van Dijk (1993) sees justification of inequity as the major political and social function of discourse.

Talk, text, and other media, are ways of expressing knowledge, experiencing the world, and valuing the world. Discourse consists of these ways (McGregor, 2004). In addition to discourse as ways, there is also the understanding of discourse as form or genre constructed through the ways of knowing, experiencing and valuing. These forms or genres are written texts, conversations, speeches, classroom lessons, images, multimedia, non-verbal communication and film (Wodak & Meyer, 2009). Discourse may be identified based on the sphere of human activity where they occur, for example, political discourse, religious discourse, science discourse, classroom discourse etc. In science education as a realm of human activity, Moje, Collazo, Carrillo, and Marx (2001) highlighted discourse as "… both the ways of knowing and the knowledge valued by the learners, the learning context and the discipline" (p. 471). Gee (1999) identified these two aspects of discourse using the terms "Discourse" and "discourse"; the former for ways of knowing based on realms of human activity, and the latter as the forms or genres employed in the "Discourses."

Gee (2011) distinguished between *Discourses and discourses* (D/d). He used Discourse (with uppercase "D") for "ways of combining and integrating language, actions, interactions, ways of thinking, believing, valuing, and using various symbols, tools, and objects to enact a particular sort of socially recognizable identity" (p. 29). Discourses (with lower case — d) are the nonverbal and verbal elements of language (Gee, 1999; Kittleson & Southerland, 2004). Much like Gee (2009), Moje et al., (2001) referred to discourse as technical language and concepts associated with talking, reading, and writing while "Discourses" are the particular ways we know, do, read, and write such that these distinguish one realm of human activity from another.

According to Gee (2011), discourse analysis studies information, action and identity — with one or more goals in mind. One goal is to describe an understanding of how a phenomenon (language or the world) works. This is the descriptive approach to discourse analysis. Such a goal may have pragmatic or practical applications, but such applications are not the motivation of descriptive discourse analysis. Another goal is to go beyond a description to intervene in social and/or political issues in order to solve a problem. The motivation here is practical application in the world. This is the critical approach to discourse analysis; it emphasizes the role of language as a power resource (Willig, 2014). However, Gee (2011) argued that all discourse analysis needs to be critical because social interactions involve real and “potential social goods and the distribution of such goods” (p. 9).

The socio-political nature of discourses helps us understand why so much effort is devoted to analyzing discourses, with researchers approaching their analysis of discourses from one orientation or the other. For my work, I focused on *critical discourse analysis* (Gee, 2004). Considering critical approaches to discourse analysis, social practices have implications for status, solidarity, power and the distribution of social goods (Gee, 2004) (e.g., education).

In my work, sense-making is core to science learning, analysis of D/discourses will play a prominent role since sense-making in small groups is a way for me to frame science as a social endeavor (Yerrick & Roth, 2005). This perspective on science as an endeavor is central to my study. According to socio-cultural perspectives, learning is a process, involves social interaction, and is influenced by social, cultural and historical contexts in order to build knowledge and skills (Fairclough, Wodak, & Mulderrig, 1997). For Gee (2011), such interaction entails the use of language to share information, achieve or do certain things and from a certain stance (identity or way of being). Hence, words, actions, verbal and non-verbal cues are involved in language as social practice. Classrooms (e.g., physics) and other settings for learning offer a place or forum where students interact in order to learn. Such interactions call for “integrating ways of saying (information), doing (action), and being (identity), as a set of tools” (Gee, 2011, p. 8). It is within social interactions that discourses are negotiated and constructed. This is why it is important to consider D/discourse in my work.

Discourse issues have implications for science classrooms (Barton, Tan, 2009; Gomoll, Hmelo-Silver, Tolar, Šabanović, & Francisco, 2017). Gee (2016) argued that critical discourse analysis should be central to issues of justice, peace, and the many socio-political issues and problems such as in/equity in today's world. This is so true given that "the exercise of power influences knowledge, beliefs, understandings, ideologies, norms, attitudes, values, and plans" (Mullet, 2018, p. 119).

Gee (2004; 2011; 2016) revealed a specific example of the problem Mullet (2018) would later highlight. Gee made this revelation when he called attention to the relation of power to D/discourses. From his perspective, Discourses/discourses are important in science knowledge production and learning which involve social interaction. As cultural practice, science knowledge production and learning are embedded in particular ways of knowing and doing, reading, writing [Discourses] (Gee, 2004; 2011; 2016). Participants who do not share in the D/discourses practiced do not enjoy the same advantages as those who share in them. So, critical discourse analysis is a well-suited approach to my work to examine gender dynamics which may be at roots of the problem of underrepresentation of women in physics. I focused on D/discourse in sense-making within a heterogeneous small group and how interactions across gender relate to sense-making across individuals in a group. Against this backdrop, I then coded for patterns of gender dynamics in a small group work within this context. The research informing this process is reviewed next.

Discourse analysis in science education. Literature centered on analysis of science classroom discourse has employed a number of different theoretical frameworks. These include discursive perspective (Johansson, Andersson & Salminen-Karlsson, 2018), discursive psychology (Martin, 2016), cultural-historical perspective (Adams, 2015), psychological perspective of activity theory (Viera & Kelly, 2014), grounded theory (Barton & Tan, 2009), and social constructivism (Kittleson & Southerland, 2004; Gomoll, Hmelo-Silver, Tolar, Šabanović,

& Francisco, 2017). In order to inform my approach to my work, I reviewed these literatures on science D/discourses, focusing on their theoretical frameworks, questions to which the researchers sought answers in such pieces of literature, the research methods, and findings.

In a consideration of discourses and positioning in undergraduate physics, Johansson et al. (2018) adopted a discursive perspective to study the discursive positions that were accessible to students in three introductory quantum mechanics courses at two Swedish universities. They asked the question of what it means to become a physicist, wondering whether certain ways of becoming a physicist and doing physics are privileged. For this work, they gathered data from observation of lectures, especially problem-solving sessions, and interviewed students. In order to characterize discourses, they adopted Gee's (2011) tools for discourse analysis. Using these methods, they found three dominant discursive practices. These are; calculating quantum physics, exploring quantum physics, and applying quantum physics. As a classroom discourse, "calculating quantum physics" was the most dominant discursive practice, and they argued that this narrows the chances of finding a position as a "good quantum physics student." This study by Johnsson and colleagues is important as it highlighted positioning in discourse (discursive positioning) as important for student learning. However, their work does not focus on positioning with relation to gender dynamics. In my research, I hope to extend this conversation as it includes exploring how discursive positioning is accessed in interactions across gender in a small group within studio physics. When students take up or allocate discursive positions, they exercise agency.

Martin (2016) employed a discursive psychology theoretical framework to provide a better understanding of agency exercised by three girls in a science classroom as they worked in a small group. The work sheds light on compliance identity. That is, "many capable students, especially girls, learn to do school well by being compliant, rather than doing science well and being agentic" (p. 40). She focused on three thirteen-old girls' positioning in conversations occurring in their everyday science lessons. Martin used positioning, and 'the grammar of agency' as analytic tools to study student agency in science as a discursive practice. Here, agency means that one can position one's self or be positioned by others for responsible action. She used pronouns, modality (modal verbs) and tenses to code for participants positioning in science discourse. Her work is important for my own research as she highlights the necessity of student agency beyond mere compliance in order to position themselves and be positioned for responsible and inquiring kind of participation in small groups. Students' exercise of agency in the small group sense-making is crucial in the SCALE-UP pedagogy. In addition, she advanced our understanding of how small group operates — a sub-community of practice within which joint activity takes place. She pointed to the need to better understand joint activity in small groups in science.

According to Martin (2016), enumeration of turns of talk show that agentic repositioning affords opportunities for participants in a joint activity science group to interact meaningfully in order to learn science in a given context. In these meaningful interactions, students' discursive practices in terms of observations, questions, opinions, and explanations depend on how the students were positioned in a conversation. The girls in the study had sense of both personal and collective agency, but their collective agency was not recognized in other public spaces beyond the small group as they did not publish the observations and inquiries they shared. The participants maintained the groups' identity as good students, completing tasks in time and according to the teacher's instruction but this focus on compliance limited the girls' agentic participation. The girls demonstrated this identity consistently in the social interactions within the small group.

Similarly, simply counting turns of talk unearths power and gender dynamics in physics discourses which may appear gender-neutral at first impression. In addition, counting the turns of talk is one way to highlight a link between agency and sense-making since participation in sense-making involves taking one's turn in a discursive session in the classroom (Due, 2014). Martin (2016) and Due (2014) inform my intention to include counting turns of talk in my approach to analysis of data on discourses in the physics course — discourse analysis.

Using a cultural-historical-activity theory (CHAT) and sociolinguistic approach, Vieira and Kelly (2014) proposed and applied a multilevel discourse analysis to understand how teachers and students constructed instructional conversations in a pre-service physics teacher methods course. Also, they were interested in how such conversations were structured thematically over time and across multiple levels of activity. Ethnographic perspective informed their methods. They collected data in the form of field notes, interviews and observations. The interviews guided their interpretation of key events or episodes they observed in the classroom while the field notes provided basis for inferences. They drew on Leont'ev's (1978, cited in Vieira & Kelly, 2014) analysis of the structure of human activity. This structure can be analyzed to obtain a segmentation of discourse levels so as to compose iterative analytic mapping process.

Classroom, specific domain of knowledge, and corresponding interactional spaces (small group, whole group discussion) are some of the available discourse levels. In their analysis, they constructed a map of a chosen class (identified by date on which class was held), the source or form of the data (e.g., audio, video, or both), action time (h:m:s), dominant discursive orientation, organization of interlocutors, arrangement of interlocutors, and narration of the discursive interactions of actors. Viera and Kelly (2014) provide an example of how one may map iterative and reflexive discourses by identifying small segments of selected actions. Their work offers me some insights for my analytical framework (e.g., how they mapped out analysis of their data).

Classroom activity types and epistemological discourse practices in the science classroom are related (Azevedo, Martalock, & Keser, 2013). In a detailed case study, Azevedo and team mapped out and characterized the discourse practices of design-based science classroom activities. They compared and contrasted the discourse practices to those of scientific argumentation. Focusing on inventing graphing (IG) as a prototypical activity in design-based classrooms, they sought to know what discourse practices of science characterized IG, the structure and dynamics of each such discourse practice, the patterns the discourse practices fell into, and how such patterns emerged from the reciprocal interactions between classroom participants. Toward describing the relationship between discourse dynamics — patterns of interaction and participation in classroom discourse, it is important to count the frequency of discourse practices (Azvedo et al., 2013). Although these researchers use the term discourse practices, they essentially align with what current reform visions refer to as science and engineering practices. The focus of my data analysis included how patterns of gender dynamics in sense-making may be similar or different across the participants.

Similarly, Kittleson and Southerland (2004) explored a design-based context. However, unlike, Azevedo and team (2015), the duo focused on the role of verbal aspects of language (discourse) in group knowledge-construction of mechanical engineering (Discourse) by students. In this work, Kittleson and Southerland employed the idea of disciplinary discourse as a central anchor of their theoretical framework. In order to analyze data, they adopted Gee's (1999) method of discourse analysis in which five aspects interconnect to form a “situation network” (Gee, 1999, p. 83). These are semiotic, activity, material, political and socio-cultural aspects. Six building tasks help break the situation into smaller pieces. Kittleson and Southerland (2004) centered on activity building, socio-culturally situated identity, and relationship building. They designated an entire lab session as an activity whereas conversations were sub-activities through which they identified concept negotiation and concept explanation. Although the SCALE-UP context I explored combines verification labs and tasks involving mathematical routines in a 3-hour class session (analogous to a lesson), I considered this session as an activity, just as Kittleson and Southerland designated a lab session as an activity.

In their work, Kittleson and Southerland (2004) found that concept negotiation was rare and underlying this rarity was the facilitating and inhibitory roles of engineering Discourse related to the groups’ interaction to negotiate concept. Their work was helpful for my data analysis approach as I adopted their concept negotiation and concept explanation as part of the codes in my data analysis scheme. In addition, their work helped to inform my own study, especially with regards to how social and cultural contexts situate discourses and relate to identity and relationship, a perspective which opens a conversation to [gender] dynamics in small group sense-making and equity. For example, as an aspect of equity, identity is shaped by the relationships that are revealed through interactions (i.e., gender dynamics). What conceptualization(s) of gender informed my work? It was important for me to answer this question in order to clarify how I am using this construct in relation to my focus on gender dynamics.

Conceptualizing Gender

Even though my work is not intended as an engagement with gender theory but an exploration of how patterns of sense-making in studio physics may be related to gender dynamics and reveal possible gender inequity in heterogeneous small group of one woman and two men, it is helpful to highlight some current perspectives on gender. Gender is understood by many to be a social construction (e.g., Butler, 1990; Eckert & McConnell-Ginet, 2013; Harding, 1986; Lober, 1994, 2011; West & Zimmermann, 1987; Wilson & Kittleson, 2013). I will now highlight some scholars' perspectives on gender.

According to Wilson and Kittleson (2013), biological sex forms the basis on which gender is culturally constructed. For example, in traditional western cultures, boys are expected to play with toy cars while girls play with toy babies. Another example that is even more culturally situated is that boys/men barbecue while girls/women prepare the meals. Lober (1994, cited in Eckert & McConnell-Ginet, 2013) call this cultural construction of gender a social phenomenon**.** In other words, it is defined and operated or performed by a group of people. This cultural construction of gender is pervasive, taken-for-granted, capable of shaping identities, interactions, and defining institutional norms.

Carlone, Johnson, and Scott (2015) frame gender, not as 'something' that subsists in the essence of the participants but as identity that is performed. Butler (1990) highlighted this idea of gender as non-essential but performative as well. Acts, gestures, enactments are corporeal signs — one example of discursive means to express gender performance as in a play. This suggests that [Gender] identity performance by an individual reveals a pattern or patterns over time, influenced by the setting; susceptible to varying interpretation in varying settings. The settings themselves are nested in influential structures, influences that may be covert or explicit.

Harding (1986) offers another angle on the social construction perspective on gender. She considered femininity and masculinity as constructed, with implications for activities in group, a construction that is a social process. This means that the determination of what counts as proper to a woman or to a man (not in the ontological and biological sense but in the socio-cultural sense) is made by society over time. It is interesting to note that in this perspective, there is no question as to who a man is, or who a woman is, or what makes a man a man or what makes a woman a woman. In other words, it is not a question of essence or ontology but of arts, appearance, or expression that are performed in social interaction.

This social process of determining what is proper to a man or woman, Due (2014) explained, occurs in the social interactions, discourse, set of ideas or figures of thought jointly shared in society. For example, considering the science classroom as a mini-society, the interactions among students reveal/enact the norms that guide what is standard or acceptable way to participate in the classroom activity centered around learning. For those standards to be seen to operate, most (if not all) members of the class need to subscribe to or share in those norms.

According to Harding, because gender is socially constructed, what it means to be female or male may vary from culture to culture. Harding's framing of the terms femininity and masculinity to describe gender seem to map on to her use of the phrases — what it means to be female, and what it means to be male. She itemizes three forms of gender which usually emerge in social life. These are gender symbolism, gender structure, and individual gender.

- Gender symbolism: The connection of items, materials or things (e.g., clothes) to gender
- Gender structure: The organization of interactions and activities (e.g., domestic life, labor market, small group). It pertains to the question of who is doing what?

- Individual gender: Female and male identity and behavior (e.g., positioning in school, and what it means to perform masculinity and femininity in that context.

Eckert and McConnell-Ginet (2013) present a clear perspective on biological sex and gender. "Sex is a biological categorization based primarily on reproductive potential, whereas gender is the social elaboration of biological sex… Gender builds on biological sex but it exaggerates biological difference, and it carries biological difference into domains in which it is completely irrelevant" (p. 2) (e.g., who does physics?). Wilson and Kittleson (2013) hold a very similar view (i.e., that gender and biological sex are interconnected).

My goal of highlighting these authors' perspectives on gender is to situate my own positioning in relation to the conversation on gender with regards to exploring sense-making in one heterogenous small group within studio physics. Gender as social construction and performance — offer me a conceptualization of gender that is appropriate for framing this research. However, I acknowledge the intellectual validity of *new spaces opened by modern contemporary culture* (Pope Francis, 2015) on gender and biological sex. In other words, other perspectives abound on gender (beside Harding's conceptualization of gender as a social construction, and Carlone and colleagues' theory that gender is performative identity). For the purposes of my exploration of gender dynamics and equity in sense-making, it suffices to focus on gender as a social construction and a performance. I now review some literature on gender dynamics and physics.

Gender dynamics, science, and physics. In a review of literature, Götschel (2011) draws attention to the presence of a robust tradition of interdisciplinary research on the entanglement of gender and physics. This research has been approached from multiple perspectives. She points out that this entanglement is an inadequately discussed area. Götschel

(2011) proposes three dimensions to investigating gender and physics — human actors, work-place culture, and knowledge production in physics. Along these lines, she suggests three dimensions of analysis with regard to gender and physics. These three dimensions are important for understanding different aspects of the gendered culture of physics. Citing the work of Schiebinger, Götschel argues that gendered practices and ideologies have structured scientific knowledge (Schiebinger, 2008, in Götschel, 2011).

Participation practices are part of what define classroom structures. Larger social structures include race, class (social, political, economic), gender, and sexuality. According to Carlone, Johnson, and Scott (2015), there is a central dilemma in attending to these structures and student agency in settings where inequities are pronounced. The central question for Carlone and colleagues was to understand how girls' agency in science classrooms constrained or allowed for what kind of girl to be, given the structures that framed what was acceptable in the setting. In their work, they explored this dilemma using a theoretical framework which highlighted gender as discursive performance. They identify "Helping others" as one of the prominent gender performances. They examined a data set of 13 girls' engagement with school science (fourth to seventh graders) as they worked in whole group and small groups settings. Their work informs my own focus on participation in sense-making in a small group, particularly, the influence of gender dynamics on how students participate in discourses and specifically, the experiences of the woman in the group.

For their methodological approach they used a longitudinal case study of one of the participants to identify and illustrate themes in depth. They found that prominent gender performances for girls included minimizing one's differences/fitting in, pleasing adults, & making oneself submissive or invisible. Narrowly constructed classroom subject positions made "girly" and "scientific" mutually exclusive as "girls were less engaged with how to become scientific and more concerned with figuring out what kind of girl to be" (p. 474). This means that social structures help or hinder student agency in science classrooms, depending on how those structures shape what the accepted way is to participate in the classroom and science discourses within a given setting. So, Carlone and her team's analysis of data suggests that structures of gender, race, and class became more salient for the participants' science trajectory over time.

The entanglement between engagement in science and gender performance goes beyond the K-12. Gonsalves (2014) provides an example of this entanglement even at the doctoral level of study in physics. She used observations, photo-elicitations, and life history interviews (11 men and women) framed by a socio-cultural approach. She examined the ways doctoral students in physics construct stories about becoming physicists. She found that recognition is salient to the participants' construction of physicist identities. Achieving recognition by self and others such as peers entailed the reproduction or reworking of persistent discourses of gender norms. By gender norms, Gonsalves highlights behaviors expected of men and women respectively, expectations which are different for each gender. Diligence, neatness, and rule-following are some of the gender norms for women. So, women are expected to follow rules in the classroom much more than men, while men are expected to be more competent with machines and tools (technical competence) as well as grasping theories behind the phenomena explored in physics (academic competence). However, even though Gonsalves highlights the gendering of physics competence as well as gender neutrality as persistent discourses in physics, she hesitates to suggest that identity categories identified in Due's (2014) paper (e.g., hard-working student, competitive student, playful student) are at all stable or persistently unavailable to girls or boys in interactions.

The forms of competence emerged as assets for achieving recognition in the physics community studied. Besides competence, performance of stereotypical gender discourses for physicists was equally salient for the participants to be recognized as physicists. This performance relied on traditional gender norms for the field. Her findings demonstrate that achieving recognition as a competent physicist often involved a complex negotiation of gender roles and the practice of physics. Gonsalves' research cited here is important for my own work as it allows me to build on how those negotiations in a heterogenous group of men and women may reveal gender patterns during sense-making. Danielsson (2012) has similar conclusion in a related study — for women, doing physics involves doing gender. An example is Keller's (1977) description of her experiences as a woman studying physics in the 1950s, a description that may be taken as typical experiences of how doing physics and doing gender are entangled for most women. Keller describes:

> I fell in love, simultaneously and inextricably, with my professors, … the discipline of pure, precise, definite thought, … with the life of the mind. I also fell in love, I might add, with the image of myself striving and succeeding in an area where women had rarely ventured (cited in Danielsson, 2012, p. 25).

Keller's experience as described in the quote highlights her self-investment with physics as a field of inquiry and physicists. She also describes her excitement with the beauty of the discipline. However, her identity which will develop through striving towards success — is tangled with her gender which is underrepresented in the field. This entanglement of aspiration to be a physicist, and gender shapes the experience of participants on the path to realizing their goal in the field. In a case study involving five women as participants, they found that the experiences of the women were shaped, not just by the masculine connotations of physics but the expectations of female physics students as well. Both gender norms abound in physics. They are traditionally constructed by the larger society and influence physics.

The traditional gender norms in physics have been constructed as masculine (Due, 2014). Pettersson (2011) is an example of research that explores the masculine gendering of physics. She uses an ethnographic approach and masculinity studies to analyze observational and interview data for masculinity and experimental practices among plasma physicists in a laboratory in the United States. Pettersson argues that in particular, cultural aspects of masculinity contribute to the understanding of how men dominate by rank and number in physics, and science in general. She describes the masculine gendering of plasma physics in terms of how established participants in a plasma physics lab described what it means to be competent in plasma physics. To be a competent plasma physicist required daily [manual] labor which include "getting greasy, and dirty, sprawling under the machines and lifting heavy things" (p. 57). This labor is socially and culturally constructed as the sort of work for men. So, it is not only identity (a plasma physicist) that is socio-culturally constructed. Rather, according to Vygotsky's socio-cultural theory, the ways of attaining and exercising those identities (e.g., participating in small group sense-making) are also socially and culturally defined. This understanding is part of the reason why Vygotsky's (1979, 1980) socio-cultural theory is appropriate for this research.

My theoretical framework elaborated with D/discourses. I illustrate my theoretical framework (see figure 1), depicting gender in the sense of the dynamics centering on it during discourses in the small group. The social interaction among the individuals in the small group is nested within the SCALE-UP context, physics as a field and the larger society. In other words, the illustration in figure 1 describes gender dynamics as important for how students participate in classroom discourses and ways of using tools as they socially interact to make sense of concepts, understand ideas core to physics, and engage in discursive practices to make sense of phenomena. In this way, they learn physics. As depicted in figure 1, gender can be either a "Discourse" or a tool in the classroom: As an influential factor in the interactions among students as they participate in science discourses — the gender dynamics during physics Discourses. As a means to achieving a certain position of power and/or competence, it is a tool. It can also be both. This is why gender is located between D/discourses and tools in the illustration of my theoretical framework. Also, the figure illustrates the social interaction between the group and the individual. My exploration of the interactions (between the individual and peers in small groups to learn), discourses, and use of tools center around gender. This centering is intended to communicate gender dynamics, and it is important for many reasons, especially, given challenges of the low persistence and graduation rates of women in physics.

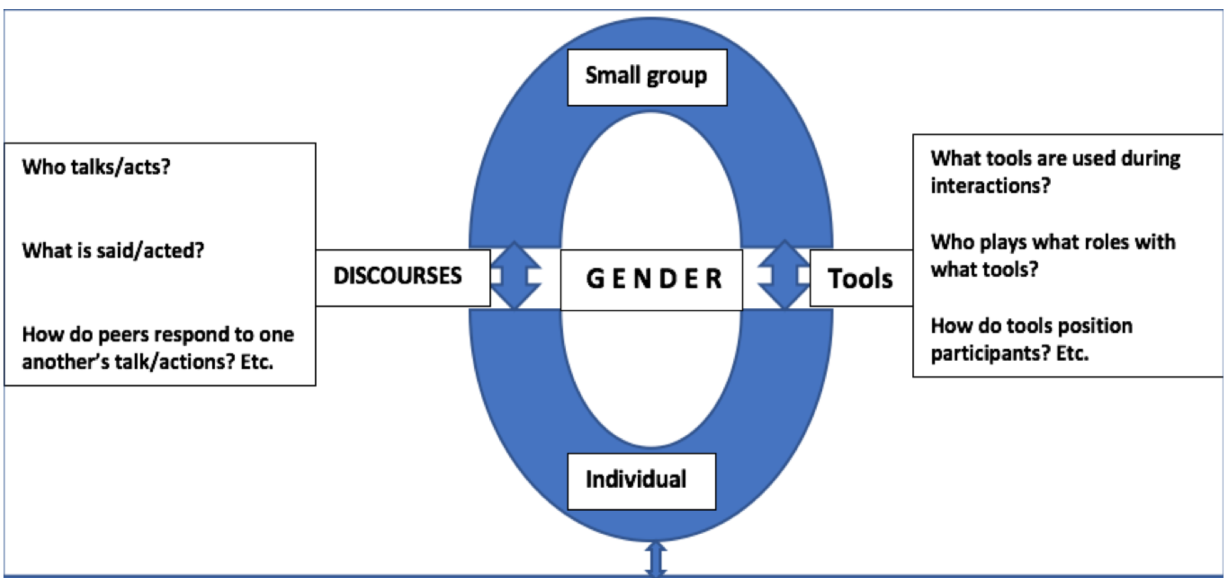


Figure 1. The place of gender in social interaction to learn physics in a SCALE-UP setting.

Often, the conversations around these challenges are framed as a gender gap (see for example Anderson & Johansson, 2016; Madsen, McKagan, & Sayre, 2013) as the comparison is with the persistence and graduate rates of men and a host of scholars have proposed solutions to closing the gender gap. For example, Lorenzo, Crouch, and Mazur (2006) suggest that by using interactive engagement in their context in Harvard University, male-female disparity in performance was alleviated and even eliminated. On their part, Pollock, Finkelstein and Kost (2007) conducted a similar study at the University of Colorado. They examined the impact of interactive engagement techniques on the gender gap. Through a study of students' learning outcomes in a mechanics course (first semester) and electricity and magnetism course (second semester), they intended to replicate the original results of Lorenzo and colleagues. For this, Pollock and his colleagues collected data in six first-semester courses and five second-semester courses, amounting to over 3000 students whose pre and post data were compared. They computed the pre and post test scores for the first-semester course using the Force and Motion Conceptual Evaluation (FMCE) whereas for the second-semester course, they used the Brief Electricity and Magnetism Assessment (BEMA).

Using this analysis Pollack and colleagues found instances in which the gender gap increased even though all students made significant learning gains. They concluded that this finding suggests that there were other influential factors, these were — student and instructor effects. Pollock and colleagues focused on the influence of student background and preparation as important for understanding disparity across student learning outcomes. They also draw attention to an instructor effect since classroom culture is shaped by practiced selected by the instructor and the way those practices are framed by an instructor. The classroom culture is particularly important given the fact that the classroom culture in physics has remained dominantly masculine as well as skewed in disfavor of female students and students from minority backgrounds.

The research on gender gap has spent its fair share of time giving attention to describing the disparity in achievement between women and men. I argue it is time to move beyond describing disparities to determining the root cause of these disparities. I argue that it is time for a more critical look at physics itself, recognizing that the gender gap is a symptom of gender inequity in physics. So, my exploratory work aims to understand patterns of gender dynamics and meanings students attribute to them. Centering my exploration on gender dynamics has potentials for informing us on it implications for gender equity in a small group within SCALE-UP. This research supports the need to confront the masculine gendering of physics.

In a dialogue with Gonsalve's paper on doctoral students' positioning around discourses and competence in physics, Götschel (2011) re-situates Gonsalve's (2014) findings in the broader context of research on gender and physics, extending the conversation to include aspects of diversity and contextuality of physics. Contextuality refers to the differences across the world of what factors may be influential for achieving diversity in physics. Götschel (2014) highlighted the masculinity and gender non-neutrality in physics as discourses that need to be dismantled. She points to these discourses by drawing attention to the nomenclature of particles, and phenomena, instruments and institutions. An example of this masculine gendering in physics is — women particle physicists are rarely honored as their male counterparts in the way many things are named in particle physic. For example, "the proton 'Protoni' is described as 'a poor lonesome cowboy' (Gisler, 2001, cited in Götschel, 2014, p. 73). I may ask: What about the 'poor lonesome girl'?

Clearly there is need for considerable *renegotiation of competence (*Due, 2014) in physics in order to deconstruct physics as quintessentially masculine (Francis, Archer, Moote, Dewitt, Macleod, & Yeomans, 2017). This deconstruction begs the question of equity which also has implications for the intellectual equality of men and women in physics. That is, if men are not biologically superior to women, what justifies a culture in physics that gives masculinity advantage over femininity? Francis and team explored participants' explanation for gender inequality in physics. They found three discourses at work on the topic of women's access to physics. These are (1) (in)equality of opportunity, (2) continued gender discrimination in and around physics, and (3) physics as quintessentially masculine supported by five distinct narratives. These narratives are; certain subjects are gender-stereotyped as being masculine or feminine (and so, appropriate for different genders), men and women are naturally different and drawn to different subjects, femininity is antithetical to (masculine) manual work, femininity is superficial, and cleverness is masculine, and physics is clever/difficult. They concluded that in order to alleviate the underrepresentation of women in physics and the physical sciences, there is need to disrupt the prevalent constructions of these sciences as masculine and hard domain.

In order to deconstruct physics as a masculine discipline, there is need to look beneath the gender gap, to go beyond a gender gap framing. This is important because a gender-gap framing runs the risk of essentializing achievement or competence in physics. This framing paints a picture of the undesirable situation. In order to go beyond a gender gap framing, there is need to reach deep down to the roots of the situation. A crucial work that the physics and science education community need to consistently do is to alleviate the situation by deconstructing the masculinization of physics and the persistent gender-neutrality narrative on physics. Such crucial work holds promise for widening participation in physics and other STEM fields, both in terms of higher education and career, with implications for equity.

Gutiérrez (2009) writes; "equity is ultimately the distribution of power— power in the classroom, power in future schooling, power in one's everyday life, and power in a global society" (p. 5). She developed an equity framework that has a dominant axis and a critical axis (see figure 3). The dominant axis is composed of access and achievement dimensions, while the critical axis consists of power and identity dimensions.

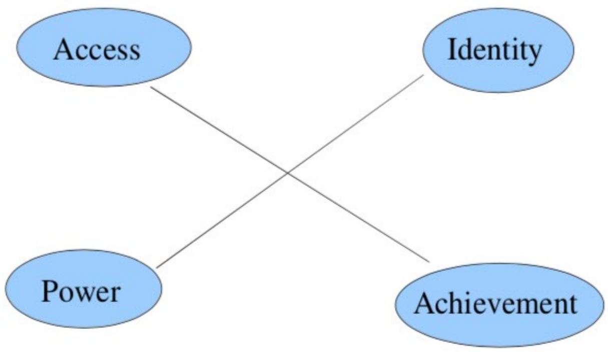


Figure 2. Gutiérrez's (2009) conceptualization of equity: Dominant and critical axes.

Even though Gutiérrez developed her conceptualization of equity in mathematics education, I argue that it is relevant for my work in science [physics] education, considering the power dimension in particular, it supports my theoretical framework given that it frames the kind of questions which I seek to answer as a way to analyze data for this study. These questions include: Who gets to talk in the small group sense-making sessions in the classroom? How does gender dynamics influence patterns of sense-making in the small groups?

My research questions are situated within a specific context. This emphasis is important because there are factors embedded within the contexts and we cannot ignore contextual factors in issues of classroom discourse (Carlone, 2003; Ladson-Billings, 2006). Informed by the importance of context, I describe the research focused on learning within SCALE-UP — the pedagogical innovation from which I selected a site as the context of my study to focus on a unique group of participants.

Learning in SCALE-UP

Robert Beichner built on “Studio Physics” (MacDonald, Redish, & Wilson, 1988; Wilson, 1994; Wilson & Redish, 1992), extending it to accommodate greater number of students. He called this revised model SCALE-UP — student-centered active learning environment in undergraduate physics (Beichner, 2008). While multiple research bases were influential in the design of SCALE-UP, “active, collaborative, social learning” (Beichner, 2008, p. 2) are closely associated with this research-based innovation. Indeed, for Cumming (2008) the centerpiece of instruction in all SCALE-UP is collaborative group work.

Extant literature on SCALE-UP suggests that attention has been largely focused on evaluating the efficacy of this pedagogical innovation for student learning by measuring learning gains in pre/post-tests. For example, Gaffney and colleagues (2008) highlighted results based on a study conducted by Beichner and others (2007) who reported reduction in failure rates of women (and minority students), and improved conceptual learning suggested by learning gains on the Force Concept inventory, gains considered to be impressive.

Similarly, Felege and Ralph (2019) reported on the efficacy of a transition to SCALE-UP format in Introductory Biology courses. Though this was in biology, their findings align with the effectiveness studies that are predominant in SCALE-UP physics pedagogy (e.g., Rudolph, Lamine, Joyce, Vignolles, & Consiglio, 2014). However, they also found a concerning decrease in performance of lower quartile students. One may ask: Who are the lower quartile students? What factors might explain the decrease in performance? In other words, what factors might explain success or otherwise of students’ learning experiences within SCALE-UP? This work, while important leaves these questions unanswered. In a review of literature. Pond and Chini (2017) highlighted positive learning outcomes reported for studio-mode courses, pointing to instructional practices, instructor effects, and student learning profiles (in terms of study strategies, attitudes towards physics, motivation for learning physics, organization of scientific knowledge etc.), in/equity was not included among factors that may be influential for student learning. What does it mean to learn science?

In my work, I was guided by the understanding that students do not learn content only, but current visions of science teaching and learning requires that students learn big ideas, concepts that cut across disciplines, and engage in the practices of science (NRC, 2012). Just as content only is not what students need to learn, redesigning a physical space in studio style is not the only aspect of the SCALEUP pedagogy. According to Cummings (2008), the Studio format of the classroom alone is insufficient for improving learning outcomes. Rather,

- ways of negotiating the learning of content, and
- who is adjudged as competent in learning content

are important aspects of student learning experiences, learning outcomes and science identity development. Those important considerations pertain to D/discourses. This importance of D/discourses in physics learning was part of the motivation for my choice of discourse analysis as an appropriate aspect of the framework that informed my method for analyzing data for my study. I analyzed data on an Introductory Physics course on electricity and magnetism. So, in the next subsection, I review literature on learning in electricity and magnetism.

Specifics of learning in electricity and magnetism. It is important to note that much of the extant research on learning in electricity and magnetism are centered around conceptual understanding and problem-solving. Research focused on problem solving (e.g., Adams & Wieman, 2015; Ceberio, Almudí, & Franco, 2016) spans expert-novice approaches to problem-solving, students use of worked-out problems to solve new problems, use of representations, mathematics in physics and evaluation of the effectiveness of instructional strategies for teaching problem-solving. Though cognitive science and educational psychology offer a variety of "theories about learning and problem-solving, researchers in PER do not clearly define or draw upon a theoretical basis for their research" (Docktor et al., 2014, p. 7) such as found to be the case in research on students' conceptual understanding and problem-solving in electricity and magnetism.

Furio and Guisasola (1998) analyzed students' major difficulties in learning the concept of electric field. In their study, they assumed that the historical study of the development of the landmark contributions to the theory of electric field will help diagnose students' difficulties. They described the work of Coulomb and Maxwell, examining the extent to which these are used by students from 6th grade to the university level. They found that most students (university level inclusive) have difficulties in their reasoning with electric field. In problem solving, the students had a preference for the "Newtonian model of action at a distance" (p. 16). These authors however do not provide explanation in detail on the difficulty and the mechanism involved. Also, they do not appear to take cognizance of the importance of context and social dynamics in student learning. Furthermore, beyond identifying those difficulties, what pathways might be helpful to support students in overcoming the difficulties? These questions beg for answers.

Using the (mis)conceptions framework, Engelhardt and Beichner (2004) noted that both high school and university students reason differently from accepted (canonical) explanations regarding direct current circuits. This conclusion is based on the mean (M) of the two groups on a 29-item instrument designed to evaluate student reasoning on direct current circuit, with university students outperforming high school students. They developed an instrument for testing/diagnosing students' difficulties. Their goal was to offer instructors an instrument for evaluating students' progress and conceptual difficulties such as describing and interpreting circuit diagrams, understanding the concepts of current, potential difference, and resistor. They called the instrument (DIRECT) — Determining and Interpreting Resistive Electric Circuit Concepts Test. In their analysis of data gathered using the DIRECT, they suggested that students, especially females, tended to hold multiple misconceptions even after instruction. While I appreciate the effort to develop an instrument intended to assess student understanding (content and achievement), the paper contains no explanation for the findings. In addition, the instrument misses the other important aspects of what students need to learn, especially engaging in the practices of science. In order to focus on all the important components of what it means to learn, my work draws from current conceptualization of learning in science, specifically the K-12 framework for science teaching and learning. My research documented here explored gender dynamics in order to highlight the need for conversations on deeper explanations for the disparities in achievement that are presented in innovative pedagogy settings such as SCALE-UP.

Similarly, Lindsey (2014) investigated student reasoning about potential energy in introductory electrostatics and universal gravitation. She found that despite relevant instruction, both written questions and one-on-one interviews administered post-instruction showed similar patterns of incorrect reasoning. They noted that similar misconceptions abound in student reasoning around gravitational potential energy when introduced to universal gravitation. Thus, students' understanding of this concept is insufficient for advanced courses in physics or other disciplines. Students confused one concept for another (e.g., potential energy and interaction strength). Lindsey argued that the language used (e.g., to frame chemical bonds and energy) and the conflation of forces explains student misconception. They noted that even when students invoked formulae, they do not demonstrate a conceptual grasp of such formulae. That is, students are not able to qualitatively explain the ideas represented by the formulae. Similar to other studies that employ the misconceptions framework, Lindsey (2014) omitted attention to deciphering the roots of such conflation (i.e., evocation of formula without conceptual understanding). My work promises to contribute to shifting the focus from formulae (which incentivizes mere memorization) to sense-making.

In a longitudinal and mixed-methods experimental study, Dori, Hult, Breslow, and Belcher (2007) compared students' concept retention and attitudes regarding the contribution of a teaching format to their learning in advanced courses. This was a post-course study that targeted 12-18 months after the students completed a freshman electromagnetism course at MIT. Students were enrolled in two formats of the same course; a studio format called TEAL (Technology-Enabled Active Learning) and traditional or lecture format. They documented long-term cognitive and affective impact of the TEAL format on the students' achievement. In agreement with outcomes-based studies of studio physics, the students in TEAL (the experimental group) had higher scores on the post-test. The qualitative aspect of the study revealed that though there were positive, mixed and negative affect for both the TEAL and lecture groups, the TEAL students had stronger positive feelings. For me, Dori and colleagues' work is important, specifically for highlighting affect in the innovative pedagogy. It is desirable that students in the innovative approach context have a stronger affective experience. Affect is important for understanding equity in such contexts as innovative classrooms/approaches to teaching. However, Dori and team's work does not contain explanations as to why students in the TEAL format of the course (the innovative format) did not offer any explanations for the patterns of affect they reported in their work. My research reported here promises to highlight participation in sense-making, and dynamics in interactions across a group of two men and one woman as important for in-depth understanding of patterns revealed in innovative classrooms/teaching approaches.

In a mixed-methods study, Yuliati, Riantoni, and Mufti (2018) explored approaches used by prospective physics teachers to learn problem-solving linked to direct current electricity in a media technology-based inquiry course. Their research design included an experimental model, using the Physics Education Technology (PHET) simulations. They investigated the influence of the PHET simulations on problem-solving skills and found that students used multiple approaches in their problem-solving but only few of them used scientific and structured approach to problem-solving. More of the participants tended to use unstructured, memory-based approaches while others indicated no clear approach. It is important to bear in mind that the PHET simulations are tools but what good do tools serve if they are not oriented towards equitably rich sense-making as crucial for participation in science discourse? Tools must be perceived for what they are — means for engaging in science D/discourse (Gee, 1999, 2011). My illustrated framework is informed by this understanding of tools (see figure 1).

It is noteworthy that most of the research reviewed so far in relation to student learning centered around direct current circuits and electric fields do not focus on equity in students reasoning along the critical dimension of power. Rather, the researchers dwell on achievement. Implications from my work on gender dynamics has potential for filling this gap by focusing on the critical dimension, especially power which is vital for students' appreciation of their place to contribute to classroom/physics discourses, beginning from their place in small group work. Gee's (2011) conceptualization of D/discourses is important for a critical look at the interactions in student groups in the sense of helping to deepen insight on how gender dynamics of students' interaction in small groups may influence how they participate in sense-making in the classroom.

In chapter three, I describe my methodological approach to this research. In summary, I employed a qualitative single case study for a fine-grained analysis of student discourses in order to explore gender dynamics during sense-making in a small group. Though laborious, by applying a known analytical method to answer novel questions my research promises to advance conversations on gender and physics — a conversation which is very important for multiple reasons. For example, according to Federico Mayor, "On a worldwide scale, science... is still a man's business. This situation is no longer acceptable... as it deprives scientific and technological research of ideas and methods" (UNESCO, 1999, p. 34).

CHAPTER 3

METHODOLOGY

Student-centered approaches for teaching physics and, more generally for teaching science, have been found to support the development of students' conceptual understanding of the discipline (Freeman et al., 2013). As one example of a student-centered approach, SCALE-UP has been shown to be effective in supporting student learning in physics, and more specifically, it has shown promise in supporting women's conceptual learning of physics (Beichner et al., 2008). However, those findings need to be more closely examined, as there is research that suggests that some promising interventions for promoting student science learning continue patterns of inequitable classroom participation, once again leaving women on the periphery of physics learning community (Götschel, 2011; Lewis et al., 2016; Madsen et al., 2013). The possibility of inequity in innovative pedagogical interventions, and the consequences of inequity hindering the persistence of women in physics —highlights the need to explore equity in a small group within physics classroom. My desire for a deeper understanding of equity and inequity in innovative pedagogical physics classrooms was influential in my decision to choose a course in SCALE-UP format as my context for this research, and propelled my need to take a different approach than pre/posttest scores.

Previous studies in SCALE-UP have used a large grain size in the research, focusing our attention on whole class normalized, learning gains, paying little attention to the ways those gains are generated (Felege & Ralph, 2019; Pond & Chini, 2017) and less still to patterns of participation in SCALE-UP classrooms. Past research that speaks to continued gender inequities in student-centered approaches to physics learning begs the question —what are the gender dynamics supported in a small group within SCALE-UP? In this chapter, I present my research questions, the details of design of the research into these questions, including the study context, participants, data sources, and in-depth descriptions of how I analyzed the data in order to answer the questions that guided this research.

Research Questions

My research was guided by the following questions:

1) What patterns of gender dynamics centered around the woman's participation emerge within a heterogenous small group in a student-centered/reform-oriented approach to physics instruction?

2) What meanings do the small group participants assign to these dynamics?

I now describe how my research was designed to answer these questions.

Research Design

In this research, I employed a qualitative approach (Creswell & Poth, 2018). The qualitative approach was appropriate for my work because it is suitable for facilitating rich or in-depth descriptions (Creswell, Hanson, Clark Plano, & Morales, 2007), something required to understand patterns of gender dynamics in interactions. The goal of this exploration was to identify and describe patterns of gender dynamics in sense-making during discourses within a small group in a SCALE-UP classroom. I designed my research here as a single case study (Yin, 2014).

Participants

The participants for my study were students enrolled in the studio version of an Introductory Electricity and Magnetism course. In order to realize the goals for this research, participants were recruited from an entire class of 80 students. The instructor helped with the recruitment of participants by announcing the study to the entire class. He supported the researcher to gain the students' audience so as to briefly introduce and explain the prospective research to the entire class. Eight students agreed to participate and signed the consent form. Nosidam (a woman) was a chemical engineering major, Demha (a man) was a Biochemistry major, Enirethak (woman, a chemistry major), Isaac (a man, biochemistry major), David (a man, computer science major) and Kay was a physics and education (double major). Then, Elleirg was a mechanical engineering major, and Nadia — Nadia a biochemistry major. However, eventually my analysis of data turned to three students of this larger pool.

Over the course of the semester of gathering data on the participants in their small groups, I got to know them more and more. For example, they shared their experiences in courses prior to enrolling in this course and during this course with me. Such revelations shaped my choice of the participants and the group I focused on during data analysis. I became curious to learn the gender dynamics in one group involving two men (Isaac and David) and a woman (Kay). My hoped that this group would offer me robust insight into gender dynamics. Finally, my choice of the select group (Isaac, Kay, and David) is that since this was an exploratory study, it was impractical to analyze data on all the groups.

Members of a group were selected by the instructor, in part, mindful of student entry knowledge in the course. This determination of entry knowledge was based on student performance on the force concept inventory (FCI) (Hestenes, Wells, & Swackhamer, 1992), or end of semester examinations in a prior course with the same instructor. Based on her score on the FCI, the instructor considered Kay as medium in her incoming knowledge for the course. Isaac was a Biochemistry major with a strong incoming knowledge for the course (according to the instructor's assessment of his performance in a previous physics course). David was a computer science major who was in the top 2% of best outcomes in the previous physics course he took with the same professor. Based on this, the instructor assessed him as having a strong incoming knowledge for the course.

The instructor of record changed groups throughout the semester removing and/or adding select participants to a group. The decision to modify group composition over the course of a semester was based on the observations of the instructor on how well students worked together as a group and the success of its individual members. For instance, it could be based on instructors' observation that a participant was hesitant to work with the other members, sitting away from the group, not participating as a member of the group, and working alone. However, for this exploratory study, the group composition for my case study was not alternated during the particular lesson selected for analysis.

The composition of the group was intentionally designed by the instructor to include a mix of women and men, the former being in the greater number in two groups each time while a third group consisted of one woman and a man. However, in keeping with my purposeful selection of the group, my goal of exploring gender dynamics around the experiences of Kay. My decision was particularly because of her gender equity awareness. So, I designed my research here as a single case study (Yin, 2014). because I followed the experiences of one woman (Kay) in a group of two men (Isaac and David). This particular group was selected because of its unique affordances for the goals of my research here: Kay was a participant with high self-confidence in physics; being particularly aware of her *agentic* voice in a group (Stroupe, 2014). The following excerpt offers evidence of her self-confidence and awareness of the importance of her agentic voice for equitable participation in knowledge-construction within a group.

> **Kay**: I know that [when] I took studio for the first semester. I was in a group. I was in a table of all males. And trying to say anything, I would literarily be ignored sometimes. I would like come into this class and am like; am' going to fight, am going to

> literarily yell my ideas until they listen to me (most participants laughed), so am going to do it. And not like, you (referring to herself) can just write everything down (take down notes for the group), then the males are going to do the experiment. I am like — I want to understand (Individual Interview, 4/13/2019).

Isaac was also a unique participant in the sense that he had some awareness of gender equity coming into this class. In an interview, he offered a glimpse into his gender awareness self-positioning, cutting in as soon as I finished asking my question.

> I usually (.) I kind of like watch where I stand because for women in STEM especially like (.), there is a huge culture of (.) not only equality but equity really. Definitely, like, I just have to give them their respect and space they need really because (.) any harsh criticism that comes out of my mouth can easily be misconstrued (swaying his hand in the air) and be taken as offensive and not forgotten. Anyway, a lot of my friends are women that I hang out mostly with, so I just have to be super conscious about these things (Focus group Interview, 4/13/2019).

On his part, David was a participant whose descriptions of his perspective on gender interactions in small group suggested he was not mindful of gender equity. In response to one of the women (not kay) who had earlier shared her perspective on her experience in a group of two men (including David), he said:

> **David**: (cutting in as soon as the women finished) I don't think that was the motivation. I am just pushy (some of his peers laughing), so you might as well say whatever you want.

The uniqueness of each participant is defined by who they are — "identity" (Gutiérrez, 2008, p. 357); their backgrounds and educational majors, the totality of their experiences (e.g., culturally), and their perspectives and approaches to gender interactions. Also, my selection of a group of one woman and two men, all unique in their awareness of gender equity, offered a most promising opportunity to explore gender interaction centered around the woman's experiences. Finally, teaching assistants (TAs) had the opportunity to play a very important role in students' learning in a group (Stang & Roll, 2013). So, my data analysis included a description of the TA's role in the gender dynamics in the selected case. The participants included in this case study are described below:

Study Context

This study was conducted in an Introductory Electricity and Magnetism course (PHY 2049C) offered in a physics department of a large research university in the southeastern US. Instructors of the course used the SCALE-UP pedagogy (Beichner et al., 2007; 2008) to examine fundamental concepts in electricity and magnetism (e.g., electric charges, electric potential, electric field, magnetic field, and direct current circuits). Throughout the course, the pedagogical approach focused on the goal of fostering student conceptual understanding and *problem solving* (in the form of using mathematical routines to compute quantities in physics) through supporting student sense-making in small groups (Beichner et al., 2008; Cummings, 2008).

In SCALE-UP, student work in small groups take two forms of activities; verification labs and more theoretical problem-solving. During verification labs, students use laboratory equipment to explore physical phenomena (e.g., building electric circuits to measure current across designated terminals of a wire) and then write a report of their activity. The more theoretical problem-solving aspect of their activity challenge student understanding of physical phenomena by requiring them to use analytical skills and mathematical thinking. For example, students worked on tasks requiring them to calculate the equivalent resistance and draw a circuit that is equivalent to a given circuit with multiple resistors. So, students explored physical phenomena by employing mathematical models to understand problem sets taken from content materials for the course or questions written by the instructor.

Sense-making entails that students share their perspectives, argue about "stuff" in the disc discipline, and engage in the practices of science which includes pushing back on one another's ideas in order to generate useful explanations of the natural world. In this work, students take opportunities to generate, use, and extend scientific knowledge (Haverly, Barton, Schwarz, & Braaten, 2018) as they learn domain-specific content and big ideas (in physics), developing proficiency in the practices of science (NRC, 2012). An example of such practices is offering explanations of their mathematical models of the physical phenomena to their peers. In this way, they learn ideas and engage in the scientific practices that are at the core of physics, and those that cut across different science and engineering disciplines.

My preliminary research within this particular SCALE-UP context (e.g., Akubo, Mathis, Smith, & Southerland, 2018, 2019) revealed a pattern in the orchestration of the pedagogy employed. Typically, SCALE-UP session begins with a 5-minutes to 8-minutes lecture to launch the session. Instructors may repeat such brief lectures to highlight areas of focus during a session. The brief lecture is followed by activities intended to provide opportunities for sense-making such as through problem-solving. There are two predominant forms of problem-solving in this context. The first form includes figuring things out during activities in which students explored physical phenomena such as the flow of electric current through a circuit and learn to explain the observations they make. The second type of problem-solving involves conceptual and mathematical modeling of physical phenomena. In both of these, students have access to white boards to make their thinking visible to their peers and the facilitators of the activities.

The sense-making activities were organized in small groups of three students as previous research in this area suggest that this is the optimum number effective for sense-making in the small groups (Beichner et al., 2008, Cummings, 2008). Each of the three groups occupied a section of a round table such that the three groups occupy one table. The table served as their work-station. Figure 3 illustrates how members in a group sat at their work-stations in SCALE-UP.

Figure 3. A SCALE-UP classroom (Beichner, 2007). Photo: Courtesy of Michael Rogers.

During the small group activities, the instructor and teaching assistants (TAs) move around in order to support student learning by answering students' questions, giving them hints, and providing clarifications. These facilitative work by the instructor and TAs take place both during the verification labs and the more theoretically oriented units. During the latter, based on instructor's assessment of the promise of a group's work to support the understanding of the class community, members of the group would be invited to present their work to the entire class through the use of white boards, electronic screens or monitors. In this way, through selecting the ideas to feature by choosing small groups, the facilitator orchestrates a whole-class sense-making through discussion. For these presentations, members of the selected group come to a designated location facing the whole class and present their work. Their peers then ask them questions on the work presented, critically appraising the work by seeking clarity and challenging the steps or approaches employed by such a group and outcomes of problem-solving. For the verification labs, the facilitation by instructors take the forms of supporting students to follow the designated experimental set-up, giving hints or directly answering students' questions.

The content addressed in this SCALE-UP course was sub-divided into two sections, each section had multiple units. Within the first four weeks of the semester, students participated in verification labs during which the students were asked to follow some specified steps in pursuit of an answer, leaving some little room for student inquiry. The labs were centered around direct current circuits. For example, students set up direct current circuits and used galvanometers to detect the flow of electric current, used ammeters to measure the amount of current that flowed past a given point in a circuit, and the role of circuit components such as resistors and switches. After this, during the remainder of the semester, students worked on the more theoretical or abstract topics such as electric fields, Gauss' Law, magnetic induction, and electromagnetic wave phenomena. (See Appendix F for course PHY2049C syllabus). The syllabus guided the students' work centered on physics content in the small groups. Guided by the syllabus, the instructor assigned the small groups a set of problem sets, requiring math skills and content knowledge to spur student sense-making around physical principles.

In the design of units, the instructor drew problem sets from Physics for Scientists and Engineers with Modern Physics (Knight, 2013). This book was intended as a pedagogical tool "to support an active-learning environment…provide a balance of quantitative reasoning and conceptual understanding" (Knight, 2013, p. viii). In addition, the SCALE-UP classroom used Mastering Physics — an online evidence-based curriculum resource used for problem sets (Knight, 2013).

Description and rationale for choice of course as my research context. The course within which I conducted this study had two parts — verification labs and a more theoretical math-based part (e.g., computing the electrostatic force exerted by two point- charges, calculating the energy and work done). Beginning from 1/9/2019, the class had been working on direct current circuit verification labs. For these labs, students built and explored direct current circuits using wires, batteries, switches, bulbs and bulb holders. They observed how the brightness of bulbs may change depending on their configuration or how those bulbs were arranged in a circuit. They also measured voltage and circuit current using voltmeters and ammeters respectively. Students were required to predict the behavior of circuit configurations and certain circuit components (e.g., the brightness of bulbs in a certain circuit configuration). After stating their predictions, students then carried out the lab activity to confirm or reject their predictions as required by the tasks in the course schedule.

According to the course schedule, the verification labs were meant to be the focus of the class for the first 4 weeks of the semester (January 7-February 1). During this period, students explored the behavior of direct current circuits by predicting the brightness of bulbs, building circuits, following laid down procedures to analyze circuits, measurement of current, resistance, and voltage. However, during the verification labs, they made use of physical concepts and math. For example, in order to understand and analyze the circuits they were building, students needed to apply rules governing circuits (e.g., kirchhoff's rule, ohm's law).

For the verification labs, course materials covered a four weeks period of study. These course materials were structured into weekly modules consisting of specific but interrelated sections and subsections. The instructor organized these modules aimed at enabling the students to achieve specific learning objectives. The idea and inspiration for the design of the content and structure of the modules were drawn from the resources developed by McDermott and the University of Washington Physics Education Research Group (McDermott et al., 1996).

The labs were not merely worksheets to be filled. Instead, given the tasks assigned in these labs, there was room for disagreement of perspectives by members in their groups, explanation of the reasons for such perspectives, and reconciliation of differences in student understanding of the material. Some of the verification labs had no categorical answers (i.e., yes or no), rather, the work that students were required to do were "nonobvious and contingent, which must be figured out by the [students] and negotiated in response to feedback from peers and the material world" (Manz & Suárez, 2018, p. 774). Generally, the tasks were designed to offer students the opportunity to fruitfully grapple with the phenomena they explored and so create the room for them to take active role in the activity. In this way, they might take the chance to engage in disciplinary uncertainty, experiencing uncertainty in a way similar to how scientists experience it (Manz & Suárez, 2018).

The labs had tasks called "experiments", and "exercises". The term "experiment" was not used in a strict sense of randomized control but in a loose sense to mean activities in which students verified their predictions of the behavior of circuits and negotiated such predictions with their peers in their small groups. In other verification labs, the "experiment" was entirely a procedural task requiring the students to follow steps given in instructions during the activity and requiring no predictions or sense-making. Procedural tasks entailed students_following instructions in a step-by-step manner to accomplish a goal. These procedures pertain to the mechanics of a task (e.g., how to set up or run an experiment). Figure 4 is an example of the procedural type "experiment" from the studio physics lab.

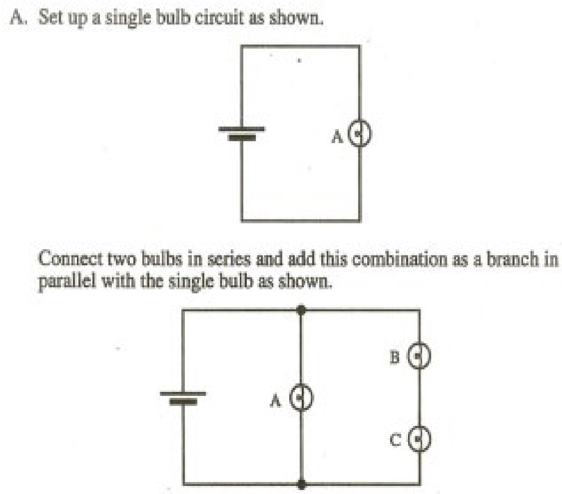


Figure 4: An example of experiment in the module (Experiment 3.5).

The “experiments” required that students provide conceptual explanation. Below is an example of an exercise following the experiment featured in figure 1.

> Explain why the following two statements are direct consequences of the definition of series and parallel connection.
> A. When two bulbs are connected in series, they have a single common junction and together, as a unit, constitute the only continuous path through that junction.
> B. When two bulbs are connected in parallel, current that passes through the bulb does not pass through the other.

I chose the verification labs as the instructional context for my study because the nature of the labs offered opportunities for epistemic uncertainty which is important for student engagement in disciplinary discourse to build knowledge. I analyzed transcripts of audio/video recorded data gathered on discursive episodes as well as focus and individual interviews.

For my data analysis, I broke the data on the selected verification lab session (lesson) into episodes. The episodes may be considered analogous to Manz and Suárez’s (2018) idea of pedagogical episodes in the sense that discursive episodes are instances of [student interactions] during which [students] “describe issues, or raise questions about [learning] that are accompanied by some elaboration of reasons, explanations, or justifications” (Horn, 2005, p.

215). For my work, an episode centered on or is bound by a single task or multiple tasks in the verification lab on which I collected and analyzed data.

Data Collection

Gupta, Redish, and Hammer (2007) argued that observing students in real time as they engage in learning content, along with follow-up interviews has potential to shed light on student learning. Thus, in order to explore patterns in gender dynamics in a small group of three participants in physics discourses, I collected data from multiple sources: (1) audio-/video-taped recordings of the selected small groups during class, (2) fieldnotes/student group, and (3) individual and focus group interviews. Data on multiple groups were collected during the first six weeks of one semester, but I analyzed data on one selected group and from one selected lesson in which students engaged in a verification lab. The audio and video recordings served as data sources for answering the first research question. These were supported by artifacts of student learning. Then, the focus group and individual interviews served as data sources for answering the second research question (See Table 1).

Table 1. Research questions and data sources

Research Question	Primary Data Sources	Secondary Data Sources
1	Audio-video tapes	Artifacts
2	Focus group interviews	Individual interviews

Audio/video recordings. I recorded all class sessions (lessons) for six consecutive weeks, which was the length of the entire verification labs section of the course (four weeks) and two weeks into the more theoretical/math routines part of the course. Since the study was exploratory, I was open to the possibility of focusing on the later part of the course as well. Because the class met twice each week for 3 hours each, this provided a total of 6 hours of audio-visual data per week on the group, yielding a minimum of 36 hours of audio-visual data across the weeks of data collection. Sessions of small group sense-making were recorded as students worked on tasks.

During sense-making units when I video and audio recorded participants in their small groups, I clamped the cameras on tripods that I placed close to the groups. The camera was positioned in such a way as to capture all members of a group. The audio recorders were placed near the base of each of the desktop computers which served as the work- station for each group. This strategic approach to positioning the equipment was intended to minimize data gathering getting in the way of participants' learning space.

Fieldnotes. Fieldnotes were written for each occasion of data collection session. Fieldnotes are descriptions of experienced or observed events, discourses, or social interactions. Fieldnotes are important because they allow the researcher to review, study and think about or think through such written descriptions time and time again (Emerson, Fretz, & Shaw, 2011). In addition, the fieldnotes facilitate efficient transcription of audio-visual data (which is typically time-consuming) (Kung, Kung, & Linder, 2005) by providing a ready clue to identifying timestamps of instances during discourses. Fieldnotes were also helpful in data analysis since "in making fieldnotes, one is not simply recording data but also analyzing" (Siverman & Marvasti, 2008, p. 199).

Artifacts. Classroom artifacts were another source of data. Patchen and Smithenry (2014) define artifacts as items or practices which are used for achieving specific objectives. In this sense, for my study, I recorded whiteboards which served the purpose of helping students visualize and share their perspectives with their peers during small group sense-making. In addition to artifacts as tools for sense-making, I also viewed artifacts as representations of learning (Radford, 2014).

Focus group/individual interviews. I conducted both individual and focus group interviews. Both of these were face-to-face and intended to further explore gender dynamics in small group sense-making by understanding what meanings participants attributed to the interactions. “Interviews are ways of listening to and gaining an understanding of people’s stories” (Bolderston, 2012, p. 68). Much of the interview data were gathered using the focus group approach (see appendix B for interview protocol) since group participation in interviews helped to elicit the participation of other interviewees, as they may be prompted to talk by their peer’s contributions. In other words, group members can nudge each other’s participation in the interview, “… and participants may form opinions after considering the views of others… tapping into this interpersonal dialogue can help identify common experience and shared concerns” (Clarke, 1999, p. 359).

The focus group interviews were conducted within a week of the conclusion of media data gathering on the class sessions (lessons). This is important in the sense that if interviews were scheduled to a later date long after the audio-visual data gathering or observation of the small group sessions, participants were likely to forget some of their experiences during discourses in their small groups. In addition, Bolderston (2012) emphasizes the importance of developing rapport with the participants. The interview was scheduled towards the concluding part of the course/data gathering session to avail me the needed time to build such rapport with my participants. A study room in one of the libraries of the university was chosen as the venue for the focus group interview because of its proximity to the SCALE-UP classroom.

Furthermore, since there is paucity of fine-grain size research on gender dynamics in small groups within SCALE-UP, there was some need for me to rely on my own previous preliminary exploratory work in the SCALE-UP context from 2016 to 2018. For these preliminary efforts (Akubo et al., 2018, 2019), classroom observations were conducted over the course of 4 consecutive weeks during a semester, and focus group as well as individual group interviews conducted not later than the 5th week. I developed interview questions over the course of a semester while carrying out those explorations of the SCALE-UP context. The interview questions were developed around gender dynamics in small groups. The questions were shared with experts (faculty and graduate students) in qualitative research in order to obtain feedback. After such feedback were received, revised versions of the interview questions were developed while incorporating the new inputs.

In order to develop individual questions for the interview protocols, I followed the guidance of Bolderston (2012) and Seidman (2006) who describe good interview questions as clear, fairly short, and conversational in tone, avoiding technical language or jargons, and open-ended in nature. These features elicit interviewees' presentation of their perspectives in their own words, tell their stories along multiple lines, with varying emphasis and feel unconstrained. In order to develop the overall flow of the interview, I adopted a funnel structure (Cheng, 2007) (see figure 5).

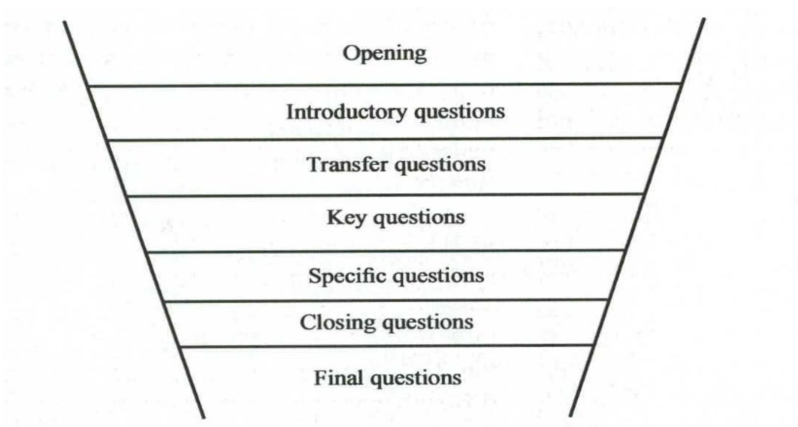


Figure 5. The funnel structure of focus group interview questions (adapted from Cheng, 2007)

The opening section of the interview was intended to start a talk session. The opening section of the interview was general in nature as questions, though relevant to the focus of the interview, are not so much at the core of the interview. The question for the opening session was:

(1) Have you taken a studio physics course before? If positive, how did you decide to choose a studio physics class for the Electricity and Magnetism course this semester?

Then, there was the introductory question. This is meant to start a conversation that borders on the purpose of the interview.

(2) What were your expectations coming into the Electricity and Magnetism studio physics course?

This question highlights the importance of prior experiences — as "students bring their own experiences and expectations into the classroom" (Gaffney & Gaffney, 2016, p. 1). Both the question for the opening session and the introductory question served the purpose of breaking the ice generally on conversation and specifically the interview.

Then, there was the transfer question. It was designed to gradually transition the participants to the heart of the focus group interview; the core of the key and specific questions.

(3) What do you think about presentation of small group work to the entire class in this studio physics course?

The key questions began inquiry into the core of the interview (i.e., data on gender dynamics in sense-making and participants' perspectives on those dynamics within the SCALE-UP classroom. There were two key questions in my interview protocol; questions 4 and 5 in the interview protocol.

(4) How did you take opportunities presented in your small group to contribute to making sense of the physics ideas and tasks you worked on in the class?

(5) How did people view their colleague(s)' contributions or roles during the labs and white board activities? (You can refer to your own experience in your group or your observation of another group).

Next in the funnel structure are the specific questions. The specific questions were intended to create opportunity for more data central to the study by building on responses to the key questions. There were two specific questions in my protocol; questions 6 and 7.

(6) In the third week of class, your groups were switched round. Flashing back at how you learned that week, what was different for each of you based on the switching of groups?

Shim and Kim (2018) draw attention to the importance of small group dynamics for how students understand their place in the science learning community of the classroom and position themselves in the science learning process. The second specific question targeted the importance of artifacts and gender dynamics in small group sense-making.

(7) What do you think mattered in how you or your peers made sense of physics ideas in your small group to learn in this course (e.g., the whiteboard, group members)? For example, how did the interaction between you and a male or female member of your group influence how you took part in making sense of the physics ideas?

Then, closing questions give participants one more chance to summarize their perspectives or thoughts. They also help the interviewer to elicit more information on the core of the interview, whereas the final questions end the interview session. They both form the concluding part of the interview. In my protocol, the focus group interview was concluded with one closing question and one final question. The closing, and final questions are numbers 8 and 9 respectively in the protocol.

(8) Were you to take a course in studio physics again, how would you suggest interactions need to go between the male and female members of your group in order to foster each member's participation in sense-making?

(9) Is there anything else you would have loved us to talk about, but we did not?

Individual interviews were conducted at opportune times, such as when students awaited the start of a class, given that they typically arrived some minutes before class start time. Other interviews were scheduled to a few minutes prior to the close of the class period, given that most students typically finished their work before the close of the class period (e.g., 15 minutes earlier). The individual interviews were opportunities for member-checking, and were scheduled to be not more than 48 hours after an identified class session in which a part, and event, or moment during that session was selected as promising for further exploration of the participant's experience. This is to ensure that the participant was still able to recall the experience.

In addition, the individual interviews were intended to check my preliminary interpretations of observed events or moments that suggested invitation to a closer look at the data. Such member-checking while data gathering was on-going was appropriate since qualitative research entails that the process of data gathering involves data analysis at the same time (Siverman & Marvasti, 2008). In addition, participants may not readily remember or recall such interesting moments afterwards if left until the focus group interview. The number and timing of the individual interviews depended on the willingness or positive disposition of my participants to speak with me regarding such moments which I wanted to inquire more about.

Data Analysis: Background to the Process

The unique identities and self-positioning of the participants had implications for data analysis. Kay's particular awareness of her agentic voice and determination to want to make her voice heard was important in how I coded data on her. For instance, in the light of Kay's intention to make her voice heard, I was interested in any hesitation on her part to want to speak or make her voice heard: I examined data in such instance or scenario that indicated any hinderance or constraint to following through with her desire to embody her agency, interpreting such data which suggested she was hesitant to speak as — negative gender interaction. Similarly, Isaac's awareness of gender equity also had implication for data analysis in the sense that data that contra-indicated this awareness suggested negative gender interaction. Finally, David's self-declaration as 'the pushy one' offered a backdrop against which I situated his discourses with the woman during small group sense-making.

Construction of transcripts. In order to analyze data on the selected small group, the audio and video data on the selected group's verification lab for data analysis were transcribed. The use of video and audio facilitated multiple access to episodes or moments of sense-making which may be missed with only one source (Siverman & Marvasti, 2008). My analysis of each episode required the construction of transcripts. In their work, Clark, Birkhead, Fernandez, and Egger (2017) provided a guiding protocol that is practically helpful since it offered step-by-step support in transcription. Their protocol required the person who does transcription to attend to and answer three questions: "How complete must the transcript be to accomplish the research process? How much detail is needed for analysis?" (Clark et al., p. 1754). The third question pertains to how the researcher will assure content accuracy. However, this last third question was not applicable to my method since I was focusing on the gender dynamics and not measuring students' physics content proficiency.

In order to create transcripts of my observation and interview data, I was guided by the first two of their three-question protocol-creation steps, answering the questions as follows. "Transcription is the process of creating a valid written record of an" (Graham, 2005) audio and video file. I determined that

- a complete transcript that corresponded to a turn of talk or an entire pedagogical episode needed not be verbatim, but my fieldnotes guided the transcription of audio and video tapes instead (Halcomb & Davidson, 2006).
- transcription included pauses, silences, utterances (e.g., ummm, ahhh), vocalizations (e.g., laughter), gestures, expressions, punctuations, as well as words. The goal of including these was to achieve a level of detail appropriate for in-depth discourse analysis (Silverman, 2011).

The episodes were numbered in order to allow for easy referencing. Using these transcripts of the verbal and non-verbal language of each participant, I organized the data for each episode in columns. The numbers for the episodes, time stamps, and data which formed the main focus of my analysis are found in the first, second and third columns respectively. The fourth column has memos to make sense of the data. The goal of this fourth column was to provide a rich description while coding the data. The fifth column includes codes specific to gender dynamics seen in the episode.

For data analysis, I coded for patterns of student talk and "unspoken aspects" of the pedagogical episodes (20 in all), and "ways in which gender is constructed within groups and made visible" (Kittleson & Wilson, 2014, p. 469) during the episodes. I developed a codebook based on ideas from other related literature (see Table 2). In analyzing my data, I proceeded episode-by-episode while including a description of the tasks around which the episodes were centered. The participants' self-declared gender identities offered grounds for a valid assumption that lay beneath my analysis of data in small group discourses (i.e., that gender dynamics plays a role in how students approach discourses). This is because these unique identities and self-positioning of the participants had implications for data analysis.

Data analysis of small group work. To answer question 1, I adopted 3 steps in the analysis of data on discourses in the small group. There were three stages of data analysis.

Stage 1 involved open coding for patterns of student participation in sense-making and noting salient gender interactions. In this first step, I examined the participants' contributions to knowledge-building in the small group as they worked on tasks in the form of a verification lab while noting salient gender interactions. In order to develop a codebook, I integrated the emerging codes with a priori codes from the literature on sense-making (Table 2). Then, the salient notes on gender interactions along with codes which emerged from the literature (Table 3) formed the raw materials for my development of a codebook on gender interaction (see Appendix H).

Table 2. Codes from review of literature on sense-making during small group work.

S/N	**Codes for analysis of Sense-making**	**Sources**
1	Explanation: There are levels of explanation (1) explicating definitions, facts (2) talk offers descriptions (e.g., of variations in a measurement or observations of phenomena (3) talk about how a phenomenon works, simple cause-effect relationships, correlations, (4) theoretical underpinnings for why a phenomenon happens	Kang, Windschitl, Stroupe, & Thompson, 2016, p. 15.
2	Procedural sense-making: following instructions in a step-by-step manner to accomplish/perform a task. It pertains to the mechanics of a task (e.g., how to set up or run an experiment)	Kittleson et al., 2004

Table 2 continued

S/N	Codes for analysis of Sense-making	Sources
3	*Negotiation* (of ideas/concepts): a form of collaborative interaction in which multiple participants actively contribute to the evolving idea or concept. Students take turns in multiple exchanges in order to come to a decision on science ideas.	Kittleson et al., 2004 Stroupe, 2014
4	Collaboration: "an active give-and-take of ideas between persons rather than one person passively learning from the other. Collaborative learning experiences are ones in which participants discover solutions and create knowledge together"	Damon, 1984, p. 334.

I chunked the data on discursive sessions (lessons) into 20 episodes, and tallied the turns of talk for each participant (Due, 2014) during each episode. Turns of talk here refer to the distinct or not-so-distinct segmentation of contributions to group sense-making such that a member talks, and one responds or cuts into the talk of another. My goal also involved exploring salient data. I paused the video every 5 minutes to write memos on their contributions within the group, noting salient quotes. The memos, artifacts, and salient quotes were helpful in identifying and coding episodes for patterns of participation and types of gender interactions in the small group.

Stage 2 entailed a priori/open coding of episodes for gender dynamics during discourses. In the second iteration of the coding process focused on gender dynamics, I used the codebook I developed (see Appendix H) based on codes emerging from open coding and a priori codes from my review of literature describing student verbal and non-verbal gender performance in small group science activities (Jovanic & King, 1998; Wiselmann, Dare, Ring-Whalen, & Roehrig, 2019). The categories which emerged from the open coding served as overarching codes. They are; positive active gender dynamics, negative active gender dynamics, subtle negative gender dynamics, and mixed gender dynamics.

Active positive gender dynamics were those characterized by clearly observable data on the following: A participant played a leadership role (such as leading peer conversations, setting up equipment) to complete a task, acknowledged peers' efforts or contributions, elaborating on a peer's explanation, resolving a critique against a peer's explanation, mindful of other's sense of belonging, elicited (and so inclusive) of other's participation. Also, participants were constructive and respectful when offering critique of others in the group. In addition, active positive gender dynamics for Kay entailed expression of her confidence through letting her voice be heard, thus exercising her agency, taking part in the practical handling of equipment and other tools.

On the contrary, active negative gender interactions (see appendix H for examples) in this study were those characterized by clearly observable data on hinderances to a participant's leadership role, disregard for a participants' sense of belonging, and biased positioning in relation to proficiency or competence. Finally, subtle gender dynamics are those characterized by not-so- clearly observable data such that the interactions are not obvious, that is, without deep reflection, they are not easily observable or noticeable (see appendix H for examples). In such interactions, a participant was hesitant to let her/his voice be heard, negotiating gender and physics identity (e.g., Kay blaming herself for not understanding, hedging a lot so to very much choose her words).

Mixed gender dynamics was another code. This refers to an episode where two of the same type or different types of gender dynamics occurred. For instance, an episode coded as characterized with mixed gender dynamics had two positive gender interactions, or two negative gender interactions, or one positive gender interaction and one negative (subtle or active) gender interaction. Often, mixed gender dynamics characterized episodes consisting of two discussion foci. A discussion focus centered discourses on a task, or an idea which anchored participants discourses as part of an episode.

In Table 3, I have drawn on the literature to present definitions of the a priori codes which were parts of my coding scheme for analysis of gender dynamics. These include discourse models (Danielsson, 2011), gender performance (Carlone, Johnson, & Scott, 2015), positioning (Martin, 2016), roles (Howe, 2014), and negotiation of gender and physics (Barton and Yang,

Table 3. Codes to analyze transcripts of students' perspectives on gender and discourse.

S/N	**Definition of Codes for Analysis of Gender Dynamics**	**Sources**
1	Discourse models: a way to describe how a student participates in a discursive session such as laboratory work a) 'practical physics student'— "someone focused on the execution of the experiment" (e.g., connecting stuff, setting things up, getting equipment/set up working, b) 'analytical physics student'— "someone focused on the physics reasoning" (e.g., application of theory, logic and mathematics, reading of instruction, report writing0	Danielsson, 2011 (p.219)
2	Gender performance: Markers of who one presents oneself to be, here in relation to traditional gender discourse. Prominent markers include minimizing one's differences, pleasing others, making oneself submissive or invisible, helping others	Carlone, Johnson, & Scott (2015)
3	Negotiation of physics and gender: This code has to do with the 'question' of how to be a physicist and be a girl at the same time in order to find a place in physics.	Barton and Yang, 2000; Carlone, 2004; Danielsson, 2012; Gonsalves, 2014
4	Positioning: This pertains to how one considers oneself as participating in a community/group or/and is considered by others as such (e.g., capable of explaining, providing answers, making things work, competent, recognizable)	Due, 2014; Gonsalves, 2014; Gotschel, 2014; Martin, 2016
5	Roles: Roles describe how individuals contribute to work in small groups. There are; (a) supportive roles; watching, listening, categorizing (b) dominant roles; controlling apparatus during practical activities. "contributing ideas, completing tasks, mediating group interaction, and remaining reticent, ... resonate clearly with the analysis of gender" (p. 112).	Howe, 2014
6	self-confidence: One's estimation of confidence in one's ability. It "comprises students' thoughts and feelings about their capability to succeed as learners in physics" (p. 1)	Nissen & Shemwell, 2016
7	Sense of belonging: An individual's feeling of being a valued, accepted, and legitimate member of the group— "reflects one's perceived fit within a group or entity"	Lewis, Stout, Pollock, Finkelstein & Ito, 2016, p. 2

2000; Carlone, 2004; Danielsson, 2012; Gonsalves, 2014). Specifically, sense of belonging (Lewis, Stout, Pollock, Finkelstein & Ito, 2016) are codes related to affect in the analysis of gender in my work here.

In my data analysis, I coded for self-confidence by adapting the conceptualization of self-efficacy — "students' thoughts, [performance of], and feelings about their — capability to succeed as learners in physics" (Nissen & Shemwell, 2016, p. 1). Self-efficacy is often quantitatively measured but here I focused on the describable self-confidence of a participant as a qualitative construct. For example, in expressing her determination for equitable participation, Kay revealed her self-confidence as follows:

> I would like come into this class and am like; am' going to fight, am going to literarily yell my ideas until they listen to me, so am going to do it. And not like, you (referring to herself) can just write everything down (take down notes for the group), then the males are going to do the experiment (Focus group interview 4/13/2019).

For the research documented here, students' experiences revealed their sense of belonging. As they participated in small group work; I coded their experiences around gender dynamics during physics discourses.

In Stage 3 of data analysis, I identified and described patterns of gender dynamics across the 20 episodes (cross-episode analysis), and obtained aggregates of participants' turns of talk across episodes. The goal was to explore the data for overarching patterns of gender interactions across multiple episodes. This cross-episodes data analysis worked as an organizing principle consisting of aggregates of — patterns of gender dynamics across turns of talk, time segments, total turns of talk, and overarching tasks. I constructed illustrations of the patterns.

How did I decide on which episode to choose? This is where the cross-episodes analysis was helpful. I first chunked the entire verification Lab duration into 4-time segments of 30 mins each (1^{st} 30 mins, 2^{nd} 30 mins, 3^{rd} 30 mins, & 4^{th} 30 mins) to allow for a spread of the exploration across representative sections of the data. Then, I looked across 20 episodes for emerging patterns of gender dynamics keeping track of the turns of talk. After this step, I aggregated the episodes, patterns of gender dynamics, turns of talk by each participant/total turns of talk, and across overarching tasks. I chose the 20 episodes because they constituted three-quarter of the entire data on the particular verification lab I chose. Table four is an illustration of the processes and stages of data analysis:

Table 4: Overview of the data analysis process

S/N	**Process in Data Analysis Protocol: Stage 1**
1a	Construction of transcripts from observation data (audio/video recordings)
1b	Development of a priori codebook for sense-making
1c	Open coding for patterns of participation in sense-making, and noting salient gender interactions
1d	Development of a codebook for gender dynamics
	Process in Data Analysis Protocol: Stage 2
2	A priori/open coding of episodes for gender dynamics during discourses
3	**Process in Data Analysis Protocol: Stage 3**
3a	Identification and description of patterns of gender dynamics across multiple episodes (cross-episode analysis)
3b	Illustration of emerging patterns of gender dynamics (e.g., Tables, Maps)
3c	Identification of emerging themes in cross-episode analysis

In the following sub-section, I present background to the episodes. Episodes are analogous to Manz and Suárez's (2018) idea of pedagogical episodes in the sense that they are instances of [student interactions] during which [students] "describe issues, or raise questions about [learning] that are accompanied by some elaboration of reasons, explanations, or justifications" (Horn, 2005, p. 215). For my work, an episode centered on or is bound by a single task, or multiple foci from a single task.

Data from student interviews. This is the stage 4 of data analysis**.** In order to explore the meanings participants' attributed to the discourses, and various components of the discursive interactions such as roles (theirs and the TA's), I was guided by some constructs to explore the transcripts of the interview. The goal of this guided exploration was to search for dominant themes emerging from the data. The guiding constructs for my exploration for dominant themes included meanings centering on — distribution of opportunity (roles) (Francis, Archer, Moote, Dewitt, MacLeod, & Yeomans, 2017), physics/science identity (Carlone, 2004; Lock and Hazari, 2016; Pettersson, 2011), and learning. These meanings were important because they had potential to offer insight into

- the participants' framing of the tasks and interactions during the discursive episodes — epistemological framing (Hutchinson & Hammer, 2009), and
- how framing may be connected with gender dynamics across episodes.

Distribution of *opportunity (*Francis et al., 2017) pertains to the questions: Who takes up the discursive space, manipulates what tool to play what role? Identity is the kind of person one seeks to enact in the here and now (Carlone, 2006; Lock & Hazari, 2016; Pettersson, 2011). *and Power* (Guttiere, 2009) is about control and pre-eminence of place.

In a follow-up iteration of data analysis at this stage, I focused on both the observation and interview data for participants' framing of discursive interactions, tasks, tools (e.g., white boards), the labs in general, the TA's roles, and learning. I specifically looked deeper into transcripts of all 20 episodes on the observation data with an eye to the distinctive meanings attributed by the participants, in terms of the way in which they revealed each participant's unique framing of discourses during tasks as well as the epistemological frames that were shared by all participants. This was important to address both research questions and strengthen the trustworthiness and rigor of my research since it involved triangulation of data across multiple data sources.

Trustworthiness and Rigor

Researchers evaluate or judge the quality of a research work using different criteria based on different paradigms of research (Patton, 2002). Trustworthiness is often used to describe the quality of qualitative research. Guba (1981), Lincoln and Guba (1985) describe criteria for trustworthiness of research that I utilized to attend to the rigor of the research reported here. They include:

- credibility (in preference to internal validity),
- transferability (in preference to external validity/generalizability)
- confirmability (in preference to objectivity)
- dependability (in preference to reliability).

How are these criteria of trustworthiness to be achieved in qualitative research? Guba and Lincoln established the following techniques: Triangulation, thick descriptions, reflexivity, and member checking. In addition, there is also analysis of contradictory or negative case or cases.

Triangulation. I gathered data from multiple data sources (audio, video, artifacts, interviews, fieldnotes). These multiple data sources contributed to the trustworthiness of my research through *triangulation* of data (Creswell, 2000; Hammesley & Atkinson, 1995; Guba & Lincoln, 1985, Patton, 1990). Also, I checked for consistency or otherwise of findings across primary and secondary data sources.

Thick descriptions. In addition to triangulation, multiple data sources were important for achieving rich or thick descriptions of patterns of gender dynamics during sense-making and participants' perspectives. Thick description is important for in-depth insight into the topic to produce context-relevant findings.

In order to achieve thick description in my research, I used fieldnotes, memos, and detailed descriptions of the selected participants in the small group, the studio physics course as a context, and the particular verification lab. Another way in which my research is trustworthy is the rendering in detail of my data analysis process as described in the data analysis section (e.g., stepwise or piece by piece rendering of the coding process).

Member-checking and analysis of negative cases. Individual interviews offered opportunity for member-checking. This process of member checking entails that I inquired from my participants, their perspectives on my interpretation of their interactions during sense-making in the small group. That is, I shared with the participants in my research, my interpretation of moments as parts of episodes or entire episodes in which I explored gender dynamics.

Lincoln and Guba (1985) called for intentional search for negative cases or cases that are contradictory to the findings. This is another way to achieve credibility in a qualitative research. In my research, I searched for patterns that were misaligned with predominant patterns in my findings.

Reflexivity. My three-year engagement with the particular SCALE-UP site means familiarity with the context. This familiarity required that I was cautious of any possible biases. Reflexivity involves the need for a researcher to be cautious, aware, and disclose or report "any personal and professional information that may affect data collection, analysis, and interpretation" (Patton, 2002, p. 566). Although, I have conducted preliminary studies within the context for about three years, I was never an employee of the physics department within which this site is nested. Also, my familiarity with the context did not hinder the credibility of my work because, although I am deeply interested in exploring student-centered pedagogies, I am very open to understanding such pedagogies, and in this way learn new information. My years of involvement in this setting combined with my drive to understand how this context operates allowed me to maintain a middle ground in the research process, so I am not — "… becoming too involved, which can cloud judgment, and remaining too distant, which can reduce understanding" (Patton, 2002, p. 50).

My Positionality

My positionality — who I am as a researcher and my awareness of the possible biases and interests I bring to my research is important to acknowledge so as to ensure the trustworthiness of my research here. Specifically, my position as an African man is important to consider. However, there are multiple ways to be an African man. In this positionality statement, it is important to highlight the human, ethnic, and spiritual or religious and professional layers of my identity. These layers form a whole in my self-reflection of who I am — an Igala black man by ethnicity, a catholic priest by calling, and a budding science education researcher/practitioner by career. My calling as a priest anchors my belief in the dignity of every human being, regardless of their identities such as biological sexes (natural or otherwise for therapeutic/other reasons), race, and class as wells as gender identities as societal and cultural expressions which build on biological sexes. This calling also shapes my perspective on equity for every human being and reinforces my career as a science educationist and researcher.

My perspective on human dignity and my acknowledgement of the importance of my career in reinforcing that perspective motivates me to focus on gender equity in this research. For a long time now, I have been pondering how I might support other human beings who do not have equitable access to means that impact how the human dignity is respected and preserved. For example, in the context of my research, I see equitable opportunity for women to participate in the field of physics and its economic (e.g., STEM jobs), and social (status) implications as capable of fostering the respect and preservation of their dignity as humans.

I grew up as the 5^{th} child in a middle-class family of 9 children (6 men and 3 women). Though I am more endeared to my mother, I experienced the immense love and influence of both parents. My mother once told the story of how she earnestly prayed to have a girl-child, having given birth to four boys at that time. This yearning of hers was unlike most Igala women who desire male children because that means your place in the matrimonial home is assured. She told me after my ordination as a priest that she had earnestly prayed to God in her heart that if she gave birth to a girl-child, she will still pray that God have one of her children be a priest to serve Him.

Vocation or calling to the catholic priesthood benefits a lot from the family as the nursery from which it is first nurtured. Preparation for the priesthood is anchored on four dimensions. These are the human, spiritual, intellectual, pastoral/apostolic dimensions of formation (John Paul II, 1992). These dimensions have played a lot of role in shaping my perspectives on several issues. For the purpose of this positionality statement, I highlight my perspective on the dignity of the human being — every human being has got God-given and inalienable rights to life, self-actualization, freedom of worship, freedom of thought etc. Among others, I consider faith and science as one opportune sphere where freedom of thought is exercised. These two spheres are not opposed, rather there is a lot to benefit both spheres through their collaboration. I consider my own experience as a priest and a scholar as an ongoing collaboration between both spheres.

Though as one from a Christian family, I desire always to cherish my family's faith in God, the specific instance of my mother's story of her faith exercise is very important as a moment that grounds and motivates my awareness and commitment to the dignity of every human being. One way to pursue this commitment is through research that is centered on gender equity because every human being has right to equitable access and fair experience in an educational context (physics in this case). So, my awareness of my mother's exercise of her faith as specifically narrated in her story was a defining moment in a focus to operate my awareness in a bid to more earnestly commit myself to gender equity. In a traditional society of the Igala ethnic group (East of the Middle-belt Region of Nigeria) as well as among several other ethnic nationalities across Nigeria where the girl-child was not to pursue western education, my parents believed in the power of education for every child — boy or girl. In a country where education still remains 'cash-and-carry' since there are hardly scholarships for those who are not politically influential, mom and dad gave their last penny to ensure each child could pursue a college education (at least). So, my natal family was influential in my awareness and awakening for gender equity.

The traditional Igala cultural society considers the girl-child as set apart for marriage and taking care of the home. Even though this cultural stereotype is fast giving way to more equitable perspectives on the girl-child, there is still some long way ahead. However, the shift is more for those educated in formal settings (attended college) than for those educated in the Igala traditional setting (did not go to college) but learned a cultural trade (e.g., local fabric making, culinary skills in local delicacies) through apprenticeship in the cultural settings. Within this culture, many people still judge the value they place on perspectives or contributions to the society based on the gender identity of the author. For example, many Igala men often and easily value the political perspectives of an Igala woman to be lower than that of a man. This cultural bias attributable to men in most cases, is even more worrisome given that in the Igala political civilization and history, the kingdom's military prowess and political survival has been theorized to be connected to the courageous supreme sacrifice of a princess of the Igala kingdom. Her name is Inikpi (also known as referred to as the beloved of Papa). Where is the social and cultural justification for gender inequity in the Igala culture and tradition? This is an interesting question for sociologists and experts in gender studies.

Though gender equity in the Igala culture and tradition is not the focus of my research here, it has certainly contributed to the motivation for my research. For example, I attended a conference of the American Association of Physics teachers in 2018, and was surprised to listen to a scholar who, to justify the gender disparity in physics, buttressed her argument with biological differences between the brains of women and men. I was never convinced by her argument that the brains of men are 'wired' differently to the effect that men outperform women in physics. Though I did not know why she held that view, I realized that many factors shape perspectives that scholars hold. It may be politics, religion, gender self-identity etc. I began to think more about what shapes my own perspectives such as the kind of questions that I am passionate about. I have come to recognize some multiple dimensions that intersect to shape my research interests. These are my faith and Igala cultural experiences in my own family, my calling as a priest, and my career goals. My career goals are to promote equity and social justice in STEM education.

This cultural awareness motivates me to contribute to gender equity in science education, and so challenge the inequity in the larger culture and society, with inequity in education as its consequence. My research work here is driven by a commitment to contribute to efforts towards dismantling the gendering of educational opportunities in physics, science education, and in society at large. So, my subjectivities are — great experiences in my family of birth, my desire to challenge my own social and cultural affinities in Nigeria where certain traditions and practices perpetuate disparity in access to political power, fairness in access to/distribution of economic opportunities. Finally, I want to make the most good use of the equity-reinforcing influence of my vocation as a priest. Given these subjectivities, I need to be aware of what may be one of my biases — to want to "prove" a point.

I am definitely very critical of the gender biases that challenge equitable representation of women in physics as wells as in the Igala culture and tradition. However, I do share in the biases of physics as a field of human endeavor in which I participate, the Igala culture of which I am a part, and the faith-community to which I belong. So, I come to this research knowing that I do not have a total understanding of gender inequity which is an implication of my exploration. This is because my own subjectivities mean that I only have a partial grasp of this ‘phenomenon’. Thus, I am open to learning from and through the experiences of those who are directly affected. This is the reason I narrow in on the experience of the woman participant in the group. In their words, Barton and Edna (2019) beautifully convey the importance of learning from the experience of those who are directly affected by the ‘phenomenon’ we [I] seek to explore in research — women. The experiences of women will help me to “more critically examine how [they] are positioned ...in [physics] both through the socio-cultural and institutional structures and in local practice” (p. 625) — a small group within the classroom.

Possible Limitations and Resolutions

This is a qualitative study in which my close observations of a small number of participants are intended to yield rich descriptions of gender dynamics during discourses in an undergraduate level physics course. Fine-grained detail is essential for generating rich descriptions. The purpose of this work is not to generalize across contexts or even within the context but to explore a single case (small group) for gender dynamics in order to understand equity in the small group, the meanings students attribute to the interactions, tasks, discourses, roles, and by implication how they frame the discourses and associated aspects of the discourses.

It is important to note that the woman (Kay) was the only participant with physics as the primary major, the two men had biochemistry and computer science as majors. Research suggests that even in similar fields such as physics, engineering, and related fields, students differ in status and comparative feelings (e.g., of shame) (Nix & Perez-Felkner, 2019). In my analysis of data, this research did not consider the effect of participants' majors(s) on gender dynamics but documents any references or allusions to the importance of major by any of the participants.

Also, in my analysis of audio and video data, findings are not intended to be framed or considered as claims on what women versus men do. Rather, the strength of my findings is designed to be anchored in the discourse analysis and many triangulated points of observation within the case study. Participant reactivity to audio-visual equipment could have been one potential challenge to my work. However, my exploratory work in this same context gave me a strategy for resolving the potential challenge — I positioned the equipment in locations such that the data collection process did not get in the way of the participants' work. In order to mitigate the situation where participants were motivated to want to appear to be sense-making or acting to the media, I was discrete, allowing equipment to sit at locations and not be carried about. Furthermore, my experience within this same context suggests that students soon became unmindful of the audio tapes and video camera. They often said they had forgotten that they were being audio/video-recorded. I argue that it was unlikely for a student to merely act out sense-making over the course of such a relatively long period of time (6 weeks) for the entire duration of data collection, and 3 hours for a lesson session. Another limitation of this study which I acknowledge is that I only interacted with the participants in the lab space, and deeply observed them there to gather the audio and video data. I was not present for other discourses they may be engaged with outside of the classroom – in the hallway, in other classes, in social spaces, in major and STEM clubs.

CHAPTER 4

FINDINGS

In this chapter, I present findings from my analysis of data on discourses by the three participants (Kay, Isaac, and David) organized around the two research questions:

1) What patterns of gender dynamics centered around the woman's participation emerge within a heterogenous small group in a student-centered/reform-oriented approach to physics instruction?
2) What meanings do the small group participants assign to these dynamics?

For this exploratory research, I employed a qualitative single case study design analyzed data on one verification lab (one lesson) transcripts of which was divided into 20 episodes of discourses. I chose to study interactions in this specific verification lab on circuits over other possibilities because it offered participants opportunities for multiple forms of interaction, such as talk, gestures, set up and/or manipulation of tools. Since this research was designed as an exploratory study, the analysis of the varied forms of interactions that occurred in the 20 episodes from this verification lab offer both rich methodological and thematic insights into gender dynamics within the SCALE-UP context.

Episodes in this work are instances of [student interactions] during which [students] "describe issues, or raise questions about [learning] that are accompanied by some elaboration of reasons, explanations, or justifications" (Horn, 2005, p. 215). I analyzed each of these 20 episodes, then moved on to cross-episodes analysis. My analysis across-episodes involved mapping aggregates of — patterns of gender dynamics across time segments, overarching tasks and turns of talk by the participants.

General Description of Students' Interactions

Before offering the results of this cross-episodes analysis, I will describe the group's sitting arrangement, general picture of the classroom in relation to their work in the small group, the tasks, a map of the gender patterns across time segments and tasks.

Kay, Isaac, and David worked to accomplish their tasks by participating in multiple discourses (verbal and non-verbal ways e.g., gestures, handling of tools, going to the supply location within the class to obtain equipment, lab supplies, and tools such as the whiteboard). At their work-station, Kay sat between Isaac (to her right), and David (to her left) as they worked on the tasks. Their interactions were such that all three were not continuously actively engage in verbal or non-verbal discourses. Rather, at times, a member did not participate actively but instead engaged in off-task activities such as checking his or her phone, resting head on the work-station table. In other words, each student came in and out of active participation in discourses at times during the laboratory. From afar, it would appear that the interactions were totally supportive, productive, and positive. However, closer observation revealed the varied nature of participants' interactions. For example, Kay and Isaac worked more frequently than David. The group seemed to get through the material at different speeds depending on the tasks or sections of the same task. In addition, number of turns of talk were more for one participant than others, and varied across multiple tasks.

Each of the participants highlighted their reason for enrolling in the class, mentioning and explaining how they selected the studio physics option though there was the traditional lecture version of the same course in the department. For Kay (a physics and education major), her enrollment in the studio model was influenced by multiple factors. These were a) guidance from another person (not named), b) her education major, c) her familiarity with the instructional approach used in studio physics, d) preparation for her own teaching career. During the focus group interview (4/23/19), she stated:

> I was told to choose studio. I am in the education department. The pedagogy that we use is a lot like it. So, I might as well be in a student-centered class to experience what it is like so that I might teach a lot like it. So, I am in the Teach [program], and when I will be teaching, this is how I will be teaching.

Isaac (a biochemistry major) made reference to his professor as having advised him to choose the studio model. He also noted that the studio model was similar to how his advanced placement physics classes were taught in his high school. So, the studio model was already a familiar territory.

> I was kind of talked into studio physics by my professor. I think my High School Physics, like AP Physics 1 and 2 education was very similar to the way we run things. Em (.) So, I think it won't be a change of base for me to take studio physics.

According to David (a computer science major), his evaluation of the course prior to enrolling in it made him conclude the studio format had something unique. However, he did not specifically indicate what that uniqueness was. He then stated that he realized it was complex as well: “This studio, I thought there was something in it, but it is more complex (laughs). I am not going to lie” (focus group interview 4/23/19).

Categories of Gender Dynamics

Three codes for describing the types of gender interactions seen in the data were developed in the open coding process. They include active positive gender interaction, active negative gender interaction, and subtle negative gender interaction. There was no evidence in the data that suggested subtle positive gender interaction, although conceptually one might expect such a code. In this section I’ll describe instances of each of these codes.

Active positive gender dynamics. These were interactions characterized by clearly observable data indicated in the following ways of participating in discourses; leading peer conversations resulting in completing a task, building consensus in the face of epistemic differences, setting up of equipment, acknowledging peers' efforts or contributions, elaborating on a peer's explanation, resolving a critique against a peer's explanation, mindful of other's sense of belonging being using inclusive language (e.g., our, we,) elicited (and so inclusive) of other's voice to participate in the heterogenous small group. Other indicators of active positive interaction include —constructively and respectfully offering critique of other's ideas (where need be). In addition, active positive gender interaction involved a participant's feeling of confidence in letting her voice be heard. This was observed in exercise of his or her agency in multiple ways such as taking part in the practical handling of equipment and other tools. The following data offers an example of active positive gender dynamics: Kay elicited David's participation.

143 **David**: Okay. What are we, what are we talking about? (shaking his head, looking at Kay) I am sorry.
144 **Isaac:** ...so for...
145 **Kay**: We are comparing 5 and 1.
146 **David:** 1 (referring to circuit #1) would have less resistance. Adding parallels to, like... if it were... I don't know... (trying to explain, attempted to draw). Do these bulbs provide the same amount of resistance as this bulb (pointing to the circuit diagrams) ...?
147 **Kay:** Yes.
148 **David**: And this (referring to a branch of the circuit he was attempting to explain) provide some amount of resistance.
149 **Isaac:** Yea, yea, it's all about resistance.
150 **David**: Parallel is less (Kay and Isaac looking at David). And adding some, there is always a difference.
151 **Kay**: Yea, yea.

Active negative gender dynamics. These refers to interactions characterized by clearly observable data on hinderances by one or multiple peers to another peer's participation. Indicators of this dynamics refusal to engage in discursive interactions centered on the tasks, dismissing a peer's contribution, refusing to share tools, ignoring or refusing to acknowledge a peer's contribution to the group work, and negative affect such as shouting (see the following data):

The discourse here suggests David's orchestration of active negative gender dynamics

341 **Kay:** And then it splits again and goes right.
342 **David:** Okay (Kay was still trying to explain when David took the pen from her hand, cutting off her explanation to present his, and she let him. He presented his alternative circuit models and said)— these are all the same
343 **Kay**: Yea (attempting a turn of talk but David would not give audience)
344 **Kay**: Okay, okay, listen, let me finish, maybe it will make sense. One way to think of this is that It hits one and then splits like this (drawing on a paper). Like when we look at this one, we can see the flow come to a junction and then it hits one junction and then it splits (demonstrating with her hands.
345 **David**: (Giggling), I understand that. You are telling me things that I already know. I get that. (shaking his head).
346 **Kay**: Then, explain to me.
347 **David:** No, (shaking his head and hands), not this
348 **Kay:** All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: "no, no, no" (frustrated and gently banged her hands on her book in front of her).
349 **David:** It's okay, I didn't ask you to stop.

Subtle negative gender dynamics. These are interactions characterized by not-so-clearly observable data such that the interactions were not obvious; that is, without deep reflection, they were not easily observable or noticeable. In such interactions, a participant was hesitant to let her voice or his voice be heard contrary to any determination to let her/his voice be heard and negotiated her/his gender and physics identity. The data below highlight subtle gender dynamics for which I provide explanation in detail in the next section.

1 **Isaac:** I don't know what he is trying to ask there but I guess like, they seem like the same definition (turning his eye contact/gaze to Kay). (Isaac was referring to items 1 & 2 in figure 2, (see Appendix ...).
2 **Kay:** I think they just want us to compare em (.) this with this one (pointing to items 1 and 2 on the monitor (as in figure 1 above).
3 **Isaac:** (after a pause) Okay ... well, I mean....

4 **David**: There is only one single common junction because there is only one wire (laughing while still looking at the screen). I don't know (Kay looked on at the lab guide on the screen- maybe pondering David's explanation).
5 **Isaac:** Yea, exactly (Isaac writing in the note).

Mixed gender dynamics. These are interactions in which two of the different categories of gender dynamics occurred. For instance, an episode coded as mixed gender dynamics was that in which there was a positive gender interaction and a negative (subtle or active) gender interaction. The interaction in the data below involves Kay's elicitation (6, 8) of the men's participation (active positive gender dynamics) but she was often mindful not to be obviously critical (13, 16) of the men's perspectives (subtle negative gender dynamics).

6 **Kay:** Is there...are there any bulb(s) connected in series or in parallel or independent of another bulb?
7 **Isaac:** Okay, so... if we look at 1, A & B are parallel with C.
8 **David & Kay**: Yea
9 **Isaac:** Specifically, A and B are not each parallel with C, just that A & B as a system is parallel with C" (looking in the direction of the other two. Again, the two affirmed)
10 **David**: And A is in series with B. But what does...?
11 **Isaac:** Yea, exactly (Isaac writing in the note).
12 **David**: And A is in series with B. But what does...?
13 **Kay:** But see, it looks like this one is okay, (cutting in and pointing on the screen) because it says in series or in parallel. A is in series with B, and the system is in parallel with C. So, I think that one... (expressing her choice from the given options in a multiple choice). And is asking if there is any that are connected.
14 **David**: Then, I will say (cutting in) B & C individually (gesturing with his hands apart) are not connected in parallel (looking at Kay). Only A & B are parallel.
15 **Isaac:** Yea, exactly (Isaac writing in the note).
16 **Kay**: So, are you saying that the answer to this question (pointing to the screen) is A? Ah, is 1?) (Looking toward Isaac who had his eyes on the monitor looking at the exercise they were working on).
17 **David**: I think the answer is false (cutting in).

Using these categories of codes, I analyzed the discourses that occurred across the 20 episodes. In order to answer my first research question, I constructed a layout of episodes, patterns of gender interaction across each episode, turns of talk by participants and the overarching tasks (see Table 5). Nine of the active positive gender interactions occurred in mixed episodes while 7 of the subtle negative gender interactions occurred in a mixed episode. This means that all but 2 of the episodes did have a positive gender interaction associated with a subtle negative gender interaction. It is important to note that even though there was a greater aggregate number of active positive gender interactions than subtle negative gender interactions, there is a greater total number of negative gender interactions (i.e., 4 active and 11 subtle—15 in all) compared to active positive gender interactions (14 in all).

It is important to note that since there were similarities in the tasks they worked on, I categorized them into overarching tasks. The four overarching tasks are as follows:

- Making sense of circuit configurations: This task type involved defining, identifying, determining, categorizing, drawing circuit networks. Students also reviewed circuit from previous labs and cross-checked their analysis with the TA,
- Building and analyzing more complex circuits: This task category required students to make predictions about bulbs in an illustrated circuit, build the actual circuits, discuss conservation of current, and analyzing circuits with multiple branches.
- Determining equivalent circuits,
- Predicting brightness of bulb based on switch type, analyzing current based on nodes in the circuit and measuring current in the circuit.

I have presented these overarching tasks across episodes within the same time segment (Table 5). Although the flow of gender dynamics starts out positive, there was more negative early on, until it really hits a low point around episode 15—with strong negative gender dynamics—which then shifts to a more positive outcome. I also constructed a map of the occurrences of the different categories of gender interactions across the overarching tasks (see Figure 6). This mapping of categories of gender interactions illustrates the overlapping of the occurrences of those categories across tasks.

Table 5: Episodes, categories of gender dynamics, turns of talk, & overarching tasks

<table>
<tr><th rowspan="2">Episode</th><th rowspan="2">Patterns of Gender Dynamics</th><th colspan="4">Turns of Talk by Participants (important for the patterns)</th><th rowspan="2">Overarching Tasks Across Multiple Episodes</th></tr>
<tr><th>Kay</th><th>David</th><th>Isaac</th><th>TA</th></tr>
<tr><td rowspan="2">1 Mixed</td><td>Active Positive</td><td colspan="2">non-verbal enactment</td><td>2</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Subtle Negative</td><td colspan="2">non-verbal enactment</td><td>2</td></tr>
<tr><td>2</td><td>Active Positive</td><td>7</td><td>10</td><td>2</td><td>6</td><td rowspan="11">Defining, identifying, determining, categorizing, drawing circuit networks
(1st 30 Minutes)</td></tr>
<tr><td>3</td><td>Subtle Negative</td><td>6</td><td>5</td><td>1</td><td></td></tr>
<tr><td>4</td><td>Active Negative</td><td>3</td><td>3</td><td>3</td><td></td></tr>
<tr><td>5</td><td>Subtle Negative</td><td>4</td><td>6</td><td>5</td><td></td></tr>
<tr><td>6 Mixed</td><td>Active Positive
Subtle Negative</td><td>5</td><td>8</td><td>1</td><td>5</td></tr>
<tr><td>7</td><td>Subtle Negative</td><td>9</td><td>6</td><td>8</td><td></td></tr>
<tr><td>8 (F1)</td><td>Active Positive</td><td>6</td><td>0</td><td>8</td><td></td></tr>
<tr><td>8 (F2)</td><td>Active Positive</td><td>6</td><td>4</td><td>6</td><td></td></tr>
<tr><td>9</td><td>Subtle Negative</td><td>5</td><td>2</td><td>4</td><td></td></tr>
<tr><td>10</td><td>Active Positive</td><td>4</td><td>0</td><td>3</td><td></td></tr>
<tr><td>11</td><td>Active Negative</td><td>2</td><td>8</td><td>1</td><td>9</td></tr>
<tr><td>12 Mixed</td><td>Active Positive
Subtle Negative</td><td>9</td><td>8</td><td>9</td><td></td><td rowspan="4">Building circuits, analyzing bulbs in the branches, discussing conservation of current.
(2nd 30 Minutes)</td></tr>
<tr><td>13</td><td>Active Positive</td><td>7</td><td>9</td><td>7</td><td></td></tr>
<tr><td>14 (F1)</td><td>Active Positive</td><td>10</td><td>6</td><td>6</td><td></td></tr>
<tr><td>14 (F2)</td><td>Subtle Negative</td><td>9</td><td>6</td><td>6</td><td></td></tr>
<tr><td>15 (F1)</td><td>Active Negative</td><td>7</td><td>10</td><td>3</td><td></td><td rowspan="4">Determining Equivalent Circuits.
(3rd 30 Minutes)</td></tr>
<tr><td>15 (F2)</td><td>Active Negative</td><td>15</td><td>10</td><td>11</td><td></td></tr>
<tr><td>16 (F1)</td><td>Active Positive</td><td>7</td><td>9</td><td>11</td><td>2</td></tr>
<tr><td>16 (F2)</td><td>Subtle Negative</td><td>12</td><td>10</td><td>12</td><td>4</td></tr>
<tr><td>17</td><td>Active Positive</td><td>11</td><td>6</td><td>7</td><td></td><td rowspan="5">Predicting brightness of bulb based on switch type & measuring current
(4th 30 Minutes)</td></tr>
<tr><td>18</td><td>Active Positive</td><td>10</td><td>5</td><td>9</td><td></td></tr>
<tr><td>19</td><td>Active Positive</td><td>7</td><td>8</td><td>8</td><td></td></tr>
<tr><td>20 (F1)</td><td>Subtle Negative</td><td>13</td><td>12</td><td>4</td><td></td></tr>
<tr><td>20 (F2)</td><td>Active Positive</td><td>3</td><td>4</td><td>5</td><td>9</td></tr>
</table>

*F stands for discussion focus.

The tasks across time segments in Figure 6 are shown on the horizontal axis while the overlapping gender dynamics are shown on the vertical axis.

Table 6: Episodes, time segments and overarching tasks

Episodes	Time Frame	Overarching Tasks
1-11	1st 30 mins	Defining, identifying, determining, categorizing, drawing circuit networks
12-14	2nd 30 mins	Building circuits, analyzing bulbs in the branches, discussing conservation of current
15 -16	3rd 30 mins	Determining Equivalent Circuits
17-20	4th 30 mins	Predicting brightness of bulb based on switch type & measuring current

The location of the gender dynamics is not the focus of the map, but the goal is to illustrate the overlapping nature of the gender dynamics across tasks and time segments.

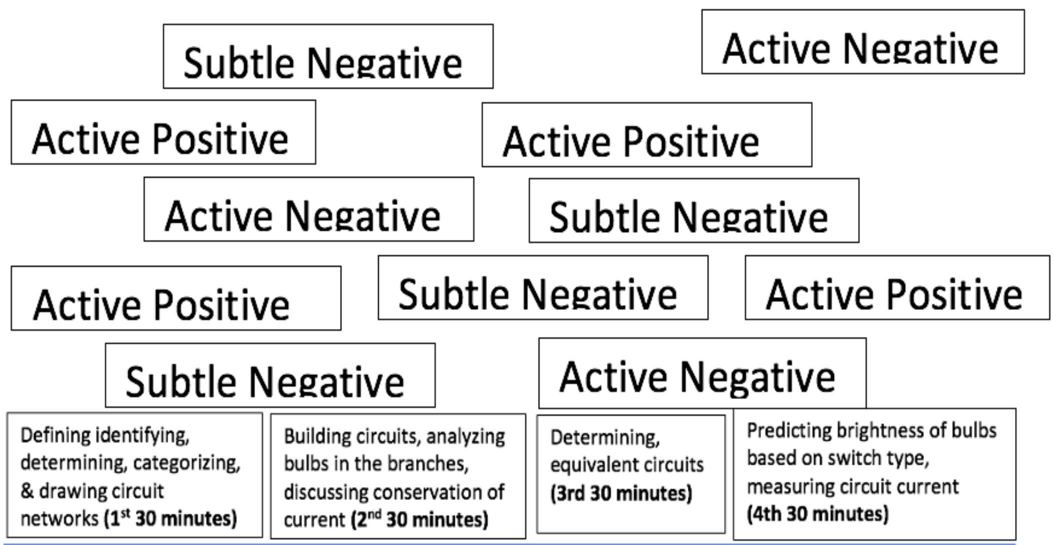


Figure 6: Illustration of overlapping patterns of gender dynamics across tasks and time segments**.**

Research Question 1: Gender Dynamics in the Small Group

Tables 5 and 6 and the map in Figure 6 were helpful for exploring patterns of interactions across episodes. I drew on these illustrations to highlight findings on patterns of gender dynamics across the episodes. Although the patterns of gender interaction across tasks or the influence of tasks on patterns of gender interactions was not the focus of this research, it is important to note that there was a spread of diverse gender interactions across tasks. The occurrence of multiple types of gender interaction (to be discussed in the next section) across the tasks suggest that the task in themselves (as designed) did not determine whether or not a given gender pattern occurred across the different time segments. Five themes emerged from the cross-case analysis. These are:

1) Kay orchestrated active positive gender dynamics.

2) The TA effectively supported active positive gender dynamics.

3) The TA did not alleviate negative gender interactions.

4) Subtle negative and active positive gender dynamics were associated in episodes, and

5) The men were asymmetrically involved with both positive and negative dynamics.

This section will be structured around the presentation of each of these emerging themes. For each theme, presentation of these findings will include the context and task for the episode, salient data, patterns of participation, and the category of gender dynamics suggested by the data.

Theme 1: Kay orchestrated active positive gender dynamics. Table 7 shows the aggregate number of turns of talk for each participant across each episode coded as active positive gender dynamics. Aggregates of turns of talk by each participant revealed that Kay took the most number of turns of talk in these episodes This is one indication of her agentic voice to orchestrate positive interactions. Her participation was targeted at actively fostering a positive interaction in the group. She had high self-confidence and awareness of the importance of her agentic voice for equitable participation in knowledge-construction within the group.

Table 7: Participants turns of talk across active positive dynamics episodes

Episodes	Participant's Aggregate Turns of Talk			
	Kay	David	Isaac	TA
2	7	10	2	6
6	5	8	1	5
8	12	4	14	
10	4	0	3	
12	9	8	9	
13	7	9	7	
14 (F1)	10	6	6	
16 (F1)	7	9	11	2

Table 7 Continued

Episodes	Participant's Aggregate Turns of Talk			
	Kay	David	Isaac	TA
17	11	6	7	6
18	10	5	9	5
20 (F2)	3	4	5	9
Total	87	77	82	22

Kay's agentic voice came from a history of not being listened to in a previous studio physics course she had taken. She narrated the backdrop to her agentic voice as follows:

"I know that [when] I took studio for the first semester. I was in a group. I was in a table of all males. And trying to say anything, I would literarily be ignored sometimes" (Interview 4/13/19).

This interview suggests that Kay was confident in letting her voice be heard and she understood it to be important for her to exercise her agency in order to support her own learning "I want to understand". Kay's self-confidence and awareness of her agentic voice was important for her orchestration of positive gender interaction in the group. Kay did not stop at revealing the historical background to her agentic voice, she shared her determination to resist the negative experience. Her self-confidence is implied in this determination:

> **Kay**: I would like come into this class and I'm like, 'I'm going to fight, am going to literarily yell my ideas until they listen to me! (most participants laughed). So, I am going to do it. And not like, 'you (referring to herself) can just write everything down' (take down notes for the group), then the males are going to do the experiment. I am like — 'I want to understand!' (Focus group Interview, 4/13/2019).

How did Kay orchestrate active positive gender dynamics? She did this in multiple ways such as taking part in the practical handling of equipment and other tools and sometimes playing a leadership role that was supportive of others' equitable participation.

143 **David**: Okay. What are we, what are we talking about? (shaking his head, looking at Kay) I am sorry.
144 **Isaac:** ...so for...
145 **Kay**: We are comparing 5 and 1.

146 **David:** 1 (referring to circuit #1) would have less resistance. Adding parallels to, like... if it were... I don't know... (trying to explain, attempted to draw). Do these bulbs provide the same amount of resistance as this bulb (pointing to the circuit diagrams) ...?

147 **Kay:** Yes.

Kay acknowledged the collaborative nature of efforts, supporting other's sense-making (see lines 145-147). Other characteristics of positive gender interaction as highlighted by Kay's participation were — She was inclusive of her peers' voices and mindful of their sense of belonging (143-145). By so doing, she elicited their participation (145-147). Also, when she was critical of other's perspectives, she did so constructively and respectfully.

136 **Isaac:** Would this actually have more current just because the current coming into that one splits into two here"? (Kay did not respond).

137 **Isaac**: You know what I mean? Like ...

138 **Kay:** O, he (referring to the TA) said that this one (referring to one of the circuit configurations has more... I (.) don't think so, because they are added in parallel and so has less resistance. If you just like look at it like this (orienting the circuit diagram in a different way for Isaac's view), it makes sense.

In addition, Kay, was not excluded from being positioned as competent or proficient by the men, especially Isaac (136-138). This positioning had potential to foster equity of voices and contribution to knowledge-building in the small group. However, as will be described, this positioning was insufficient to alleviate gender inequity in this context. Episode eight illustrates Kay's orchestration of positive gender dynamics.

During the 8th episode, participants were required to draw standard circuit diagrams and identify networks. Kay participated in the discourse in such a way that she facilitated a positive gender interaction for her peers while she experienced same. Part of the characterization of positive gender dynamics as emerged from the analysis of data is that though it may involve observable affect such as frustration or struggle as may be indicated in participants words or facial expressions, such emotions do not degenerate to hindering another participant's efforts to engage in discourses to construct knowledge. In such interactions participants were able to negotiate their understanding and build consensus even if or when they had epistemic differences.

Episode 8 was particularly interesting because it was the only episode which had two discussion foci that were both active positive gender interactions. Data suggest that Kay's leadership role, Isaac's support of kay's leadership role were supportive of positive gender interactions in the small group. The episode during which the interaction under consideration occurred was a continuation of a previous episode (i.e., episode 7).

Context and task for episode. This episode emerged from participants group work on exercise 4.4 (figure 7). Students were given several circuit diagrams and were asked to redraw them into standard circuit diagrams showing all the bulbs in each network. They were also asked to identify and categorize the circuit diagrams as series or parallel networks. The third task the students were required to do was to rank the circuits according to the amount of current that flowed through each of the circuits.

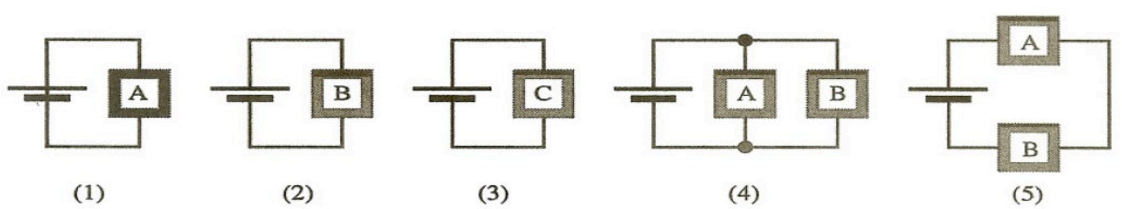


Figure 7: Unconventional circuit diagrams to be re-drawn into standard circuit diagrams

Participants finished working on items A through C in exercise 4.4. The last item on the task required that they explain their reasoning to a staff member (a graduate teaching assistant). This exercise anchored episode 8. Below is data for the second discussion focus (F2).

Discussion focus 2 (F2): Data (lines 136-151). In discussion focus 1, Kay and Isaac explained their work to the TA as required in the instructions for the Lab. They reviewed their work based on the feedback from the TA. David did not participate in the discussion focus 1. He had his head on the table. At the start of the interactions here in this second discussion focus, David still had his head on the table and was not actively participating. So, the first 7 turns of talk were between Kay and Isaac.

136 **Isaac:** Would this actually have more current just because the current coming into that one splits into two here"? (Kay did not respond).

137 **Isaac**: You know what I mean? Like ...

138 **Kay:** O, he (referring to the TA) said that this one (referring to one of the circuit configurations has more... I (.) don't think so, because they are added in parallel and so has less resistance. If you just like look at it like this (orienting the circuit diagram in a different way for Isaac's view), it makes sense.

139 **Isaac:** ...it has less resistance?

140 **Kay:** At least that's what I got from him (referring to the TA). (Looking at Isaac)

141 **Kay:** We added the third lamp because they are parallel.

142 **Isaac:** Wait, so if we add a parallel to this (to referring to one of the wire branches in the circuit), then, it makes the resistance less than this (pointing to another branch of the circuit). Is that what you are saying? (looking at Kay to whom he directed the question).

143 **David**: Okay. What are we, what are we talking about? (shaking his head, looking at Kay) I am sorry.

144 **Isaac:** ...so for...

145 **Kay**: We are comparing 5 and 1.

146 **David:** 1 (referring to circuit #1) would have less resistance. Adding parallels to, like... if it were... I don't know... (trying to explain, attempted to draw). Do these bulbs provide the same amount of resistance as this bulb (pointing to the circuit diagrams) ...?

147 **Kay:** Yes.

148 **David**: And this (referring to a branch of the circuit he was attempting to explain) provide some amount of resistance.

149 **Isaac:** Yea, yea, it's all about resistance.

150 **David**: Parallel is less (Kay and Isaac looking at David). And adding some, there is always a difference.

151 **Kay**: Yea, yea.

Active positive gender dynamics. *I*n this discussion focus, Kay had 6 instances of talk, Isaac 7 and David had 4. Kay's turns of talk consisted of 2 explanations, affirmations, and metacognition respectively. Isaac's were all questions and David's turn of talk included 2 explanations, one question and one metacognition/explanation.

Kay contested Isaac's perspective and cited the TA to support her explanation, presenting her contestation with "I don't think so" and "if you just like look." In this way, Kay was orchestrating constructive criticism. Kay's statements indicate she cared about the feeling of sense of belonging of Isaac while contributing to the construction of knowledge in the group. Isaac ignored David's question on the group's current stage of work, but Kay brought him up to speed by answering his question. Kay did not show any negative affect with David's failure to contribute verbally to the group's work at the start of this episode. It is not clear whether Kay did in fact dislike David's withdrawal from verbal contribution but did not wish to betray her dislike for it. However, she helped him come back into the groups thinking by explaining the current stage of the task in the work. In this way, Kay elicited David's participation. During this episode, she assumed a leadership role; leading the sense making in the group. Kay's support for David's re-entry into verbal contribution is further suggested by her affirmation of his contribution on 2 occasions with the words, "yea, yea" (lines 151).

Isaac positioned Kay as capable of providing explanation. This indicates the ally Isaac in Kay's enactment of positive gender interaction. This positioning as well as ally work is suggested by his question directed to her (see line 142). Kay answered his question, making him willing to ask her for explanation or to seek her validation (lines 136 & 137, 139). But when Kay did not answer, Isaac asked another question (line 137), another opportunity for Kay's leadership in knowledge-construction Though it seemed just a rhetorical question; (i.e., he did not really need an answer), Kay provided explanations, citing the TA (lines 138, 140, and 141).

In this episode, David played a minimal role. Across multiple episodes, most active positive gender dynamics occurred when David's participation diminished. However, he also positioned Kay in a leadership role, though less so than Isaac, asking her question — seeking for clarification and validation. David who had not been actively participating in the group as indicated by resting his head on the table and seemed to be sleeping (field notes 1/19/2019) needed to catch up with the group, and so he asked to know what the group was focusing on at that time. Isaac did not respond to his question, but it was Kay who did (line 145). David was polite and respectful (positive affect) while asking his question, stating he was sorry (i.e., for not participating all the while and now asking for update on the group's work). Kay responded (line 145). David immediately moved to offer explanation on the circuit analysis they were working on, but he was uncertain (146). After Kay answered his question (147), David took two more turns of talk which were explanations (148, 150). In her leadership role by answering the men's questions, validating their contributions, and eliciting David's participation, Kay supported their participation and fostered equity in knowledge-building in the group.

Kay's leadership role during this episode also reflects her self-confidence. For example, in responding to Isaac's question and explanation (line 136), Kay contested his view by citing the TA's explanation, reviewing her explanation based on the TA's input. Though Isaac re-stated the TA's feedback, he differed in his explanation of the equivalent resistance. Kay challenged Isaac's view, disagreeing with Isaac's different view, but she presented her contribution as a constructive critique using the markers ("I don't think", "just like"). In her challenge of Isaac's misreading of the TA's feedback, Kay was confident in the correctness of the TA's feedback and advanced the feedback. This contribution suggests Kay's self-confidence with her own knowledge. Kay's leadership role is an indication of her self-confidence.

Theme 2: The TA effectively supported active positive gender dynamics. It is also important to highlight the TA's role in relation to Kay's orchestration of positive gender interaction in the small group. This is because this relation deepens insight into how active positive gender interaction emerged and was fostered during discourses. The TA used facilitative strategies to support the participants. These included asking nudging questions [e.g., "So how much current would go through that?" (121)], elaborating on the participants' perspectives [e.g., "The way you drew them now, it shows you there are two main branches. But, if you look at it, all the lamps are of the same brightness" (117)], acknowledging their sense-making [e.g., "Yes, because, this point is connected to this point anyway... " (119)], especially in the form of explanations [e.g., "Parallel to one of them to reduce the resistance. That is why 5 ends up being the one with the most current" (133)]. Data on discussion focus 1 of the same episode 8 suggest the TA participated in some episodes in ways effective in supporting positive gender interaction.

111 **Isaac:** "And then we have to explain to someone who knows this."
112 **Isaac:** Here are three circuits 4.4. These are how all our circuits look.
113 **TA:** Okay
114 **Isaac:** Em (.) so we said, based on our drawings. We said that this one is the best because the bulbs are in parallel with the battery. And the ones with the least.... Why is that the one with the most amount of current? Because it draws equal amount of current here and here to the branch (pointing on the circuit diagram he had drawn) from the battery
115 **TA:** And then (he drew circuit C). Is it there and there to that branch or... (all three students looking up at the TA) or it is the same amount for each bulb?
116 **Isaac:** It's the same amount, well, it's the same amount for each branch and this one increases even more because it is in parallel. So, there should be quite a bit of current coming...
117 **TA**: (Cutting in) See here, you need to pay attention to how you define a branch. So, as you know, as long as the wires are perfect, it doesn't matter how you draw it. Right? The way you drew them now, it shows you there are two main branches. But, if you look at it, all the lamps are of the same brightness.
118 **Kay:** So, we can also draw it like that? (He draws the circuit diagram in an alternate way)
119 **TA:** Yes, because, this point is connected to this point anyway...

120 **Kay:** Okay, that makes sense.
121 **TA:** So how much current would go through that?
122 **Kay**: All these would have like (.)
123 **Kay:** Yea
124 **Isaac:** And that one (referring to the next circuit in the same task) is the next best one because...
125 **TA:** Okay
126 **Isaac**: We figured that one is the next best one because it is just one bulb. And then Once we added a second bulb in parallel, it adds more resistance because it has the mist resistance (Kay is looking up at the TA, but David had his eyes down, resting his head on his elbow).
127 **TA:** Alright, that sounds good to me but now compare 3 and 5 (circuit diagrams)
128 **Isaac:** 3 and 5?
129 **TA:** Yes, why has 5 less resistance than 3?
130 **Isaac:** Because it creates more branches as it goes around. Em (.)
131 **TA:** To compare them, what you can do is basically... What is the exact difference between 3 & 5? I mean you can tell one battery and one lamp over; they both have 2 lamps. Why did you add the 3rd line?
132 **Kay:** We added the third lamp because they are parallel.
133 **TA:** Parallel to one of them to reduce the resistance. That is why 5 ends up being the one with the most current.
134 **Kay and Isaac**: Okay.
135 **Isaac:** Thank you.

Active positive gender dynamics. In this episode, Kay had 6 turns of talk, Isaac had 11, the TA 9, and David did not take any turn of talk. Isaac called for this item on the task (line 111) and started the episode by explaining the group's work to the TA (112). Kay's contributions consisted of one question, affirmations and multiple short responses. Isaac's were in the forms of short questions, metacognition and mostly explanations. The TA's turns of talk included 3 questions, 3 explanations, and 3 affirmations.

Isaac initiated the group's work in this episode, calling for the group to check their work with a staff member. He began to present their work to the TA (lines 112, 114, 116, 124). By so doing, Isaac played an executive role. In his presentations while also explaining their work to the TA (124 & 130), Isaac was inclusive of his peers, mindful of their belonging by using the plural personal pronoun [i.e., "... so we said.... (line 114), "we figured that one ...." (line 126).

In response to Isaac's presentation, the TA offered a constructive critique — "see here, you need to... (line 117). In her turn of talk, Kay targeted improving Isaac's presentation of their work as she proposed an alternative explanation and checked for validation with the TA: "So, we can draw it like that (drawing the circuit diagram in an alternative way)?" (118). The TA validated her explanation as correct and further explained Kay's work (119) to which Kay responded that it made sense to her. Kay's role to overcome the inadequacies of their work as presented by Isaac suggests support for Isaac, a manifestation of her orchestration of positive gender interaction. Her role here also highlights her own confidence and agency in explaining the circuit configuration and resolving critique by the TA.

The TA's turns of talk with Kay and Isaac were 6, using questions (115, 121, 129, 131) further explanations (117, 119, 131, & 133) and validation (113, 119, 125, 127) to support Kay and Isaac's participation in this episode. Kay and Isaac appreciated the TA's efforts to support their work (134 & 135). This episode highlights an active positive gender dynamic orchestrated by Kay and supported by the TA. It is interesting to note that David did not take any turn of talk in this discussion focus.

One indication of the effectiveness of the TA's supportive role for orchestrating positive gender dynamics is a pattern in the occurrence of those dynamics and the TA's presence which emerged from the data (Table 5). Across the 20 episodes which I analyzed for this study, there were 14 occurrences of active positive gender dynamics, five of which were stand-alone episodes whereas the other nine were in mixed episodes. Three-quarter of those total number of active positive gender interactions were associated with Kay's orchestration and the TA was present and actively played a role during 6 of the total number of active positive gender interactions, taking a total number of 35 turns of talk across those 6 episodes.

The TA's support of Kay's orchestration of positive gender interactions in those episodes were in the forms of asking nudging questions [e.g., "So how much current would go through that?"121)], elaborating on the participants' perspectives [e.g., "The way you drew them now, it shows you there are two main branches. But, if you look at it, all the lamps are of the same brightness" (117)], acknowledging participants' sense-making [e.g., "Yes, because, this point is connected to this point anyway..." (119)]. The TA made three appearances during discourses within the first 30 minutes of the Lab, with 6 occurrences of active positive gender interactions, one appearance during the third 30 minutes segment of the lab, with one occurrence of positive gender dynamics. The data suggests that appearances of the TA playing facilitative roles were associated with more occurrences of positive gender dynamics.

There were three occurrences of active positive gender interactions during the second 30 minutes segment of the discourses even though the TA was absent. Similarly, there were three occurrences of active positive gender interactions in the fourth segment of 30 minutes with only one appearance by the TA. My interpretation of this discrepancy in the second segment of 30 minutes is that it may have benefitted from the ripple influences of the TA's efforts during the first 30 minutes segment of discourses. Also, for the deviation of the fourth segment of 30 minutes from the pattern of association of the TA's roles with the occurrences of active positive gender interaction, it is worthy of note that at this time, the participants have spent the longest time together, and they may have begun to come to terms with Kay's relentless push for positive gender interactions. So, the men who were asymmetrically involved with orchestrating negative gender interactions may have improved towards the positive spectrum of discursive interactions after multiple support by the TA.

Theme 3: The TA did not alleviate negative gender interactions. There were only 5 episodes in which the TA was present, and his turns of talk ranged from 2 to 9, with the high end occurring in episodes 11 and 20. The TA was associated with both positive and negative interactions, suggesting that the mere presence of the TA did not assure positive gender dynamics, but his orchestration of certain instructional moves supported positive gender dynamics but did not alleviate negative ones. This trend is seen in episode 20 in which David continued to participate in such a way that was not considerate of equity of voices nor recognize the epistemic value of his peer's contributions. Though the TA was responsive to David's epistemic move to check his peers' contribution in a less-than-constructive critique, David's orchestration of negative gender interaction was not alleviated (i.e., the finding under consideration).

This finding is supported by the pattern of association between the occurrences of gender dynamics and the TA's presence. In the first 30 minutes segment of the discourses, even though the TA was present three times across multiple episodes, negative gender dynamics were predominant (two active and seven subtle). Then, for the third and fourth 30 minutes segments of discourses, one occurrence of negative gender dynamics was recorded in each segment while the TA was present once during each of the segments. In the next section, I present findings from analysis of data exploring patterns of negative gender dynamics in relation to the participants, the TA's roles in relation to the dynamics, and then a summary of findings based on my first research question which centered on patterns of gender dynamics.

Context and task for the episode. The following was the task given in Exercise 4.4. "Draw a standard circuit diagram showing all the bulbs in the circuit. List the series and parallel combinations for each of the circuits. Rank each of the circuits in part A according to the current through the battery”.

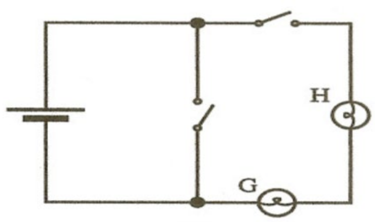


Figure 8: Item #4 in exercise 4.5.

The following turns of talk are the data on the episode:

169 **David**: So, are you saying that these (pointing at the diagram he was drawing) end up being in series? (At this point the TA came by and Kay raised her hand)
170 **Kay:** So, we are still a little confused...
171 **TA:** Why are you doing that? (Tone raised and asking why David was writing equations depicting his mathematical model of the circuit).
172 **David**: I want to know how it (his equations as a mathematical model) fits in with this (referring to their circuit analysis earlier presented by Kay).
173 **TA:** Is it for the ranking?
174 **Kay:** Yea.
175 **TA:** He [David] said that he just wanted to see if three of them are in parallel to each other.
176 **David**: So, you are saying that this circuit, and this circuit (pointing to them on his diagram), are exactly equivalent?
177 **TA**: I know for sure that it is correct.
178 **Isaac:** (Cutting in) no more waste of time.
179 **David:** We are not going to argue (smiling). Tell me. What is wrong? (looking up at the TA).
180 **TA:** I know there is a trap in there. There is nothing wrong.
181 **David:** So, why didn’t they yield different current?
182 **TA:** They don’t
183 **David**: Then, then, (stuttering, obviously frustrated) just look (referring to his equations in efforts to mathematically make sense of the current in the equivalent circuits).
184 **TA:** Here is the thing. These two are equivalent (pointing) as long as you can understand that these three are equivalent (pointing on David’s sketch). See wires in a circuit are perfect resistors, no matter how you draw them, as long as there is one connection wire between these two points, then the same current flows through them.
185 **David**: Okay, okay, I understand that. Can you just look and see what my math is trying to get at? That’s all ‘am talking about.

186a **TA**: O, okay, I am sorry (bending to take a look at David's paper on which David had been writing), and asked David to explain to him.

186b **TA**: Okay, could you explain to me.

187 **David;** Okay, I decided... okay, I was like okay we call this circuit ... we pretend that all of the resistors in the circuit are just each 1.5 ohms. Right? Total resistance for this circuit should be 1.5 + 1.5+1.5, and if you work this out, 4.5. He checked the final answer (i.e. the effective resistance using his math model, talking the TA through his steps and he exclaimed)

188 **TA:** Okay, let's hope it does work! If it doesn't, we have a problem.

189 (David held up his right hand as a signal to the TA to hold off speaking).

190 Kay and Isaac who had been listening to the conversation between the TA and David began to move and shift some of the wires and circuit components on the table).

Active negative gender dynamics. In this episode, David and the TA took the most number of turns of talk; 10 each. Kay took 2 and Isaac had none. Isaac and Kay had reviewed this task, but David wanted to do same all over by himself. Perhaps, he was not satisfied with the explanations and conclusions reached by his peers when they analyzed the circuit 4.4 in episodes 7, 9 and 10. David's intention to further explore the circuit analysis is suggested by the questions (169, 176), metacognitive (172) forms of his participation, a combination of both (181 & 185), one instance of explanation (187). Kay had only two turns of talk; metacognition (170) and affirmation (174) respectively. The fact that Kay and Isaac had already talked through this task in the preceding episodes may explain why she took very few turns of talk and Isaac none, but more importantly, David did not give consideration to his peers sense of belonging and voice. By so doing, David constrained equity in terms of voices and sense of belonging. The TA's turns of talk were predominantly metacognitive (175, 177, 180, 182, & 190), with an instance of explanation (184) and another of affect (186). The TA's role in this episode consisted in evaluating David's explanations. This explains why majority of his turns of talk were metacognitive.

Since David did not actively participate in the analysis of this circuit which Kay and David did analyze in episodes 7, 9 and 10, he would rather seek answers to his questions than move to another task. The interaction in this episode suggests that David was determined to be convinced of the correctness of the explanation given by Kay and supported by Isaac (see episodes 9 and 10). David's challenge to his peers' work is suggested by his statement: "So, are you saying that these (pointing to the sketch he was drawing) end up being in series?" (line 169). This hesitance to advance to the next task may be motivated by David's self-positioning as the critic in the group. By being critical of Kay's perspectives, David may also be positioning himself as the gatekeeper of the epistemic value of discourses in the group by wanting to test out the conclusions that Kay and Isaac had earlier arrived at. David's positioned Kay's ideas as less in epistemic value compared to his.

Though David seemed to struggle with uncertainty, he navigated it a way that orchestrated negative gender dynamics. Unlike Kay who did not shy away from uncertainty — "So, we are still a little confused" (170), David's participation in this episode also suggests a subtle refusal to acknowledge his own uncertainty and cognitive struggle with the content. His question in line 172 in which the TA probes David's intention to contend explanations already presented by Kay and Isaac suggests curiosity — "I want to know how it fits in." However, an instance of negative affect resulted from David's approach.

David soon became very insistent on the correctness of his own perspective (179, 181, 183, 185, 186) despite his own uncertainty. The TA asked (173) David what he wanted to know about, but it was Kay who responded positively — "yes" (174). The TA was patient, letting David explain his perspective. He started by explaining what the task required of them (175) and David asked to clarify and present a destructive critique of an explanation already settled by Kay and Isaac (line 176). The TA answered with certainty: “I know for sure that it is correct” (177) and Isaac considered David’s question to be a waste of the group’s time since he (Isaac) and Kay had gone over the work in previous episodes. This conclusion is supported by the data in line 178 where during a conversation between David and the TA (lines 176 & 177), Isaac said: (Cutting in) “no more waste of time” (line 178). David responded — “We are not going to argue (smiling). Tell me. What is wrong?” (looking at the TA) (line 179). David’s response suggests that he did not consider the exchange between him and the TA as a waste of time, his voice became intense as he replied to Isaac’s reservation. Then, he stuttered and hedged (lines 181 & 183), indicators associated with his participation in discourses that involved negative affect in other episodes (e.g., episode 15), and uncertainty centered around the circuit analysis ideas he was checking out. The TA’s next turn of talk was an explanation, instead of the largely evaluative forms of participation up until now. He explained:

> Here is the thing. These two are equivalent (pointing at the circuits, see figure 9) as long as you can understand that these three are equivalent (pointing on David’s diagram). See wires in a circuit are perfect resistors, no matter how you draw them, as long as there is one connection wire between these two points, then the same current flows through them (line 184).

The TA’s switch from metacognition to explanation did not succeed in calming down David’s negative affect totally as David hedged on and asked for the TA’s closer “look” into his work: “Okay, okay, I understand that. Can you just look and see what my math is trying to get at? That’s all ‘am talking about” (line 185). At this the TA apologized: “Oh, okay, I am sorry (bending to take a look at David’s paper on which David had been writing/drawing), and asked David to explain to him) (line 186). David explained but the negative affect continued to influence his speech and composure; his hands shaky and voice was shaky as well as intense as he hedged multiple times (line 187). David is a math and computer science major. He approached the circuit analysis from his math perspective whereas the TA was advancing a conceptual approach to the circuit analysis. All the while, Kay and Isaac continued to hold off patiently until David apparently realized that his model was not helpful to ‘prove’ the correct result. The TA said: “Okay, let’s hope it does work! If it doesn’t, we have a problem. David realized his model did not fit and apologized.

191: **David:** O okay, it doesn’t work (smiling). It’s crazy. I am sorry.
192 **TA:** It was as simple as that! (walking away).
193 **David**: Sorry (laughing).

The data suggest that David may have been genuinely experiencing cognitive discontentment with the explanation earlier given by Isaac and Kay. In order to pursue a path out of this discontentment, he adopted a mathematical modelling pathway. David might have participated in this insistent way that suggests rivalry between him and his colleagues, but especially Kay, who had been the leading participant based on the data discussed in episodes 7-10.

Overall, the conversation was between David and the TA as David advanced his mathematical model of the circuit network in an analytical discourse. Kay stated the group’s uncertainty, inviting the TA to help with clarification of their answers. In this way she played the executive role of fostering positive interaction, but this was the most Kay participated verbally during this episode. David had taken a mathematical route to check their circuit diagram analysis. So, he responded that he wanted to know how their predicted answers compared to his mathematical modeling. In addition, David hogged all the TA’s attention to support his own sense-making. Thus, he drew on the TA’s support as a resource and he completely took it over for his own thinking, without consideration for his peer’s verbal participation.

Isaac too took only one turn of turn. Could Kay and Isaac be reticent because they did not consider the math modelling check by David as productive for their work? This is plausible given that they had followed the instruction on the task and worked on it already. Nearly the entire time in this episode, the conversations were between the TA and David. David talked the TA through his mathematical modelling of the circuit networks while Isaac and Kay listened on. They let David take some time to express his views, making room for his sense of belonging even though they had a contrary opinion. Throughout this episode, David had long turns of talk in bids to explain and clarify his mathematical model of the circuit network. These multiple and long turns of talk toward this goal made him dominate this episode. Up until this episode, neither Kay nor Isaac had such contestation to the point of taking such much time to air their contestation.

Theme 4: Active positive and subtle negative gender dynamics were associated. Multiple episodes (i.e., 1, 2, 6, 12, 14, 16, 20 — see Table 5) were characteristically mixed. I found that both active positive gender interactions and subtle negative gender interactions co-occurred in an episode in such a way that in the first six of those seven mixed episodes, active positive gender dynamics occurred first, and then subtle negative gender dynamics followed in the same episode. A different pattern of sequence of occurrence emerged in episode 20 where subtle negative gender interaction occurred first, then active positive gender interaction. A closer look at those selected episodes to explore what factors might explain the ordering of the types of gender interactions in the mixed episodes revealed multiple factors. These are;

- the order of non-verbal enactment and what was said in the turns of talk
- how David took up his peers' contributions.
- Isaac's role as Kay's ally
- the timing and type of instructional moves by an instruct or

In the next section, I will illustrate how data support each of these explanations.

The order of non-verbal and verbal discourses. These were important for the ordering of the types of gender interaction across episodes. The turns of talk presented in the data below provide an example of the occurrence of positive gender dynamics which is then followed by negative gender dynamics.

1 **Isaac:** I don't know what he is trying to ask there but I guess like, they seem like the same definition (turning his eye contact/gaze to Kay). (Isaac was referring to items 1 & 2 in figure 2, (see Appendix ...).

2 **Kay:** I think they just want us to compare em (.) this with this one (pointing to items 1 and 2 on the monitor (as in figure 1 above).

3 **Isaac:** (after a pause) Okay ... well, I mean....

4 **David**: There is only one single common junction because there is only one wire (laughing while still looking at the screen). I don't know (Kay looked on at the lab guide on the screen- maybe pondering David's explanation).

5 **Isaac:** Yea, exactly (Isaac writing in the note).

Isaac moved to elicit Kay's voice (line 1), and then later differentially took up and endorsed David's explanation (line 4) in a more positive light (line 5) while hesitant (line 3) to do same with Kay's (line 2) the gender interaction began positive, then followed by subtle negative instance. The data (lines 1-5) were from transcripts of episode 1.

In episode 1, the students' task was to provide a conceptual explanation for each of two statements provided in the exercise. The statements described series and parallel circuits (Task 4.1, Exercise 4.1 Appendix...,). During this episode, students worked on two tasks (exercises 4.2 and 4.3) as given below.

> Explain why the following two statements are direct consequences of the definition of series and parallel connection.
>
> A. When two bulbs are connected in series, they have a single common junction and together, as a unit, constitute the only continuous path through that junction.
> B. When two bulbs are connected in parallel, current that passes through one bulb does not pass through the other (Exercise 4.2 Appendix....)

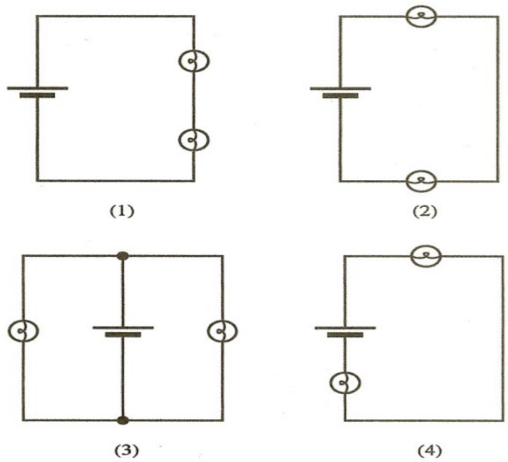


Figure 9: Circuits to be categorized based on definition of series and parallel networks

At the start of the lesson, the instructor introduced the verification lab by providing 5 minutes of instructions. While students waited for the instructor to finish giving the preliminary instructions that launched the lab of the day, Isaac was sitting still, apparently listening to the instructor's launching lecture. Kay began to lay out some wires and checking out the bulb holders — setting up equipment (though the first task on the module did not require the items), while David had the voltage source in his hands and was unwinding the cord wrapped around it — setting up equipment.

How David took up his peers' contributions. Another consideration that explains the ordering of the types of gender interactions is how David took up his peers contributions. For example, in episode 20. For this episode, students worked on identifying the number of nodes in a circuit, the configuration of bulbs in the circuit and their brightness.

Below is an excerpt from the turns of talk in the group.

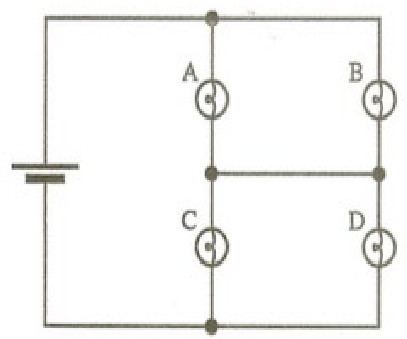
682 **Kay:** So, all of these... this splitting is all happening at the same time. Right? In one way, C and B are together as A and D are together. Right? So, we know that they are not going to have separate brightness. Right?

683 **David:** (shaking his head in disagreement) That's just making stuff up, like I can just draw (laughs) a circuit and said — o they will go

this way and they will be the same, that's not a rule. Like, you can just like draw a line (Kay tried to explain more but **David** cut in).

684 **David**: (cutting in) No, that's what you were saying (shaking his head).

How many nodes are there in the following circuit?



Predict the relative brightness of the bulbs in the circuit, and tell whether the bulbs are arranged in series or in parallel.

Figure 10: Identifying, nodes, circuit configuration and predicting bulb brightness

During this part of the discourse, David orchestrated negative interaction as he dismissed Kay's explanation as "just making stuff up" (line 683), dismissing the epistemic value of her contribution to knowledge-building while disrupting the flow of her explanation by visibly rejecting her ideas (i.e., shaking his head in disagreement) and cutting into her turns of talk. So, he expressed negative affect while dealing with epistemic difference between Kay's interpretation of the circuit configuration and his.

In the second focus of the episode, David orchestrated a positive gender interaction, seeking to build consensus by asking the TA for support (686 and 687).

686 **David**: I just want the TAs to tell us how we can tell (referring to determining the brightness of the bulb. (Kay raised her hand to draw the attention of an instructor. then, the TA came).

687 **David**: We are having a little bit of problem trying to define what is going on here. I think that all the bulbs are the same brightness because they are connected in series and parallel (Kay and David looking up to the TA).

688 **TA**: They are all the same brightness. Em... A and B are in parallel or in series?
689 **Isaac**: They are in parallel, and they will always be in parallel.
694 **TA**: Okay, it helps to like redraw. Like, if you think about it. What you were saying is kind of true. Right? Because, C is not in series with B but C and D together are in series with A and B.
695 **Kay**: Yea, that's what I was thinking.

During these exchanges, David's efforts to build consensus offered an opportunity to Isaac and Kay to have their explanation validated by the TA, resolving the epistemic difference in the group. These ways in which David took up his peer's contributions orders the dynamics as positive, then followed by a negative interaction.

Isaac's role as Kay's ally. The importance of Isaac's role as Kay's ally in knowledge building is suggested by episode 16 for example. In this episode, Kay took the leadership role and since she orchestrated active positive gender interaction across multiple episodes, this form of interaction occurred first. In addition, Isaac came on board right on the heels of Kay starting the conversation. In his ally role, he alleviated the edge that often was associated with epistemic differences. He made a joke of this difference, so it not be a source of negative affect. As soon as he noticed the difference between Kay's perspective and David's (see lines 363-365), Isaac said: "Okay, (laughing), we already have differences on one" (366). His laughter suggests a move to make light of what often sparked negative affect in discourses between Kay and David.

The timing and type of instructional move by an instructor. In addition, the timing (earlier in the episode as against later in the episode) and type of instructional moves by an instructor (in this case, the graduate teaching assistant) had potential to influence the sequence of emergence of the categories of gender dynamics. This conclusion is supported by data from episode 16 made of two discussion foci.

360 **Isaac**: So, there are two exit points from the positive end of the battery. Right? (The trio all looking at the circuit displayed on the monitor, while Kay drew her equivalent circuit).

361 **Isaac**: This is interesting (commenting on the nature of the circuit in the exercise 4:10. The three continued working individually. After a while).

362 **Isaac**: I think it's this (pointing to one of the circuit diagrams).

363 **Kay**: Which one? The second one?

364 **David:** The first one.

365 **Isaac:** Em…

366 **Kay**: I see this. This is what I see for the first and second one (pointing to her alternative circuit she had drawn).

366 **Isaac**: Okay (laughing) we already have differences on one.

367 **TA**: Differences are always welcome.

In this episode, the TA normalized epistemic differences saying — "Differences are always welcome" (367). Kay thought that junction in the circuit diagram did not matter in making sense of the configuration whereas David thought it did. The TA affirmed the students' epistemic practice of offering reasons for their conclusion but stated that it did not matter if the current went through a junction or not. The data suggest that the TA's role (i.e., normalizing differences, affirming student science practices while highlighting correct content) in his turns of talk played a role in the ordering of the types of gender interaction; active positive gender dynamics during the first discussion focus but subtle negative gender interaction during the second discussion focus of the episode (see Table 5). The TA's timely presence as well as support for positive gender dynamics was important for the positive interaction among the participants.

In the data from the first discussion foci of episode 16, students worked on an exercise in which they were given circuit diagrams drawn in unusual ways and four other circuit diagrams drawn in a form with which students were familiar. Their task was to determine which of the second set of circuit diagrams was equivalent to any of the circuits drawn in unusual forms.

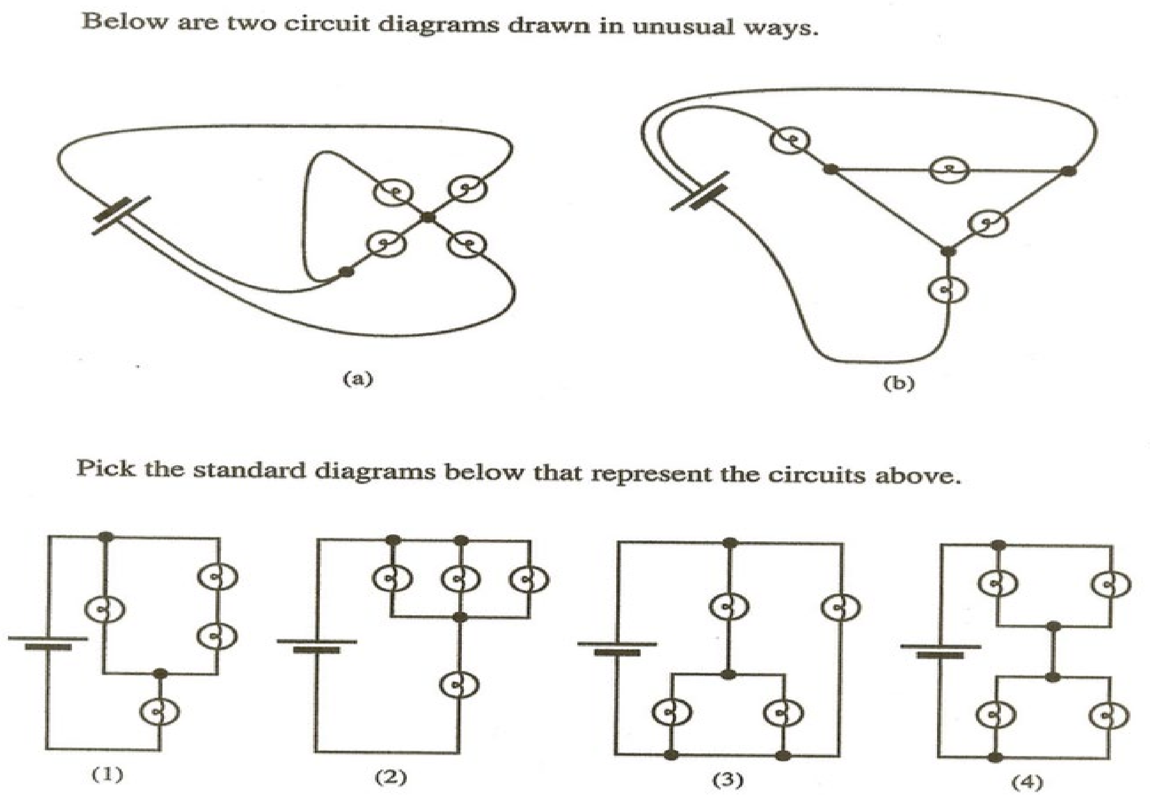


Figure 11: Unusual and standard circuits: Determining circuit equivalence

Data from episode 20 also support the importance of the timing and type of TA's instructional role in the ordering of the types of gender interaction. In this episode, the TA did not participate in the discussion focus 1 because he did not come to the group at that time. This is not to say that his absence was the cause of the subtle negative gender interaction which occurred. But, the trend across multiple episodes indicate that certain instructional moves by the TA during discourses among the participants helped to support the orchestration of active positive gender interaction. Thus, it makes sense to note that the second discussion focus during which the TA was available to the group and played a supportive role panned out as an active positive gender interaction.

696 **TA**: when you look at it, it's basically two parallel circuits in series with each other.
697 **Kay**: Yea

698 **David:** So, none of the individual bulbs are in series with each other? (gaze on TA, may for validation).

699 **TA**: No,

700 **David:** The two parallels are in series with each other and no single bulbs are in series with each other.

701 **TA**: Yea, and the brightness will be the same. Right?

702 **Kay**: Yea.

703 **TA**: Because, the same current is going to go into each parallel pair.

704 **Isaac**: So, this is kind of what I get out of it (Showing the TA the group's lab report work).

705 **TA**: Yea

706 **Isaac:** (Shared the conclusion with Kay and David) So I am going to say that A and B are in series with C and D. And then, A is parallel to B and C is parallel to D (Kay nodded her head in agreement). Let's go to 5.5.

In this discussion focus 2, the TA supported positive gender dynamics by providing explanation (696), evaluating (699), validating (701), and affirming (705) students contributions. These instructional moves supported the group to arrive at a consensus explanation which Isaac (line 706) re-stated to the group and then they transitioned to the next task (i.e., exercise 5.5).

Theme 5: The men were asymmetrically involved with both dynamics. This theme emerged from data highlighting the clearly observable and subtle actions and inactions of David and Isaac to different degrees such that Kay had a less than equitable participation in the small group. Across multiple episodes, data suggest the men orchestrated negative gender interactions; David more than Isaac. These patterns of negative gender interaction were either subtle or active. The active negative gender interactions were only stand-alone occurrences. That is, they either occurred in an episode without any other type of gender interaction or it was an episode with double foci such that both foci were negative gender interactions. Data analysis revealing Kay's orchestration of positive gender interactions already foreshadowed the men's asymmetric involvement in active positive gender dynamics. So, I now draw on episodes 14 and 15 to highlight the men's asymmetric orchestration of negative (subtle and active) gender interactions respectively.

In episode 14, there were two discussion foci; the first was active positive gender interaction and the second was subtle negative gender interaction. The task for this episode required students to observe the brightness of the bulbs in different branches of a circuit (Figure 12), compare their brightness, and predict the brightness of bulbs in a branch when a bulb is removed from another branch. They were also asked to make observations and write down their observations, giving explanations.

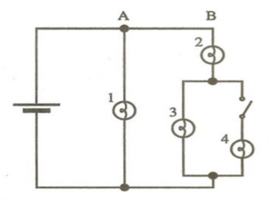


Figure 12. Circuit with different branches

The task for this episode is as follows:

> Notice that there are two branches of the circuit, labelled A and B, that are connected in parallel directly across the battery. Several alterations to each branch are listed below. In considering the effect of each alteration, begin with the circuit in its original state.
> (1) Predict the effect on branch A on each of the following alterations to branch A: (a) Unscrewing bulb 2, (b) shorting out bulb 3. Explain your reasoning

In this section of the episode, students' discussion focused on the second question in the task which required them to predict the behavior of the circuit when they shut out one of the bulbs. Kay had 9 turns (4 explanations, 2 questions, 2 metacognitions, 1 question) and multiple instances of hands-on manipulation of wires and bulbs (practical discourse). Isaac and David had predominant metacognitive turns of talk (6 each) but David had multiple occasions of manipulating wires and bulbs (practical discourse). Kay and David had multiple instances of participation in setting up the lab equipment (hands-on). David had 10 instances of talk; 6 of those were metacognitive, 3 affects, 1 question and 1 explanation. David's turns of talk were spread across the episode in exchange with the TA who had 6 turns of talk — two of which were metacognitive, and two others were practical discourse centered on building the circuit. (264, 270-272).

Subtle negative gender dynamics. Data from episode 15 suggest the orchestration of subtle negative gender dynamics by the men, as shown in Isaac's bid for transition to the next task:

264 **Isaac**: Okay. #2 (calling for the next task).
270 **Isaac**: We can try it. (**Kay** began to connect the wires to check the brightness while David looked on, and Isaac wrote notes in the group's lab report book. Kay kept building the circuit, and got up, stepping away. Isaac and David sat, not talking to each other for a while).

In response to Isaac's bid, Kay made her prediction of the circuit behavior but did not complete her statement. Rather, she provided elaborate explanation:

266 **Kay:** Okay, if we unscrew 2 (she unscrewed one of one bulbs). Nothing changes because they are independent of each other. The only thing that might actually change something is if we add another bulb, because that pulls more em (.). It is in series that pulls more current. Right? (looking at David, but he said nothing).

To justify her prediction, Kay offered the explanation while beginning to manipulate the wires and bulbs to test out her prediction. Thus, she positioned herself as capable of providing explanations. However, David was hesitant to adopt Kay's prediction and explanation. He responded "maybe..." (line 267). This response was a signal on the upcoming subtle gender dynamics. Isaac was supportive of Kay's perspective and expectantly looked at Kay to validate his support of her;

268 **Isaac**: Because that has more connection. Right? (Looking expectantly at Kay which Kay did)
269 **Kay**: That's true (pointing towards Isaac in a snappy way, and thanking her for her role to advance the group's work);
272 **Isaac:** Thank you for bringing the wires (Kay continued to build the circuit, screwed in one bulb which lit, but one of the bulbs in the circuit

did not light up. However, David soon took over the wires and bulbs right after he suggested an alternative approach to connecting the wires (fieldnotes 1/19/2019).

275 **David:** Let's connect it another way.

276 **Kay:** At first, we had... (David wanted to take the part of the circuit kay was working on, she quickly handed it to him) (fieldnotes 1/19/2019).

277 **David:** This should be circuit... (reaching for the wires, his hand bumping into Kay's).

278 **David:** Sorry (retracting his hand).

279 **Kay:** Go ahead (yielding).

280 **David:** (Connected some alligator clips to the circuit board saying) — this was the right idea. Right? This was the right idea (talking through the setup he was building).

David stretched his hand to pick the wires which Kay was working on to build the circuit; perhaps in a bid to contribute towards accomplishing the task or to contest the control of materials by Kay and so assume leadership. David's hand collided with Kay's, but he apologized: David: Sorry, (retracting his hand) (line 278.) Kay let him have the wires (fieldnotes 1/19/2021) saying "go ahead" (279). David connected the wires and the bulbs lit. He declared — "This was the right idea" (280). David implied that his efforts demonstrated he had the "right idea" (280). David's declaration of a "right" approach to accomplish the task offered no reference to Kay's efforts. Kay had multiple moments of engaging with the materials which David did not acknowledge. Fieldnotes highlight such multiple moment of Kay's engagement with the circuit materials in efforts to build the circuit:

> At the start of this episode, she unscrewed one of one bulb, and began to connect the wires to check the brightness while David looked on, and Isaac wrote notes in the group's lab report book. Kay kept building the circuit and got up at a point to go get more wires from the supplies. Kay continued to build the circuit, screwed in one bulb which lit, but one of the bulbs in the circuit did not light up. Kay shifted some wires, and David unplugged one wire and plugged it back in at a different junction. The two kept adjusting the wires' connections and bulbs lit up (fieldnotes 1/19/2019).

David orchestrated negative gender interaction.

Active negative gender dynamics. Data from episode 15 suggest the orchestration of active negative gender dynamics by the men. This episode had two discussion foci. Students were presented with a variety of circuit diagrams and their task was to determine which of the circuit diagrams were identical, that is — which of the circuit diagrams represented the same physical circuit. The goal of this task was to illustrate and help students understand that a circuit may be drawn in multiple ways. The approach recommended to them was to redraw an apparently complicated circuit so as to more easily identify the circuit configurations; series or parallel.

The task is as follows:

A. Which of the following circuit diagrams below can be used to represent the same physical circuits; that is, which circuits have the same electrical connections? To make this decision, you may find it helpful to redraw some of the circuits.

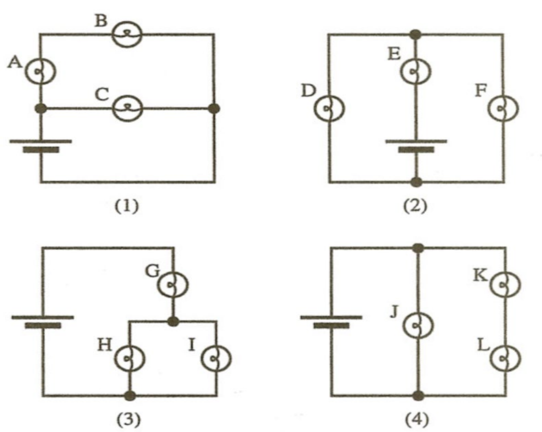


Figure 13. Circuits for which equivalence was to be determined

B. How many different circuits are represented by the diagrams above? In each case, identify the series and parallel connections of bulbs and networks.

Analysis of data on this episode revealed two active negative gender interactions across both foci of discussion.

315 **Isaac**: Em..., so for B (and he read aloud). Well, we are back to it (laughing). Em, so, there are 3 different circuits.

316 **Kay**: The only thing is this one is the same as ... (shook her head and paused, pointing on the screen).

317 **David**: No, it can’t be. If what you just told me is true, then that cannot be true.

318 **Isaac**: No.

319 **Isaac**: Em(.), actually yea,

320 **Kay**: I think it is. I think it is.

321 **Isaac**: Yea.

322 **Kay:** Because if you look... If you trace it from the battery, there is a bulb after the battery, and then the current splits into 2 different ones. So, we are only seeing two different circuits in each of them.

323 **Isaac**: I agree (and wrote her conclusion).

324 **Kay**: So, in A (referring to the prior item on which they disagreed and agreed to return) we need to say that ... 1 and 4... wait. Yea, that’s what we said. 1 and 4 are the same, and then, 2 and 3 are the same.

325 **Isaac**: Yes (David sat silent).

326 **Isaac**: So, for 1 and 4, the connections are em(.) C is parallel with B, and J is in parallel with K and L.

327 **Kay**: Yes, nodding her head

328 **Isaac:** And then, K and L are in series.

329 **Kay**: Yes, for 1, you can just say (.) like, they (A and B) are in series with each other and in parallel with C.

330 **Isaac**: (.) yes!

331 **Kay**: (Looking at David): Do you get this...?

332 **David**: I thin(.)k so...

333 **David**: Ah, no (shakes his head in disagreement saying:) that can never happen.

334 **Kay**: Another way that you can think about it is like... follow the flow...

335 **David**: That’s what I was doing earlier but then abandoned it. See, you can’t always like... pen. (signaled to Kay to give him a pen so he would express his idea on paper). He drew his diagram of the circuit and said: This is different from this (comparing his model with that of Kay). Then, he drew an alternate circuit saying (this is the same as this. Like, if you follow the flow.

336 **Kay:** Yes (When he was through, **Kay** took the paper and began to explain her perspective as well.

337 Then, **Isaac** wrote the group’s conclusion so far).

338 **David**: (Cutting in) but it’s arbitrary to say that it splits between 1 and 3 (referring to the bulbs in the circuit).

339 **Kay:** okay, okay, okay, we are going to say...it goes like this… (demonstrating with her hand).

340 **David:** Okay

341 **Kay:** And then it splits again and goes right.

342 **David:** Okay (Kay was still trying to explain when David took the pen from her hand, cutting off her explanation to present his, and she let him. He presented his alternative circuit models and said)— these are all the same

343 **Kay**: Yea (attempting a turn of talk but David would not give audience)

344 **Kay**: Okay, okay, listen, let me finish, maybe it will make sense. One way to think of this is that It hits one and then splits like this (drawing on a paper). Like when we look at this one, we can see the flow come to a junction and then it hits one junction and then it splits (demonstrating with her hands.

345 **David**: (Giggling), I understand that. You are telling me things that I already know. I get that. (shaking his head).

346 **Kay**: Then, explain to me.

347 **David:** No, (shaking his head and hands), not this

348 **Kay:** All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: “no, no, no” (frustrated and gently banged her hands on her book in front of her).

349 **David:** It’s okay, I didn’t ask you to stop.

350 **Isaac:** (Finished writing and said): It’s okay. So... If I can find something that we can agree upon. G is in parallel with the bulbs H and I. Right? (Kay and David nodded in agreement).

351 **Isaac**: Okay, then I will write that (writing in the group’s lab report). Are we skipping 4;10. 11, 12, or 4:11, 12, 15?

352 **Kay:** (Checking through the lab manual) No, it’s 12, 13.

In this second discussion focus, participants worked on the B part of the task (see figure 13). Kay had 15 turns of talk — 6 explanations, 5 roles (affirmations and following of procedures), as well as 4 instances of negotiation of gender and physics. For David, there were 10 turns of talk consisting of 3 explanations, 5 self-positioning (as unmistaken in his views), and 2 metacognitive turns of talk whereas Isaac had 11 turns of talk made of 7 instances of metacognition, 2 roles (reconcile epistemic differences/build consensus) and 2 explanations. Isaac elicited participation by reading the task aloud but soon realized that this task had potential for epistemic conflict similar to the first discussion focus (264-280). “... well, we are back to it....” (315). Kay responded to Isaac’s elicitation by proposing an explanation of the circuit:

316 **Kay**: The only thing is this one is the same as ... (shook her head and paused, pointing on the screen).

317 **David**: No, it can't be. If what you just told me is true, then that cannot be true.

In line 316, Kay hesitated to present her idea in a conclusive way as she did not finish her statement. She shook her head and paused, but David declaratively refuted Kay's perspective: "No, it can't be. If what you just told me is true, then that cannot be true" (317). Then, Kay and Isaac exchanged multiple turns of talk to make sense of the circuit (318-330) while David wasn't verbally participating. Then Kay said: "Do you get this...?" (331) (asking David). David's silence during these turns of talk suggests that it makes sense to understand Kay's question as her approach to eliciting participation from David. He seemed to want to answer in the affirmative, then hesitated and responded with a categorical "no." He said: "Ah, no, (shakes his head in disagreement and continued) — that can never happen" (line 333). He meant that the explanation of the circuit configuration given by Kay was outrightly wrong. David's dismissal of the epistemic value of Kay's perspective suggests this active instance of negative gender interaction.

In efforts to convincingly convey her perspective to David, Kay explained in a different way (334, 336, 339) but David continued to disagree (335, 338). Isaac was already persuaded by Kay's explanation and was writing it down in their lab report book; an instance of his self-positioning as Kay's ally. Once more, Kay attempted to explain the circuit configuration, but David cut into her turn of talk, saying "okay..." (342). Kay was still trying to explain when David took the pen from her hand, cutting off her explanation to present his, and she let him. He presented his diagram of the circuit (fieldnotes 1/19/20) and said: "These are all the same" (342)., meaning that there is no difference between Kay's version and his. He then shifted the paper on which he drew the diagram closer to kay so she could have a better view. Kay responded — "yea," (her hand raised, perhaps waiting to collect her pen from David so to draw on the same paper while attempting to explain but David would not grant audience as he looked away (fieldnotes 1/19/20).

The negotiation of gender and physics for Kay continued and was getting more and more intense with David as she would not give up her confidence in her perspective explaining the circuit configuration. She said:

> Okay, okay, listen, let me finish, maybe it will make sense. One way to think of this is — it hits one and then splits like this (drawing on a paper). Like, when we look at this one, we can see the flow come to a junction, hits one junction and then it splits (demonstrating with her hands). (344).

Kays' repetitive use of the word "okay", suggests her struggle to navigate her gender and physics identities. Despite her effort to make David see that her interpretation of the circuit configuration was correct, David was dismissive of her view as offering no novel epistemic contribution. While giggling, he said: "I understand that. You are telling me things that I already know. I get that" (345) (shaking his head). Even at this dismissive utterance, Kay still wanted to elicit a productive conversation from David as she urged: "Then, explain to me" (346) but David would not take up her elicitation. In fact, his response displayed strong negative affect. He said: "No, (shaking his head and hands), not this" referring to Kay's explanation as incorrect and so unacceptable to him. At this, Kay's experience of active negative gender interaction seemed to reach a climax for her in this episode as she replied:

> All you have to do is just say what you wanted to say (her eyebrows raised, voice shaky, tone rising, and the look on her face observably suggesting anger and frustration). That may help [more] than yelling at me: "no, no, no" (348).

She gently banged her hands on her book in front of her.

All this while, Isaac seemed to have considered that not verbalizing his support of Kay's perspective but recording (in their lab report notebook) may be a better way for him to navigate and defuse this epistemic difference that has become epistemic conflict. So, he did not talk. However, as he often did when epistemic difference between Kay and David seemed to degenerate into epistemic conflict, he offered a way to achieving consensus by saying — "It's okay. So... If I can find something that we can agree upon; G is in parallel with the bulbs H and I. Right?" (350, 351), (Kay and David nodded in agreement).

Summary of Findings for Research Question 1

Data analysis across 20 episodes suggest that the woman (Kay) participated in the small group discourses in such a way that she orchestrated active positive gender interactions by fostering collaborative work in the group, eliciting her peers' participation, offering constructive critiques, and building circuits. Other ways she enacted active positive gender dynamics are measuring electrical quantities, helping keep track of work to be done (metacognitive), and mindful of the men's sense of belonging. The TA was effective in supporting positive gender interactions, but not successful at alleviating negative gender interactions. The men were asymmetrically involved in both the positive and negative gender interactions.

Kay experienced negative gender dynamics orchestrated by the men (David more than Isaac). In the face of such negative gender dynamics, she contested traditionally male gendered roles such as setting up and working with the lab equipment. During this contestation, she experienced negative gender dynamics in the forms of being seen by David as causing him frustration, and so yelling at her. The woman's self-positioning was central to her contestation of male gendered roles during the interactions in the small group to learn. This contestation influenced how she participated in the small group work — explanations, engaging in the setting up and control of lab equipment etc. The interactions made negative gender dynamics visible. Even though the negative gender interactions were mostly subtle, they were active ones as well.

Subtle negative gender dynamics were the predominant form of negative gender interactions. The subtle negative gender interactions occurred in association with the active positive gender interactions; the former almost always after the latter in order of association. Multiple factors explain this sequence of association;

- the order of non-verbal and verbal discourses in an episode
- how David took up his peers' contributions
- Isaac's role as kay's Ally, and
- the timing and type of instructional move by an instructor.

Research Question 2: Meanings Attributed by Participants to the Gender Dynamics

This second section on findings from data analysis focuses on the meanings attributed by participants to the gender interactions orchestrated and experienced during the discourses, the roles, tools and the labs. The question which guided data analysis in this section is — What meanings do the small group participants assign to the gender dynamics? In presenting findings from this section of data analysis, I will draw on data in the form of participants' responses during the focus group interview to highlight the following themes which emerged:

1) Meanings attributed to presentation of small group discourse to whole class

2) Meanings attributed to roles, tools and the labs

3) Meanings assigned to the gender dynamics and the TA's role.

Meanings attributed to presentation of small group work. Discourses in the studio model included presentations of small group work by members of a small group to the whole class. In order for a group to present to the whole class, the instructor had to select such a group to present. During the verification lab, the focal participants' group was selected on some occasions to present their work. I asked to gain insight into what this part of the learning experience meant for the group.

Researcher:

> On several occasions, most of you presented your group works to the entire class. Like today, Isaac, Kay and David did. What does that feel like — Having to make that presentation before the entire class? Or what does that mean for you?

Kay stated that a small group may be "accidentally" selected by the instructor who expected correct answer during the presentation. She also indicated that it was uneasy to make presentations to the whole class, but it was also an opportunity to explain one's thinking. According to Kay;
"He (the instructor) gets pissed off sometimes if he accidentally picks you (referring to a group) and you end up being wrong (smiling). It's nerve racking but you get to explain your thinking." By the phrase "pissed off," Kay meant 'the instructor was not impressed if he picked a group that failed to present the correct answers.

In his turn of talk, Isaac offered an explanation for the uneasiness that Kay highlighted in small group presentations to whole class. He highlighted the existence of a) class demography to include physics majors and non-physics majors as one factor that might contribute to a presenter's uneasiness b) different levels of identities such as passion to learn the content and presentation skills. Isaac explained: "Considering the demographics of this class, like not everyone is from physics or engineering or people who want to go into that, I do get a little nervous because people who are more passionate and outspoken …" This suggests status associated to a major.

For David these presentations were a "no-risk" part of their studio experience: "To be honest, he (referring to the instructor) only picked you if you got it right. So, there is no risk (laughing)." David's mention that the activity had no risk to it sheds light on how he participated in the discourse. There was no room for risk(s), even getting an answer wrong in the sense-making activities centered on the tasks was a risk to be avoided. David's perspective on risk(s) offers insight into why the negative gender interactions were such that David often dismissed Kay's perspectives which he evaluated as wrong or of no epistemic value. David noted that the instructor's selection of small groups whose work he (the instructor) may have expertly evaluated to be correct took any risk out of the activity. Could that be the only reason why it might be a risk-free experience? But what if it even had a risk to it? Kay offers an interesting perspective.

For Kay, presenting small group work to the entire class was a mini teaching practice. She highlighted the epistemic value in taking risk in the form of being wrong; a learning resource which supports activation of canonically correct content when there is need for recall.

> Well, that's the same like teaching. In the same way, even if you are wrong. it's still like (.). I know (.), for me and what am doing (referring to her physics-education major), it's almost better sometimes when you are wrong because it's something that is memorable in the classroom. Like if I go up and say 'it's this divided by this (gesturing) whereas it's this multiplied by this', everyone would remember that when it comes to the quizzes. Like, o, that girl who said it wrong. that's the wrong way of doing it. Like, it's always memorable. it's like a learning moment. But from the flip side, it's just feels like you are telling everyone the right answer. Like, hey, this is the right answer, you can write it down. If you do write it down, you get points. it's like (.) I don't know, it like goes both ways.

Kay's perspective which indicates the epistemic and pedagogical value of 'being wrong' elicited David's normalization of 'being wrong'. He mentioned the occurrences of the presentation of wrong answers during the activity:

> I don't think you have to be particularly good because 90% of the time when you go up there, you are just like so wrong: Here is what was given to us, here is the equation we plugged it into, here is what you get when you put into your calculator.... three points, let's go (clapping his hands excitedly and laughing).

So, with Kay's presentation of her own perspective on the epistemic value of 'being wrong,' David revised the perspective he had shared prior to Kay's views. He became more positive on the epistemic value of canonical incorrectness.

Meanings attributed to roles, tools and the labs. All participants stated that roles emerged spontaneously; without formal assignment by members to specific roles. This insight on roles emerged from the following conversation.

> **Researcher:** My next question is this: I noticed that across all your groups, people were playing different roles at different times. For example, someone records your works on the whiteboard or your group report notebook, or sometimes when you go up to present, how do you choose who leads the presentation? Like who does the talking while you are all there. Or sometimes, somebody does the setting up of the equipment? How did you get to determine who played what role?
>
> **David**: So, for presentation, usually it goes something like —' I am not doing it.' Then, someone else says 'I am not doing it.' Then the third person has to do it."
>
> **Kay**: I feel like ...We did not really have a conversation about who is doing what. It just happened every time. Like when I walked in, I got the materials, set it up, like got things set up, go grab the white board and like record it on there. And then, he (pointing to Isaac) works through everything, like clarifies everything before we turn in. We kind of like do the calculations. It's not like you do the calculation. We all kind of like do the calculations (gesturing). The circuit-building was like team effort. Like, hey, what is going on?

Kay highlighted multiple roles that the group members assumed: She mentioned her own roles in the setting up materials for the lab, Isaac's role as the recorder who took notes (their lab report) and made sure it was ready for submission. Then she concluded with shared roles — the math-based routines (calculations) and the building of the circuits. It is interesting to note that Kay did not mention any specific role played by David. These multiple roles indicate discursive positions (Golsalves, 2014) in the epistemic space.

Kay mentioned the white board as one of the tools she had to convey to the group's work-station in her multiple roles to foster the group's work. According to Kay, the white board offers a place for the “messy work of knowledge-construction, creating needed space for mistakes which are important for cognitive growth. the board was necessary for her doing of science. She drew on her high school experience to illustrate the importance of this tool.

> In my notes from high school experience, you are not allowed to use pencils, you ‘ve got to write everything in pen. I kind of took the white board on the table as the place to do the rough work and my paper is the final work. Like, this is actually how it’s supposed like to go. If they had taken the white board away from me, I wouldn’t have known what to do (giggles). Because, that is like what I know how to do (laughing). So, I like the white board because it is not permanent — it’s okay to make mistakes and stuff like that. It’s kind of like, for me it’s more comfortable. I am like — It is okay to make mistakes on my white board. It’s not okay if I make mistakes in my final draft.

So, the white board helps to scaffold Kay’s doing of science — explaining and communicating.

Similarly, Isaac stated his perspective on the place of the white board. For him, the white board was an important tool, relevant for illustrating ideas to the group during discourses.

> I think the white board is a good thing for our group because it is a great way for us to illustrate our ideas together. Because, if you are writing on paper, there is one piece of paper, allowing one person to write. So, with the white board, we can kind of visualize what is going on.

The white board offered a shared space for epistemic work. In contrast, David’s perspective was contained in just a word in response to a woman in another group but who participated in the focus group interview. She said: “If you don’t have the white board, you can’t go up to present”. Then David responded: “No” (laughing). Here, David seemed to agree that the white board was important, but he seemed to joke about the topic, thus, making it unclear if he really considered the white board as a necessary tool. This makes sense with his epistemological views of right and wrong — leaving no need for messy sense-making.

Though Isaac had a positive perspective on the importance of the white board, he was critical of the quality of the tools they used in the studio physics class. He considered them imperfect and frustrating; adversely impacting the quality of his group’s results.

> I think, first, it (referring to the learning experience) was kind of frustrating. For some other reasons for me, this is one of the classes I think we used imperfect systems to model whatever, ideal phenomenon. So, in the first month and a half however, our systems were somewhat imperfect that it impacted a lot of our results. It kind of hindered a lot of our progress because we thought we got results that were weird but (.) Either we had to change bulbs or whatever it was or wires. So, we had resistance that would throw off our numbers... So, there were lot of things that really stalled our progress in that month and a half. We could have done better by either just better equipment or just for that month and a half do youtube videos. So (.), however, from then on, I feel that a lot of the things we used were good to model the systems that we learned.

Isaac mentioned youtube videos as a possible alternative to accomplishing learning centered on the concepts the verification labs were designed to teach. Isaac's statement describes the messy nature of science learning, but he indicated an intention to escape this messiness via watching instructional youtube videos. This indication suggests that Isaac may be conceptualizing learning (at least in this instance) as presentation of information to the learner.

This perspective presented by Isaac prompts the question in my mind: How might youtube videos replace real time investigations? It is true that learning involves presentation of/access to information but mere access to information and recall of information is in the lowest level of the cognitive ladder (Adams, 2015; Tekkumru-Kisa et al., 2015). Such instructional videos may be a starter stimulus such as during emergency teaching as experienced by teachers and students during the covid-19 pandemic. However, instructors must go beyond mere presentation of stimulus to orchestrating active cognitive engagement in critical thinking, utilizing real time investigations that do not shield students from the messiness of *doing science [physics] (*Danielsson, 2012*)*. Isaac expressed his view in response to David's perspective on the question of how each of them experienced the verification labs. So, David's presentation of his perspective was prior to Isaac's but for the sake of the flow of the narrative, I presented Isaac's response before David’s. David did not think the verification labs had much epistemic value. He said:

> I don't think the labs were so useful. I know the whole principle of studio is that you do hands-on, you play with stuff and you learn. You know what I think is better in comparison with the circuits? Watching a youtube video. I am dead serious (laughing). I don't think there is that much (.), at least for me. I don't think I get as much from labs. Any time we do labs, we spent like two hours, recording all these data. For instance, we did one on electromagnetic induction, where we are dropping a magnet in an electric field, I think I could have learned that principle in a 7-10 minutes youtube video. Like why would I (.), why do we need to (.)?

So, for David, the hours spent gathering and recording data were not productively spent. He argued that he could have learned the same physical principles targeted by the labs in less time by watching a youtube video. Could these meanings he attributed to the labs be the rationale behind his predominantly negative gender interactions during the discourses? It is interesting to also note that David did not explain what he meant by “learned” a physical principle to the exclusion of the practices of science [physics]. Current framing of what it means to learn science (NRC, 2012) emphasizes the integration of students learning of cross-cutting concepts, core ideas, and engagement in the practices of science such as observing, asking questions, analyzing data etc. Engagement in the practices of science offers the opportunities for learners to experience the messiness of science. This messiness in itself has cognitive and epistemological value. So, David’s idea of what it means to learn science deprives learners of this invaluable benefits of the messiness of science.

For Kay, what does it mean to learn? Kay’s response to what the verification labs meant to her offer some insight into her own conceptualization of what it means to learn (i.e., her framing of learning). In order to explain what it means to learn, Kay distinguished between knowing and understanding. For her, the Labs offered a needed context for her to understand while the tools (e.g., the white board) within the lab were important for her to know stuff. Understanding was needed for long term physics identity development which she framed in terms of her pursuit of physics-education as her majors. In contrast she defined ‘knowing’ in terms of checking off a list.

> (Cutting in) I like to look at the difference between knowing and understanding. A(.)s for me personally, I can understand through the labs, but I can know what I need to do through things like the white boards. To be honest, for this class, you just need to like ‘know what’ to be able to pass the quizzes. For me, I am furthering with physics as my major. So, it is very important for me to like, understand what is going on. So, I think knowing is perfectly okay for this class, to like, check it off your list. None of you guys are like physics majors. Right? To pass the class and to like, have a general idea of what is going on. You can't just do like white board and just get it. To really understand it, you have to do those labs (gesturing to convey emphasis).

In Kay’s experience, knowing was sufficient to pass quizzes in the class, but understanding was important in order to both pass the assessments and have a general idea of “what is going on.” It is interesting to note that Kay’s framing of learning emphasizes the conceptual while excluding the practices of science [physics] such as modelling phenomena, designing and conduction research, communicating research etc.

Meanings attributed to the gender dynamics, and the TA’s role. In order to specifically gain insight into the meanings participant attributed to gender interactions in the group I asked: “As a person, do you think you had enough opportunity in your groups to share your knowledge in your group or contribute?” After asking this, there was some silence for almost 30 seconds, with participants looking at each other, some nodding, then sudden break out into smiles and laughter. There seemed to be hesitation to break the ice on this very part of the conversation. Isaac highlighted the inequitable nature of discourses in the group, stating this in the form of what they could have done better. He also alluded to his equity awareness as ‘standing back’. He said:

> I think in my groups, we could have contributed more equally. I think I definitely stand back compared to them (referring to Kay and David) because they did more of the dirty work, and I feel comfortable from the position because I feel like if something goes wrong, I can look from outside (gesturing with cupped hands and raised arms to illustrate 'outside-in') and say: Okay, how do we consider this thing going right: How should we like do the wiring? Is it the frequency? Or things like that.

Isaac stated that he was comfortable playing the role he did during the group work (i.e., recorder) while positioning himself as an extra pair of eyes to check the group's work and thinking through possible ways to resolve epistemic uncertainty. Isaac revealed he was intentional at standing back while letting Kay and David do the more complex work ("the dirty work"). However, he gave credit to his peers who did the "dirty work."

David did not contribute to this very conversation. So, in attempt to elicit his voice while intending to specifically focus on gender dynamics I asked. the following question.

> **Researcher:** "When you have the opportunities to make your contributions, what were your group members responses and how did you see such responses?"

Isaac described the nature of the interactions during the discourses and provided a rationale behind how the group orchestrated the discourses. "There was a lot of pushback. Like, in 90 mins of a class, I think it is important that when each of us makes a claim in a group, we try to challenge each other and if the claim stands up to the push back we say the claim is valid, we write it on the paper, we move on."

In addition, Isaac revealed that though the gender dynamics were heated at times, there was nothing overboard; only epistemic differences and negotiation. He continued: "We 've done a great job of not going over that line of being suspicious of each other. We are really trying to confirm that things go well and that over all the response was good. When we do our labs, we all go home friends."

As Isaac seemed to pause, Kay cut in, introducing her perspective on the TA's role during the discourses:

> Yea, and I think that another reason why the TAs were so helpful is that even if like if we got something and he (referring to Isaac) or they (pointing to Isaac and David) got something and I didn't, they can like understand everything and I can like raise my hand (raising her hand) and ask the TA real quick so that I can like bounce the idea back, just like we are not like 100% convinced yet. So, I feel like that was another good aspect of the TA.

Kay indicated that the role of the TA during their interactions to learn was resourceful and effective especially during their navigation of epistemic uncertainty. It is interesting to note that Kay did not even make an indirect reference to the negative gender interactions she experienced, rather, she highlighted the active positive interactions she orchestrated, largely characterized by collaborative work, and supported by the TA whereas David still did not contribute to this very conversation.

Another turn of interview question offered me a possible chance to gain insight into David's thought, so I asked:

> It's kind of interesting to me, like on your different perspectives... for example, as a woman, considering what you bring to the table, I mean your group. I don't know if I interpreted your perspectives well. Like there were times I would think to myself: Okay, this is the group of so and so and so, and they are all girls, or you (referring to the group of Kay, Isaac, and David) and the men are in the majority, and she, she, and he (referring to another group) in which the women are in the majority. I am kind of curious (most participants laughing, and I did too) was there anything that played out in relation to that?

I framed this question this way because the focus group was made of multiple small groups. Isaac cut in, highlighting his gender equity awareness while distinguishing between equality and equity. Isaac mentioned "a huge culture of not equality and equity." It makes sense to interpret this as meaning the importance of gender equity, describing it as a "huge culture." By the use of the phrase "not equality," it also stands to reason that Isaac does not mean that equality is not important, rather, he excites the mind to ask the question: How can there ever be gender equality without gender equity? He also indicated “harsh criticism” of women (in contrast to constructive criticism) as a hinderance to gender equity, mindful of according them due respect in contrast to perpetrating micro-aggressions against them.

> Usually (.), I kind of like watch where I stand because for women in STEM especially like (.), there is a huge culture of (.) not only equality but equity really. Definitely, like, I just have to give them their respect and space they need really because (.) any harsh criticism that comes out of my mouth can easily be misconstrued (swaying his hand in the air) and be taken as offensive and not forgotten.

In order to conclude his perspective on gender equity, he drew on his own experience and social interactions outside of class as a rationale behind his awareness of gender equity: “a lot of my friends are women that I hang out mostly with, I just have to be super conscious about these things.”

Having heard one of the men’s perspective, Kay took the floor. This time around, she was forthcoming with the meanings she attributed to the negative gender dynamics. She drew on her experience of negative gender interaction in a group within a previous studio physics class as well. Kay called out some characteristics of negative gender interaction she experienced—being ignored by her male peers, and playing supportive roles only. She stated:

> I know that (.) I took studio for the first semester. I was in a group; I was in a table of all males. And trying to say anything (emphasizing the difficulty of even contributing) I would literarily be ignored sometimes. I would like come into this class and am like, am' going to fight, am going to literarily yell my ideas until they listen to me (most participants laughed), so am going to do it. And not like, you (referring to herself) can just write everything down, take down notes for the group, then the males are going to do the experiment. I am like I want to understand (raising her hand).

She highlighted how she navigated the experience; determination to exercise her agency by making her voice heard, refusing to choose roles that were merely supportive to the men, and contesting roles gendered in favor of men such as control of lab equipment. She contested this gendering of roles by engaging in the experiments as resources for doing science.

David's perspective on negative gender dynamics was communicated in his refutation of another woman participant's interpretation of how he (David) engaged in the discursive interactions. She said:

> Like, I was in a group of two guys (referring to two men with whom she was once in the same group— David was one of those men) that are not equitable. They didn't even listen to me. I was like 'no', 'no'. I don't think it went well either. (One of the men in the same group looked towards David, because that was the group the woman was talking about).

She evaluated the interactions as a negative experience she had, and concluded it was orchestrated by the men, especially David. In response to the woman's evaluation and conclusion, David cut in: "I don't think that was the motivation. I am just pushy that everyone be equal, so you might as well say whatever you want." David rejected the woman's interpretation of his framing of participation in the discourses as an orchestration of negative gender interaction. In fact, he argued that he was pushing for equality, and dismissed her perspective as a mere expression of her opinion to which she was entitled. It is not clear how the instance of David's participation cited by the woman amounts to pushing for equality.

Isaac responded to David's refutation. His response offered a contrast that shed more light on the meaning attributed by the woman to David's discursive engagement as truly negative. In fact, Isaac validated the woman's interpretation:

> I think context does matter because if I say I treat everybody equally and I am equally harsh to everybody (David said "yea" loudly), it's going to come up differently and that will definitely happen. That's just because if I treat them (referring to women) differently for example Kay (pointing to her), that (.), because there is just the precedence that being harsh to women is something we want to get rid of whereas if I say it is okay with him (pointing to another man in the referent group), because guys can take it, that's also a culture I want to get rid of. But being harsh to women is something of specific focus.

So, Isaac pushed back on David's claim to orchestrating equality in his discourses, challenging his conceptualization of equality. He (Isaac) advanced the conversation, that gender bias either by a man against a woman or a man against a man is not acceptable.

Summary of Findings for Research Question 2

The findings from this second section of data analysis deepen insight into gender dynamics in the small group within the scale-up context, and reveals participants' epistemological framing of discursive interactions, tasks, tools, the labs in general, TA's roles, and learning. I will engage in illustration of the emerging deeper insights during the discussions in the next chapter where I will highlight connection between findings from the two research questions. For example, guided by the first research question, I found that the men were asymmetrically involved in both the active positive and negative gender interactions. This indicates how they were engaging in the discourses. But why this asymmetry? In trying to make sense of why this asymmetric involvement in the gender interactions occurred, the men's conceptualization of what it means to learn and their approach to the tasks in order to learn, their perspectives on the messy nature of the doing of science, and the epistemic value or otherwise of being canonically (e.g., conceptually) wrong during sense-making — are all important for understanding this asymmetry. In this second section of the data analysis, multiple layers of findings emerged. Participants revealed the meanings they attributed to presentation of small group work to whole class, their own roles, tools they used, and the verification lab, gender dynamics and the TA's role. These meanings are important for understanding why they participated in the discourses the way they did.

In addition, the inclusion of this second question (and the data required to answer this question) contributed to the trustworthiness of my research (Guba, 1981; Lincoln & Guba, 1985) especially through the criteria of triangulation of data and member checking. In other words, this one more step in the data analysis process further enriches the trustworthiness of this research. So, I did not rely on my own observation data and interpretation of that data on discourses only**.** Rather, the participants' own words were an invaluable source of data. Second, my participants' interpretations of the discursive interactions and the role of gender dynamics during those discourses provided a way for me to check my own interpretation of the observation data. That is, in the light of the meanings they attributed to those interactions and all the other foci of data gathering such as the use of tools, and the roles played by the TA, I had additional opportunity to boost the quality of this research through the criteria of credibility, confirmation and/or [refutation] of my own interpretations. The meanings offered insight into how the participants interacted during the discourses (their approach to the discursive stuff), suggesting framing-dynamics exploration in the next sub-section.

Research Questions 1 and 2: Gender Dynamics and Epistemological Framing

It is interesting to note that the meanings which participants attributed to discursive interactions, tasks, tools (e.g., white boards), the labs in general, the TA's roles, and what it means to learn (i.e., their approach) revealed some insight into how they participated in the discourses— suggesting the emergence of *epistemological framing* (Hutchinson & Hammer, 2009). This very important insight highlighted the need for yet another iteration of data analysis on the observation data in order to explore how patterns of gender dynamics may have shaped or not shaped epistemological framing or vice versa.

This iteration of data analysis is therefore an act of letting my two research questions 'talk to each other' or putting them in conversation with each other in a specific way (i.e., gender dynamics and epistemological framing). In Tables 8-11, I present analysis of data on each of the three participants, thus, supporting the theme that anchors findings on participant's epistemological framing. My analysis revealed that although participants differed in how they framed discursive interactions, tools (e.g., white boards), the labs in general, the TA's roles, learning, their epistemological framing of tasks were generally productive. In a productive framing of epistemic discourses, participants engage in explanation and navigate epistemic uncertainty. Both of these are important for making sense of phenomena (Hutchinson and Hammer, 2009). This productive epistemological framing persisted across most of the episodes regardless of the kind of gender dynamics that occurred. Their predominant pattern of participation in knowledge-construction was explanation in order to make sense of the circuit configurations (see Tables 8-10).

Across all 20 episodes I explored, there was only one episode (episode 11) that did not have explanation as a form of participation. David was focused on checking for correctness of his mathematical model of circuit configuration and the equivalent resistance. During this episode, David orchestrated an active negative gender interaction in which he was not mindful of being inclusive of Isaac and Kay, giving no room for them to take any turns of talk to contribute, and manifesting negative affect (i.e., raising his voice, visibly angry).

I now present in tabular form, each participant's framing of the discursive interactions, learning, use of tools, labs, their roles and the TA's roles.

Table 8: Kay's epistemological framing

Episodes	Gender Dynamics	Items Framed	Epistemological Framing	Example Data
Across episodes	Active negative	discursive interaction	contestation of gender inequity	"I would like come into this class and am like, am' going to fight, am going to literarily yell my ideas until they listen to me."
Across episodes (e.g., 8 Focus 1)	Active positive	task	explanation to make sense of circuits	"It looks like this one is okay, because it says in series or in parallel. A is in series with B, and the system is in parallel with C. So, I think that one... (expressing her choice from the given options in a multiple choice). And is asking if there is any that are connected."

Table 8: Continued

Episodes	Gender Dynamics	Items Framed	Epistemological Framing	Example Data
Across episodes		tools (e.g., white boards)	'place' for messiness in knowledge-building	"I kind of took the white board on the table as the place to do the rough work... If they had taken the white board away from me, I wouldn't have known what to do (giggles). So, I like the white board because it is not permanent — it's okay to make mistakes and stuff like that."
Across episodes		TA's role	helpful support for knowledge-building	"The TAs where so helpful is that even if like if we got something and he (Isaac) or they (pointing to Isaac and David) got something and I didn't, they can like understand everything and I can like raise my hand and ask the TA real quick..."
Across episodes		learning	knowing versus learning	"To be honest, for this class, you just need to like 'know what' to be able to pass the quizzes... For me, I am furthering with physics as my major. So, it is very important for me to like, understand what is going on."

So, across multiple episodes, Kay framed discursive interactions as contestation of gender inequity, tasks as activities which require explanation of the circuit configurations. For her, the white board was the place for messiness in physics inquiry, within the contexts of the labs as the medium for learning. Learning for her consists of knowing and understanding, supported by the TA to navigate epistemic uncertainty in order to construct knowledge.

For Isaac, discursive interactions were contexts that revealed gender dynamics that called for orchestrating interactions that leverage priority of equity for women while mindful of equality in the terms of recognizing that men too can suffer inequity. So, for Isaac, it is equity for all, but first for women. This is illustrated by the example data (Table 9: column 5 of row 1).

Then, like Kay, Isaac framed tasks as requiring explanation of circuit configuration, tools (e.g., the white board) as a 'place' for shared illustration of ideas or thinking.

Table 9: Isaac's epistemological framing

Episodes	Gender Dynamics	Items Framed	Epistemological Framing	Example Data
Across episodes		discursive interactions	building epistemic consensus for equity and equality of participation, first for women, but also for men	"if I say I treat everybody equally and I am equally harsh to everybody, it's going to come up differently and that will definitely happen. ... if I treat them (women) differently for example Kay, that (.), because there is just the precedence that being harsh to women is something, we want to get rid of whereas if I say it is okay with him, because guys can take it, that's also a culture I want to get rid of. But being harsh to women is something of specific focus. So, I think being equally harsh to men or women might be considered as some sort of obstacle"
Across episodes (e.g., 1)		task	explanation to make sense of circuits	"Specifically, A and B are not each parallel with C, just that A & B as a system is parallel with C."
Across episodes		tools (e.g., white boards)	a 'place' for shared illustration of thinking	I think the white board is a good thing for our group because it is a great way for us to illustrate our ideas together
Across episodes		the labs generally	context for unmessy inquiry	"So, there were lots of things that really stalled our progress in that month and a half. We could have done better by either just better equipment or just for that month and a half do youtube videos."
Across episodes		learning	unmessy inquiry and information acquisition	"I think, first, it (referring to the learning experience) was kind of frustrating... It kind of hindered a lot of our progress because we thought we got results that were weird..."

For him, labs are good but not unnecessary if messy, and learning is unmessy inquiry and acquisition of information. It is interesting to note that the role of the TA was not included in the analysis of Isaac's framing. This is because there is no referent data from Isaac in this regard. Even though Isaac appreciated the supportive role of the TA (e.g., "thank you" — see line 135) in their navigation of epistemic uncertainty, there was no instance when he took the responsibility of inviting the TA's presence.

I now present a table to illustrate my analysis of David's epistemological framing. For him, discursive participation needs to be approached by 'being pushy,' tasks are activities requiring explanations to be free of mistakes by drawing on the TA's support to navigate and resolve epistemic uncertainty in order to learn. He framed the labs themselves as not useful for learning. Rather, the labs were a waste of time and this waste of time can be avoided by acquiring information through video media on youtube to learn, which David claims is time efficient for learning.

Table 10: David's epistemological framing

Episodes	Gender Dynamics	Items Framed	Epistemological Framing	Example Data
Across episodes	Active negative	discursive interaction	"pushy" for equality	"I am just pushy that everyone be equal, so you might as well say whatever you want."
Across episodes (e.g., 8 Focus 1)	Active positive	task	explanation to make sense of circuits	"Then, I will say B & C (referring to circuits) individually (gesturing with his hands apart) are not connected in parallel.
Across episodes		TA's role	support for navigating epistemic uncertainty	"Okay, okay, I understand that. Can you just look and see what my math is trying to get at?"

Table 10: Continued

Episodes	Gender Dynamics	Items Framed	Epistemological Framing	Example Data
Across episodes		the labs generally	Labs not useful nor time efficient	"I don't think the labs were so useful. I don't think I get as much from labs. Any time we do labs, we spent like two hours, recording all these data."
Across episodes		learning	learning as information acquisition	"... we did one (referring to lab) on electromagnetic induction, where we are dropping a magnet in an electric field. I think I could have learned that principle in a 7-10 minutes youtube video. Like why would I (.), why do we need to (.)?

It is interesting to note that David did not say anything to indicate his framing of tools. However, observations of his participation during work on tasks in the small group showed him making use of the white board, sheets of paper to illustrate his ideas/thinking through diagrams. These suggest that David considered tools as important for knowledge-building in the small group.

I constructed Tables, 8, 9, and 10 based on my exploration of both the observation and interview data. I specifically looked deeper into transcripts of all 20 episodes on the observation data. This iteration of data analysis was with an eye to epistemological framing as anchored in the meanings students attributed to multiple aspects of their participation in discourses (see Table 11for episodes 1-5).

Table 11 is intended to illustrate the data analysis work needed to achieve the goal of highlighting each participant's unique framing of discourses during tasks as well as the epistemological frames that were shared by all participants. (See appendices I, J, and K for same analytic work centered on episodes 6-16).

Table 11: Participants' epistemological framing during discourses

Episode	Patterns of Gender Dynamics	Meanings Attributed as revealing of each participant's framing of discourses during tasks			Predominant epistemological frames
		Kay	**Isaac**	**David**	
1 Mixed	Active Positive	Discourse as collaboration (e.g., setting up equipment), and metacognitive evaluation - "I think they just want us to compare em (.) this with this one"	Discourse as collaboration "Is everyone on the same page?" "So, what's going on?"	Discourse as collaboration setting up equipment	Discourse as collaboration, and metacognition,
	Subtle Negative		inequitable validation		
2 Mixed	Active Positive	navigating uncertainty, offering explanation	discourse as explanation, building consensus	discourse as explanation	navigating uncertainty collaboration (setting up of equipment), explanations,
	Subtle Negative	negotiating gender and physics	inequitable validation		
3	Subtle Negative	negotiating gender and physics (through positioning peers as competent by asking multiple questions to them), TA as resource	Self-positioning—data recorder	discourse as evaluating (Kay's explanation)	positioning, TA as support
4	Subtle Negative	negotiating gender and physics (by positioning David as more competent, presenting her explanations with hedges)	Self-positioning—data recorder validating group's work	providing explanation, confident self-positioning (but less competent positioning of kay)	positioning, metacognition, navigating uncertainty, explanations,

Based on Table 11, negotiation of gender and physics was peculiar to Kay, self-positioning as recorder of constructed knowledge was Isaac's main epistemological framing, and discursive explanation and inequitable evaluation characterized David's framing. However, all participants shared discursive explanation as a framing of epistemic discourses.

Indeed, in addition to discursive explanation, across the episodes, discursive collaboration, metacognition, positioning, and navigating uncertainty were shared by all three participants. These characterize productive epistemological framing found across most of the episodes. Across all the episodes explored, there was only one episode (episode 11) that did not have explanation as a form of participation. In this episode David was focused on checking for correctness of his mathematical model of circuit configuration and the equivalent resistance. During this episode, he orchestrated an active negative gender interaction in which David was not mindful of being inclusive of Isaac and Kay, giving no room for them to take any turns of talk to contribute, and manifesting negative affect (i.e., raising his voice while visibly angry in multiple turns of talk with the TA). I wondered if negative gender dynamics helped or hindered discursive explanation in a small group. I turned to episode 15 since it had the most observable indicators of negative gender interaction. It was in episode 15 that Kay and David ended as follows:

> 347 **David:** No, (shaking his head and hands, while raising his voice), not this.
> 348 **Kay:** All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: "no, no, no."

In episode 15, Kay and David had epistemic differences making sense of a circuit configuration about which they were uncertain whose idea was correct. It is interesting to note that this episode with active negative gender dynamics had the highest occurrences of explanation (11in all). That said, this episode was a mix of both productive and unproductive epistemological framing given that Kay engaged in discursive explanation but had to negotiate gender and physics in efforts to resist David's epistemic dismissal framing as an unfortunate route to discursive explanation. So, though episode 11 was characterized by negative gender dynamics, there is no evidence to suggest that it lacked explanation as a productive epistemological framing because of the negative gender dynamics. Rather, it makes sense to think that David's framing of the interaction as doing school rather than equitably engaging in sense-making with peers may have played a role.

Summary of Chapter Four

In this chapter, I presented findings which emerged from my analysis of data in the form of audio/video recordings of observations of discursive episodes and focus/individual interviews.

Work in this chapter consisted in a general description of — students' interactions, categories of gender dynamics, instances of these gender dynamics (active positive, active negative, subtle negative, and mixed). In order to highlight the dynamics in/across episodes, I tallied participants turns of talk while grouping the episodes according to time segments and mapping the occurrence of the gender dynamics across the tasks.

The following findings emerged from my analysis of data: The woman in the group orchestrated positive gender interactions, the TA was effective in supporting positive gender interactions, but not successful at alleviating negative gender interactions. The men were asymmetrically involved in active positive and negative gender interactions, with subtle negative gender dynamics being the predominant form pf negative gender dynamics. The subtle negative gender dynamics occurred sequentially after the active positive gender interactions in mixed episodes. In order to gain deeper insight into the gender dynamics, I analyzed transcripts of the focus and individual interviews. Findings suggest that the participants differed in the meanings they attributed to presentation of their small group work to the entire class, the tools, their roles, the TA's role and how they framed the discourses. However, their epistemological framing of tasks was generally productive across the episodes; the epistemic discourses were predominantly in the forms of explanations, navigating uncertainty, and metacognition. In the next chapter, I present my discussion of these findings.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

The research centered on a purposefully selected small group consisting of one woman and two men in an undergraduate course within a studio physics context and I explored the woman's experiences in the select small group. This exploratory single case study had a two-fold purpose — to identify and describe patterns in gender dynamics, and to understand what meanings students ascribed to the gender interactions and related aspects. Using socio-cultural theory and discourse analysis as theoretical lenses, I analyzed interactions of the heterogenous group across 20 episodes of discourses, and interviewed the participants in a focus group. In my analysis of discourses, I searched for findings in the forms of emergent themes that reveal gender dynamics while in a focus group interview, I also sought to know the meanings they ascribed to the discourses, meanings which had potential to reveal participants' epistemological framing of discursive interactions, tasks, tools, the labs in general, the TA's role, and learning. Socio-cultural theory (Vygotsky, 1978) serves the purposes of this research because of its emphasis on social interaction and my focus on gender dynamics in a small group which manifests in interaction in a group during gender performance. Gender equity is unmasked in the social interactions involving the participants, not in the This is one of the reasons I used socio-cultural theory as my theoretical framework. Furthermore, positioning and roles are constructs that are implicated by both sociocultural and gender equity lens. Positioning and roles were important for unmasking micro-aggression during subtle negative gender interactions. Similarly, the constructs were critical to revealing epistemic dismissal and disrespect during active negative gender interactions orchestrated by David. These unmasking and revealing depended on how participants positioned themselves during discourses in the small group. So, they fit into my theoretical framework which had implications for analysis, thus reinforcing discourse analysis which was key to my analytical approach.

In relation to gender dynamics, findings suggest that the woman (Kay) orchestrated all active positive gender interactions by fostering collaborative work in the small group during discourses. The TA was effective in supporting positive gender interactions, but not successful at alleviating negative gender interactions. In contrast, the men were asymmetrically involved in both the positive and negative gender interactions, and subtle negative gender dynamics were the predominant forms of negative gender interaction. Also, the subtle negative gender interactions occurred in association with the active positive gender interactions; the former almost always after the latter in order of association.

The findings suggest that participants differed in the meanings they attributed to presentation of small group work to whole class, discursive interactions, tasks, tools, the labs in general, the TA's role, and learning with insights into participants framing, but they were in agreement on the whiteboard as a tool, how the roles emerged in their small group, and the TA's role as supportive. The different meanings are important because they deepen the insights into the gender dynamics and offer new ones into the participants' physics identities and epistemological framing of the different categories. In this way, this work offers possible interconnections among gender dynamics (with implications for gender equity), epistemological framing, and physics identity. These interconnections are both theoretically and practically important; theoretical because they advance a more wholistic conversation on gender equity issues in physics which though discusses physics identity and gender dynamics as intricately linked (Archer, Moote, Francis, Dewitt & Yeomans, 2017; Hazari et al, 2015), these two lenses are not clearly linked to epistemological framing as a lens or a construct. One practical importance of the interconnection among gender (in)equity, physics identity, and epistemological framing is that they functioned together to shape the experience of the woman (Kay) in the small group; experiences that will be impactful in the sense of hindering or helping a woman to persist or not in physics. In other words, underrepresentation of women in physis progresses or worsens one woman at a time.

Gender Equity, Epistemological Framing, and Physics Identity

I situate these findings in the context of the current conversations centering on gender equity, epistemological framing, and physics identity. This work of situating my findings within the larger literature of the science and physics education communities is important to make sense of my own research in terms of how it fits into the communities' conversations, and advances those conversations in terms of implications for research, teaching and learning, and perhaps social action as well. One of the emerging themes as a finding from this exploratory single case study is interconnections among gender equity, epistemological framing, and physics identity. Figure 15 illustrates this interconnection. Figure 15 speaks to the way in which gender equity shapes how students frame epistemic discourses (epistemological framing), which in turn sheds light on students' physics identity. In addition, gender (in)equity plays a role in whether students participation in small group discourses entails (a) physics identity **or** gender equity awareness (social identity) — doing physics or doing gender (Danielsson, 2012), (b) gender equity awareness **and** physics identity. Kay had to negotiate gender and physics, pushed by her experiences in the small group to choose between doing gender and doing physics but she resisted this dichotomy.

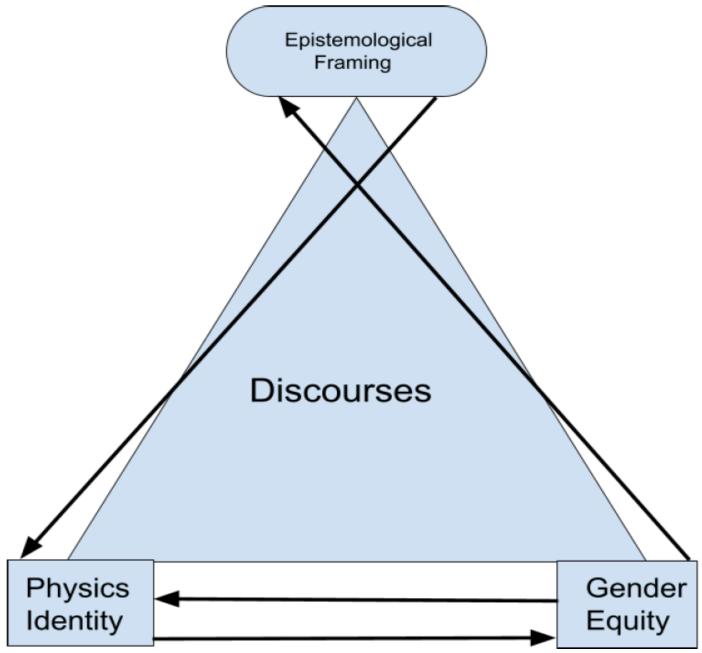


Figure 14. Interconnections: Gender equity, epistemological framing, and physics identity

Perhaps, I will refer to the latter as a social-disciplinary identity (which is desirable). Kay is an example of the power of socio-disciplinary identity as she operated her gender equity awareness, to frame discursive participation as contestation of gender as well as navigation of disciplinary uncertainty as important to develop her physics identity. This powerful picture is made panoramic by discourses. She said: "I am going to 'I'm going to fight, am going to literarily yell my ideas until they listen to me! ... . For me, I am furthering with physics as my major. So, it is very important for me to like, understand what is going on...." Students need not split their identities or choose between their social identity and their physics identity. Finally, Physics identity has implications for gender equity.

Gender equity means the absence of sex-based stereotypes and gender bias (covert or overt). This has serious consequences for students learning experiences, outcomes, persistence in physics and much more (Cromley, Perez, Wills, Tanaka, Horvat, & Agbenyega, 2013). "Gender equity in [education] is the elimination of sex role stereotyping and sex bias from the educational process, thus, providing the opportunity and environment to validate and empower individuals as they appropriate career and life choices" (Hilke & Conway-Gerhardt, 1994, p. 8, cited in Potvin et al., 2009, p. 843). This conceptualization of gender equity is not only true for the educational process at large, but the interactions that occur during epistemic discourses (such as in a group).

I adopt Dini & Hammer's (2017) conceptualization of epistemological framing as pertaining to how students approach learning, problems, tasks etc. It centers on their operationalized idea of — 'What is my task here?' in the contest of learning; their interpretation of "What is it that's going on here"? (Goffman, 1974, cited in Hutchinson & Hammer, 2008, p. 509). Epistemic uncertainty is necessary for a productive epistemological framing and is important for a productive disciplinary engagement in [physics] (Manz & Suárez, 2018; Watkins, Hammer, Radoff, Jabber, & Phillips, 2017). How one approaches engagement in science shapes what kind of science person one becomes — science [physics] identity. One's physics identity is one's construction of what it means to be a physicist? One needs to answer the question: What kind of person am I seeking to be and enact in the here and now? (Gee, 2000). The 'here and now' may be a discursive interaction, an entire physics classroom, during career considerations etc**.** In order to discuss the findings and proceed with the goals stated above, this chapter will be structured around a discussion of research question1, discussion of research question 2, followed by a consideration of the implications of these knowledge claims that I offer.

Research Question 1 Discussion

In this subsection, I discuss the findings in the light of the literature on gender (in)equity, physics identity and epistemological framing. This discussion is guided by the following outlines:

- Negative gender dynamics: Gender inequity and physics identity,

- Positive gender dynamics: Gender equity and physics identity,
- The meanings students attributed to the gender dynamics, presentation of small group work, tools, roles — in the light of their epistemological framing and physics identity

Finally, I highlight the research and pedagogical implications of the findings.

Negative gender dynamics: gender inequity and physics identity. Scholars continue to document the presence of gender bias and microaggressions against women in physics (Francis et al., 2017). This issue traverses K-12 (Eikerman & Rifkin, 2020), undergraduate (Kost-Smith et al., 2010; Nissen & Shemwell, 2016) and graduate (Gonsalves, 2012; Götschel, 2014) settings. Microaggressions are "subtle, stunning, often automatic, and non-verbal exchanges which are 'put downs' of [minoritized people] (Pierce, Carew, Pierce-Gonzalez, and Wills, 1978, p. 66, cited in Osanloo, Boske, & Newcomb, 2016, p. 3). According to Boysen (2019), microaggressions are subtle expressions of an underlying prejudice (hence the "micro" in the title). Examples of microaggressions include using racial epithets. In one episode described in Chapter 4, David disagreed with Kay's explanation in a turn of talk, dismissing her contribution as offering him no new epistemic insight:

345 **David**: (Giggling), I understand that. You are telling me things that I already know. I get that. (shaking his head).
346 **Kay**: Then, explain to me.
3 47 **David:** No, (shaking his head and hands, while raising his voice), not this.
348 **Kay:** All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: "no, no, no."

These data suggest microaggression by David against Kay in the form of David's denial of audience to Kay as indicated by shaking his head (meaning 'no') while denying the epistemic worth of her contribution. Kay's experiences highlight the continued prevalence of such hindering experiences in a small group even within a classroom context designed around a pedagogical innovation such as studio physics.

There is no consensus among scholars as to the promise of pedagogical innovations to improve student experiences, especially in relation to equity (see for example, Delpit 1998; Tal & Tsaushu, 2017). Despite this, research on studio physics has reported reduced failure rates for women and minoritized groups (e.g., people of color) in studio physics as well as in later classes (Gaffney, Richards, Kustusch, Ding & Beichner, 2008). However, this is still a problem because their failure rate is still higher than that of white men. Failure rate is determined based on achievement or outcomes through calculation of leaning gains. But I argue that to make fair sense of women's outcomes in a course, there is need to understand their outcomes in the light of their experiences. Those experiences result during discursive interactions which I have analyzed using the lens of Vygotsky's sociocultural theory because of its centering of social interactions shaped by culture and society. Those experiences are important because they inhibit or hinder gender equity, a much-needed conversation in studio physics. Students achievement in terms of learning outcomes is important but a focus on comparative achievement often quickly slides into preoccupation with what Lubienski (2008) has called gender gap-gazing. I argue that gender gap is one of the symptoms of gender inequity whereas there is the need to make more progress with gender equity.

Findings from this examination of gender dynamics within the small group suggest the presence of both active negative experiences (dismissal) and subtle ones (microaggressions) in Kay's experiences. In the face of these experiences which were asymmetrically orchestrated by her male peers, evidence from the interview suggests that Kay was determined to contest the male gendering of participation in physics discourses. She accomplished this by letting her voice be heard in a push for gender equitable participation and taking part in handling and setting up equipment—a typically male gendered role. Unfortunately, her determination was insufficient to stop or provide her immunity from these negative experiences. Thus, even with her efforts to orchestrate positive gender interactions, subtle negative gender interactions were nonetheless associated with these active positive gender experiences.

Despite Kay's determination to contest gender inequity, she was unsuccessful at overcoming the other forces. The nature of the interaction orchestrated by her male peers and their discursive positioning explain the emergence of these negative experiences. Isaac was more or less an ally with Kay, but to David, she was almost always positioned as an opponent. This disparity in the nature of their self-positioning and positioning of Kay had asymmetric consequences for gender inequity. Isaac was helpful in Kay's efforts to push against gender inequity, but he did not play this important role of an ally to Kay in every episode and this limited efforts to overcome inequity. In contrast, across multiple episodes, David's discursive participation often involved orchestration of negative gender interactions, thus, gender inequity across those episodes. The following data illustrates this orchestration.

345 **David**: (Giggling), I understand that. You are telling me things that I already know. I get that. (shaking his head).
346 **Kay**: Then, explain to me.
347 **David:** No, (shaking his head and hands), not this
348 **Kay:** All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: "no, no, no" (frustrated and gently banged her hands on her book in front of her).
349 **David:** It's okay, I didn't ask you to stop.

Student roles in small groups can be understood as discursive positions taken up by them, assigned to them or which emerge during discourses, with implications for gender equity. For example, Johansson and colleagues (2018) found three discursive positions that were accessible to the participants in their study. These were calculating quantum physics, exploring quantum physics, and applying quantum physics. In most physics departments, quantum physics is an upper level course. Yet, gender equity awareness was a scarcely discursive position accessible to students. So, in the case of women as students in physics, how can we expect them to successfully move to upper-level course when there is no productive, discursive position made available to them in an introductory level course? When the only discursive position made available to them based on social expectations in the group lack epistemic agency and thus sense making power? It is worth noting that despite her earlier negative experiences in physics, Kay would not give up her bid to be positioned as an active, sensemaking member of the group even in the face of her unsuccessful contestation against the forces of gender inequity in her small group. But I fear, that Kay is somewhat anomalous in her persistence.

A student such as Kay whose awareness of gender equity is part of her physics identity; what it means for her to do science and be a physicist includes her agency for gender equity — but it was difficult for kay to have a gender equity discursive position at the epistemic table at which the trio sat. Kay's competence and her self-positioning as such could not tear down the wall of gender inequity in the small group. To a very large extent, Isaac positioned her as competent but according to Gonsalves (2014) competence is insufficient as a means to be recognized as a physicist. Isaac had some awareness of gender equity, so, in some instances, he was successful at alleviating negative gender interactions. In contrast, David's self-positioning, his positioning of Kay as often offering him no new epistemic contributions during their discourses, alongside Isaac's in-and-out positioning of Kay as competent (while he is David's ally at times) add to the weight of evidence that "performance of stereotypical Discourses for physicist that relied on traditional gender norms for the field" (Gonsalves, 2014, p. 503) — remains active. In such moments when Isaac was David's ally but not Kay's, Kay was in epistemic dilemma to negotiate her doing of science and her gender equity identity at such times but determined to contest the male gendering of discourses.

It has been recognized that affect plays an essential role in the doing of science (Davidson, Jaber, & Southerland, 2020). So, it is also important to highlight the place of affect in the negative gender dynamics. According to Belcher (2007) students participating in the technology-enhanced active learning format of an electricity and magnetism course in MIT reported stronger positive affect and cognitive impact as a result of that participation in comparison to the lecture format of the same course. Findings from the work presented here advances Belcher's conversation by highlighting the fact that even within the same format, there are different affects. Belcher's work offered no explanations for the disparities in affect as reported by the participants in that study. In the case of Kay, Isaac and David, the interactions were both influenced by (and influenced) the participants affect. Positive affect was associated with positive gender interactions (e.g., excitement, laughter during such interactions) whereas negative affect (yelling at a peer) was associated with negative gender interactions. David often manifested negative affect when he orchestrated negative gender interactions and as Kay contested such dynamics, she too struggled to navigate negative affect and doing of physics. These manifestations, contestations, and navigations were often during discursive interactions that were characterized by epistemic differences. At such moments, Isaac often worked to build consensus. However, it is important to clarify that I am not saying all epistemic differences entailed negative affect on the part of David. There were occasions when Kay and David differed in their interpretation of circuit configurations. In order to work at resolving this difference, they turned to the support of the TA. Such moments highlight students learning of social skills.

Positive gender dynamics: gender equity and physics identity. Through her ways of participating in the discourses (her physics identity), Kay orchestrated positive gender interactions. These multiple ways in which Kay achieved this orchestration include leading peer conversations towards completing a task, building consensus to resolve epistemic differences, setting up of equipment, acknowledging peers' efforts or contributions, elaborating on peer's explanation, constructively and respectfully offering critique of other's ideas and responding to a critique against her ideas in a similar manner, mindful of other's sense of belonging, being inclusive in her language (e.g., "our", "us") and elicitation of others' voices to participate in the heterogenous small group. Carlone (2003) and Hazari et al. (2015) imply that these ways of active participation are positive not only because they foster students' learning of science content, but also because they make room for gender equity and shaping of learners' science [physics] identity. It is noteworthy that when Kay had to minimize her own voice to be heard by the men or had to qualify her knowledge claims, those were interpreted in this work as her navigation of subtle negative gender interactions, not positive ones. So, this study does not imply that anything that Kay did is interpretable as positive gender dynamics. In this study, I interpreted things a bit differently based on my identification of overarching codes in the forms of categories of gender dynamics (negative subtle dynamics in this case) which emerged from the data. Often, inclusive language may appear to be positive, but a closer look may reveal linguistic subtleties and socio-cultural nuances. A closer attention to the immediate context as well as larger societal contexts is also helpful to situate such interactions.

Carlone (2003) centered on a context within K-12, my work here advances our understanding of similar issues — gender equity in knowledge construction within small groups in an innovative context for undergraduate physics. This advancement is in multiple ways. First, it is an advancement in the sense of shedding light on what this issue looks like in an undergraduate physics context, and how both gender equity (awareness) and physics identity both provide a window into learners' epistemological framing of discursive interactions, roles, tools, learning. The second sense in which this work advances the field is that this exploratory case study calls to question some of the assumptions found in previous works (i.e., inclusive language is always positive). Research findings from both contexts are important for multiple reasons. For example, issues of persistence of minoritized groups in college physics begin to take roots right from the middle school (Tyson et al., 2007; White & Cottle, 2011).

Kay's orchestration of positive gender dynamics within the small group in scale-up takes the opportunity offered by the innovative context to leverage her alternative and (broadened) meaning of what it means to "do science" and be a "science person" (Carlone, 2003). In her orchestration of positive gender interactions, Kay contested the business-as-usual approaches to teaching and learning physics; such approaches do not consider the historical experiences and identities of the participants, forcing students to uncritically accept what it means to do science or be a scientist (Carlone, 2003). On the contrary, the ways in which Kay participated indicate her self-positioning as one who was determined to validate her gender equity and epistemic voices; not one or the other, rather, both as important for what it means to do science and be a science person. As was highlighted in chapter 4, Kay's response during the focus group interview indicates this socio-disciplinary identity.

> I would like come into this class and I'm like, 'I'm going to fight, am going to literarily yell my ideas until they listen to me! (most participants laughed). So, I am going to do it. And not like, 'you (referring to herself) can just write everything down' (take down notes for the group), then the males are going to do the experiment. I am like — 'I want to understand!' (Focus group Interview, 4/13/2019).

So, Kay's orchestration revealed that her agentic voice consisted in her inseparable gender equity and epistemic voice — doing science and her gender equity identity are inseparable.

Kay's experiences in discursive participation offers one instance that richly illustrates Vygotsky's social cultural theory helps to make social and cultural influences visible in shaping the experiences of learners in social interaction (here in small group) regardless of their age. It is noteworthy that Kay traced the history of her awareness of her agentic voice to her experience in a small group within a studio physics course she took earlier. This history of her experiences indicates that the social and cultural mainstream ways of participation — cultures of power (Barton & Yang, 2000; Delpit, 1998) which her orchestration contested (i.e., examples—not being listened to, being ignored, ideas disputed by others) were influential in shaping how she participated in discourses thereafter. Her experiences also indicate that these problems are not encountered in traditional science classrooms only. Indeed, the findings presented here suggest that this culture of power is present even in a small group within an innovative, research-based context. These findings point to a need to challenge any established social, historical, and cultural biases as experienced by Kay during gender dynamics in her small group within the innovative space. Such challenge is important in order to break barriers to equitable representation of women in physics (Lock & Hazari, 2016).

In order to overcome barriers to Kay's success in physics, there is need for small group discourses to leverage [her] identities in knowledge-building (Sabella et al., 2017). But how might this leveraging happen? Findings from my research contribute to emerging answers. For example, during discursive interactions, the available *discursive positions* (Johansson et al., 2018) and how they are taken up, assumed, or distributed will help or hinder gender equity. Kay pushed for active positive gender interaction in an introductory physics course. In doing science, she leveraged her socio-disciplinary identity [gender equity awareness and physics] in specific ways to push for gender equitable participation in discourses within her small group, however this leveraging had only partial degrees of success despite her efforts.

Research Question 2 Discussion

The participants' perspectives on what the discourses required them to do, their roles, the role of the TA during participation in those discourses in their small group, and their approaches to tasks, tools, learning, and the labs in general were helpful to gain insight into their epistemological framing of the discourses and all it entailed. I now focus on the participants epistemological framing in relation to gender dynamics during the discourses, and physics identity. As illustrated in Figure 15, gender equity issues emerging from gender dynamics during discourses was helpful for gaining insight into their epistemological framing which in turn helped to shed light on their physics identity.

Epistemological framing, gender equity, and physics identity. Extant research on gender in physics at the undergraduate level (e.g., Danielsson & Lundin, 2014; Quinn, Kelley, McGill, Smith, Whipps, & Holmes, 2020) indicate absence of specific focus on the construct of epistemological framing in terms of how gender dynamics in small groups reveal students' framing of discourses. Similarly, research centering on epistemological framing in quantum mechanics does not link with gender (e.g., Dini & Hammer, 2017).

Findings from my work indicate an emerging link between gender dynamics (with its gender equity implications in small groups and participants' epistemological framing, and physics identity. As highlighted by findings from data analysis (see Tables 8-10), participants varied in how they approached discursive participation. For example, Kay framed discursive participation as contesting gender inequity in the masculine gendering of handling and manipulating equipment, Isaac navigated gender equity issues and physics knowledge-construction by working to build consensus, and David framed discourses as having no room for wrong answers. However, as a group, their predominant forms of participation in knowledge-building consisted in discursive explanation — explanation of circuit configurations, struggling with uncertainties, and using metacognitive skills. Even though the students individually varied from episode to episode and from moment to moment in how they framed the activities, they were overarching consistencies which make for identification of emerging patterns in their epistemological framing.

Why the consistencies? Extant literature and research suggest that students epistemological framing are not stable ontological entities but are activated by contextual clues (Hammer, 2004, 2004a). So, context is very important for epistemological framing (Berland & Crucet, 2015). But what if the contextual clues are near-stable in what they activate? This is the case for the task the small groups worked on and may account for the emerging consistencies. The tasks activated explanation to make sense of the circuit configurations. Hutchinson and Hammer (2009) suggest that productive epistemological framing support student sense-making whereas unproductive epistemological framing hinders students' sense-making of the natural world. This framing of discourses (i.e., contestation, ally, no-room-for-wrong-answers) was shaped by their gender equity awareness. This insight aligns with Yaka (2019) who utilized a gender-framing lens in her research on anti-hydropower movement in Turkey.

The participants' awareness of gender equity and commitment or otherwise to gender equity revealed their epistemological framing during discursive interactions (see Tables 8-10) but also depicted in Table 12 (reproduced in Appendix K).

Table 12 Individual and shared epistemological framing during discourses

Episode	Patterns of Gender Dynamics	Meanings Attributed as revealing of each participant's framing of discourses during tasks			Predominant epistemological frames
		Kay	**Isaac**	**David**	
15 (F1)	Active Negative	discourse as negotiation— "Okay, I can redraw this." and consensus-building: "We will go back to it later".	discourse as self-positioning for consensus-building; "I don't want to move on without resolving this"	discourse as epistemic dismissal through negative affect: "we already said that it doesn't make a difference. Right? Like whenever it... Whatever, whatever..." (shaking his head in disagreement)	discourse as negotiation and self-positioning in the face of epistemic differences and conflict
15 (F2)	Active Negative	discourse as negotiation of gender and physics to navigate experience of negative affect—"All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: no, no, no"	discourse as consensus-building ("So... If I can find something that we can agree upon"	discourse as epistemic dismissal through negative affect: "No, (shaking his head/hands, raising voice), not this." (Giggling), I understand that. You are telling me things that I already know. I get that. (shaking his head).	discourse as negotiation through consensus0building to overcome micro-aggression
16	Active Positive	navigating uncertainty, through positive affect, and leading knowledge-construction, with TA as a support	navigating uncertainty, through inclusive coordination of knowledge-building	navigating uncertainty through positive affect and inclusive language ["we have done some wrong connection")] but no room for mistakes	navigating uncertainty through inclusion and positive affect

For Kay, the discourses were opportunities to contest male gendering of physics with its consequent gender inequity. Her experience of gender inequity in a previous course designed as studio model influenced how she participated in the small group discourses. Kay's ways of participation in the discourse seemed to imply that she considered gender equitable discourses as necessary for productive epistemological framing of discourses i.e., sense-making. Though it is true in terms of the participation of the person who suffers inequity, but it is not necessarily the case for the entire group. There were instances when kay's agency was ignored, thus gender inequity in terms of her participation in the group, yet, the men still engaged in sense-making in the small group.

Determined to exercise her agentic voice for gender equity, she participated in the discourses in ways that orchestrated positive gender interactions. These orchestration of positive gender dynamics, I argue, activated her framing of discourses as opportunities for gender equity, and the multiple roles as discursive positions for collaboration in knowledge-construction. She also considered the white board as the needed space for the messy work of knowledge-construction. For Kay, mistakes were important for learning and it is okay to take risks. Orchestration here is understood as what the individual did, whereas *activation* (Hammer, 2004;2004a) implies that the framing are not stable ontological units but are elicited by the context, and prompting of the learner's experiences, and what she or he does to learn. She also considered the white board as a resource that activated her framing of learning as messy work of knowledge-construction. For Kay, mistakes were important for learning and she recognized that "it is okay to take risks".

In addition, Kay framed learning as knowing and understanding; the former is sufficient for passing in the course (class) while the latter is important for sense-making; in her words: "What is going on?" And finally, she framed the role of the TA as effective facilitation of positive gender interaction for productive knowledge-building such as resolving epistemic uncertainty and differences in the small group involving Isaac and David. Now, I highlight gender interactions and Isaac's revealed framing of discursive interactions, the place of the discursive tools, what it means to learn, and the role of the TA.

Isaac framed the discursive interactions as requiring recognition of diversity in the forms of class demography (physics majors and non-majors), presentation skills, passion and gender equity-mindedness which he referred to as "standing back." For Isaac, doing science (his physics identity) involves getting rid of gender bias (as expressed by men or women, but he recognized the male expression of gender bias against women as "a huge unacceptable culture." In Isaac's framing all these have consequences. In the class, there were physics majors, non-physics majors, and students with different levels of competence. Isaac said that these classifications meant competition among students with different levels of proficiencies, and this competition made him “get a little nervous.” Also, he was aware of issues of gender equity noting that any harsh criticism of women’s ideas can easily be misconstrued, taken as offensive not only during the discourses but may not be forgotten after the discourses.

Isaac acknowledged the discourses as doing of science, made messy by imperfect tools. For him tools are to be used for “perfect modeling” of physical phenomena and that in the absence of better equipment, instructional youtube videos are alternative resources for achieving the same learning goals. In this instance, Isaac’s framing of youtube videos as alternative learning resources reveal his framing of learning as presentation of information. It is important to remember that Isaac was often an ally in Kay’s orchestration of positive gender dynamics. So, it makes sense to see how his productive framing of discourses is aligned with Kay’s — not only to get work done but to understand. However, since they were moments when he was involved in subtle negative gender dynamics against Kay, it is also logical to see why his framing will differ from Kay’s — instruments for “perfect modeling” of phenomena. In contrast to Isaac, David was almost often involved in active negative and subtle negative gender interactions against Kay.

David’s pattern of participation in the discourses suggests he was not mindful of gender equity. For him discourses meant one has to be “pushy,” and also reveals his physicist performance — identity. Even though he did not explain what it meant to be pushy, patterns in his discursive participation suggest inattention to positive discursive positions. He was often “pushy” in his discursive participation, giving room for negative gender interaction. In addition, David’s epistemological framing of discourses included his interpretation of the discourses as needing to be risk-free. In other words, for David, there is no room for any risk in discourses; not even any wrong answers. However, in terms of presentation of small group work to whole class, he revised his perspective after Kay’s sharing of her own perspective activated a more riskadmissive framing in his epistemology. This revision highlights the unstable nature of students epistemological framing (Hammer, 2004, 2004a). His revision also suggests that Kay's unrelenting orchestration of positive interactions, though generally unsuccessful, had some impact.

David framed roles (e.g., who presented to whole class) as obligations which one of the members of a group must take on; when others decline the role, it unavoidably falls on whoever was the last to decline — "... the third person has to do it." David did not see the roles as discursive positions that were spontaneously assumed, with implications for the distribution of power, and so having implications for gender equity in the group (Quinn et al., 2020; Wiselmann, Dare, Ring-Whalen, & Roehrig, 2020). Also, the labs were tools for learning, but he considered the time spent doing the labs as not useful. For him, the labs were "ineffective". Like Isaac, he too proposed youtube videos as effective for learning. It is not clear what David meant by "ineffective." It makes sense to interpret this as a reference to efficiency of time given that the group had to struggle with some epistemic uncertainty. This is because he mentioned that the same principle which the 3-hours discourses centered on could be learned with way greater time efficiency. Here, a connection between David's framing of the discourses, his role during the discourses, and the tools is highlighted: Since he saw the labs as a 'waste of time,' it is difficult to envisage why David will participate in ways that would orchestrate positive interaction that will activate productive epistemological framing across all episodes. The only instance of unproductive framing of a discursive episode was when David insisted on checking the correctness of work already done by Kay and 1saac (see Table 7, episode 11).

So across multiple episodes, the participants framed the TA's role as supportive of learning and positive interaction, the lab itself as a discursive activity as helpful for Kay, not so helpful for Isaac, and not helpful at all for David. For Kay learning entailed both knowledge and understanding for physics career development (physics identity). In Isaac's framing, learning implicated students' identities and competing identities across multiple learners made him nervous (as a learner). Then for David, learning entailed conforming to the instructor's framing which he perceived as giving room for no risk.

Implications

These findings offer implications for both continued research as well as pedagogy.

Research: **Gender equity work in physics.** These findings hold several implications for research in this area. As the first of these implications, the findings offer insights into gender dynamics within small groups in studio physics. Such understanding is relevant for further research targeted at understanding studio physics at large (i.e., across whole class, whole site and multiple sites). The findings could form the basis for later quantitative work that might reveal generalizable patterns. The findings call into question expectations that assigning students into small groups assures equitable participation in discourses. This research extends the work of Quinn and colleagues (2020) who suggest that putting some structure into students work in small group is important for equitable participation. I argue that in addition to some structure, the dynamics or interactions as well as students/TA's awareness of/commitment to gender equity issues is important for gender equitable participation in discourses.

Secondly, these findings shed light on the importance of discourses as a veritable petri dish for understanding the connections among gender (in)equity, epistemological framing and physics identity of participants in a small group discourse. Thus, research on discourses in small groups need to attend to discursive designs that advance towards optimal fostering of equitable gender dynamics, productive epistemological framing, and student development of physics identity in order to promote sense-making and persistence in physics. For example, Tekkumru-Kisa and colleagues' work centered on analysis of the cognitive demand of science tasks, though in the K-12 setting, could be important for designing tasks with varying epistemic uncertainty in undergraduate physics. However, in addition to the design of such tasks for classroom discourses in undergraduate physics, both gender equity awareness and commitment to orchestrating gender equitable interactions is critical, thus agency for gender equity.

Carlone and colleagues' (2015) work on agency and gender performance, with implications for gender equity, and her work on active learning and participation (2004) offer instances of how consequential gender inequity in science discursive spaces can be: In addition to limiting the available discursive positions for girls, gender inequity in science classrooms can adversely shift the science identity trajectories of girls. Though Carlone's work and the research I documented here focus on different levels of the education system, K-12 for her, and undergraduate for me, we both highlight that gender inequity in science discourse groups are gravely consequential for girls. Gender is one of the structures that limit the discursive space and agency for girls by often constraining them to choose to perform gender or chose to do science. Kay's discursive insistence on not having to choose between these two identities (though not generally successful) is an encouraging example of how the duty to work to dismantle gender inequity in physics/science classrooms and the field at large devolves, not on the woman (alone), but on and everyone, and entire systems.

Similarly, the research I report here aligns and builds on Hazari and colleagues' (2015) research linking power structures in physics classrooms, teacher positioning, student engagement and physics identity development. Findings from their work suggest that affective engagement, cognitive engagement, and physics identity development are entangled. In like manner, findings emerging from my research implicate affect in patterns of gender dynamics such that discursive interactions in the small group were not merely cognitive activities, but they involved the participants' positive and negative affect as well. Also, as shown in Figure 15, my findings suggest a tripod interconnection among gender dynamics, epistemological framing, and physics identity. This tripod interconnection echoes Hazari and team's (2015) suggested relationship among affective engagement, cognitive engagement, and physics identity. However, whereas their work centers teachers' positioning as important for K-12 students' identity development, I argue that there is even 'something' else that may have potential to shape what that positioning will look like — that is, instructors' awareness of/commitment to gender equity issues in physics and their continuous reflection on self/practice and resolve to take actions towards alleviating and dismantling it. In the research documented here, my goal was not to explore the awareness of gender equity issues by the TA, but it is important to note that negative gender dynamics was not alleviated by the TA. This finding may motivate future study of TA's gender equity awareness in relation to negative gender dynamics in small group discourses.

Also, Rosen, and Kelly (2020) administered a survey to students enrolled in different formats (online and in-person) of the same undergraduate physics lab. Part of the purpose of their research was to measure students' views about social engagement (socialization) in the labs. This quantitative study reported significant differences between students in the two formats related to views of socialization. Students in the in-person labs valued socialization more than students taking the course online. However, it is important to note that in both formats, socialization was valued, they only differed in degree. This highlights Vygotsky's socio-cultural theory (1979, 1980). So, their work indicates that regardless of the format, learning [disciplinary discourse] is a process of socialization. However, they found "no difference between women and men in terms of their views of socialization with peers and instructors in the laboratory regardless of the type of laboratory course" (p. 10).

Central to Rosen and Kelly (2020) is the measurement of their participants' beliefs about socialization, and academic help seeking which are attitudinal measures in the affective domain. They reported their finding on/around this main focus while mindful of gender differences and gender gap. For example, they stated that "finding suggests that self-selection into laboratory type may diminish gender gaps in affective domains... (p. 1). While this study remains methodologically valid and very important, similar to other studies with a lot of focus on gender gap (see for example Dawkins, Hedgeland, and Jordan, 2017), I argue that a gender gap framing has potential to mask differences in views of socialization. I propose that focusing on gender dynamics while mindful of its gender (in)equity implications holds more promise to reveal possible differences in views of socialization; views which can shape students' framing of discursive interactions. In contrast to Rosen and Kelly, I have documented variations in students framing of discursive interactions, and indicated how these variations were influenced by differences in their awareness of gender (in)equity issues. This work suggests that it is in the dynamics of discursive interaction, especially in small groups (Kittleson & Wilson, 2014) as a petri dish that we stand greater chances of unmasking differences in students' views of socialization as well as how they orchestrate that view. Putting findings from the research I have reported here in conversation with those of Carlone and colleagues, Hazari and team, Dawkins and others, Rosen and Kelly's works offer insights into opportunities for collaboration in gender equity work across both K-12 and undergraduate levels of education.

Third, this study highlights the existence of barriers that are a hinderance to equitable participation in physics by women as highlighted by Kay's experience. These barriers which are revealed during discourses include;

- the lack of or low level of discursive participants' awareness of gender equity issues,
- the need to foreground class level and department level opportunities and resources for supporting students' and teaching/learning assistants' awareness of gender equity and its importance in discursive dynamics in undergraduate labs (e,g, Due, 2014; Quinn et al., 2020).

Research on the effectiveness of opportunities and resources (e.g., a department-wide required course on gender equity, diversity and inclusion in physics to be offered in the freshman year) may have potential to enrich our understanding of how such opportunities and resources may engender students' awareness of and orchestration of positive gender interactions during discourses in small groups. Another focus may consist in instructor's integration of gender equity awareness into curricula designs and its impacts on student gender equity awareness and orchestration of gender equitable discourses. Quinn and colleagues motivate a conversation.

Kay's experience which was at the core of this study has revealed the insufficiency of one individual's awareness of gender equity issues and agentic voice to overcome gender barriers to women in a small group physics discursive space, and by implication other discretionary spaces (see for example Barthelemy, McCormick, & Henderson, 2016). Given this, the insights from this study call for a critical mass of participants who are gender-equity aware. In this regard, I particularly appreciate the work of James Day, Jared Stang, Natasha G. Holmes, Dhaneesh Kumar and D.A Bonn. In Day et al. (2016), these gender-aware physics scholars and researchers argue in favor of more explicitly checking the statistical methods used in research centered on measuring performance across gender. This is important because the outcomes of women, especially women of color, and other people of color are adversely affected by their experiences of inequity in physics (see for example Nissen & Shemwell, 2016; Rosa & Mensah, 2016). The aggregate of their perspectives on gender equity will constitute a beneficial reflection of a system-wide framework and policy that recognizes that gender inequity experienced by women takes away from the richness that comes from diversity through the participation of women in physics, both in classroom discourses and in the field in general — and work towards alleviating this problem.

Finally, epistemic uncertainty (Manz & Suárez, 2018), epistemological conflicts (Wieselmann et al., 2019), and epistemic disagreements constitute a necessary components of a productive epistemological framing. Epistemic disagreements in this study were often associated with negative gender interactions between Kay and David. In this exploratory case study, epistemic disagreements between Kay and David did not just entail different epistemic views, but one or both parties manifested negative affect. While epistemic disagreements are a necessary aspect of doing science, students need help to productively move through uncertainty. They will need help with learning to negotiate these disagreements if we are to move toward more equitable participation in small group discourses as learned from on my group within the innovative context. Scaffolding epistemic uncertainty that may leverage just the needed epistemic disagreements without lessening the cognitive demand of tasks in an introductory undergraduate level physics course could be important. This importance could entail designing instruction that will elicit epistemological diversity through epistemic uncertainty. In order to "develop a comprehensive picture of student experiences" (Perez-Felkner, 2019, p. 11) centering on gender dynamics, epistemological framing and physics identity, research foci need to broaden to multiple small groups, be collaborative across SCALE-UP courses, sites or institutions, and methodological approaches.

Pedagogy: The role of the TA. Teaching assistants are important in undergraduate science teaching and learning, and they play a variety of roles in these settings (Stang, 2017). Research suggests that teaching assistants performance impacts students' learning experiences and learning outcomes (Wan et al., 2020) especially for minoritized groups in STEM (National Academies of Science, Medicine et al., 2019), and this is also true in physics (Dusen & Nissen, 2020).

Findings from this study revealed that the TA did not alleviate negative gender interactions. By implication, the simple presence of the TA was not sufficient to foster gender equitable participation in small group discourses during the lab. However, this finding may not be surprising given the paucity of focus on TA training and/or TA professional development in gender equity within their undergraduate teaching work compared to research on student engagement (e.g., Stang, 2017), TA's teaching practices (Wan, Geraets, Doty, Saitta, & Chini, 2020), beliefs (Spike & Finkelstein, 2016). However, one implication of this finding is that small group in itself is not a recipe for equity, rather the role of instructors (Quinn et al., 2020) [such as the TAs] during small group discourses is important, for equity, especially for minoritized groups in physics.

Research suggests that attention to equity does not often include gender equity specifically in small group dynamics across heterogenous groups or the multiple gender identities that abound. For example, in their study on learning [teaching assistants], Dusen and Nissen (2020) operationalized equity in terms of outcomes while mindful of their own positionality which included their gender identities. In another study Quinn and colleagues (2020) made the following clarion call:

> As the culture in physics evolves to remove systematic gender biases in the field, instructors in educational settings must not only remove explicitly biased aspects of curriculum but also take active steps to ensure that potentially discriminatory aspects are not inadvertently reinforced (p. 1)

Although Quinn and team did not focus on the role of TAs in students' interactions across gender during discourses in small groups, the implication of their work for teaching and learning clearly indicates the role of instructors (including TAs) in equitable learning experiences for students. The findings from my research on the selected small group contributes to the conversation on the role of TAs in undergraduate lab courses. The case study highlights the importance of the TA's role in gender equitable discourses in a small group within innovative contexts. TAs often have the role of support instructors and taking or failing to take certain active steps during the small group discourses do help or hinder gender equitable discourses in a small group. One implication of this finding is that TA training and professional development programs and opportunities need to give greater attention to supporting TA's development of awareness of gender dynamics as well as their commitment to gender (in)equity associated with gender dynamics. So, TA's may benefit from a seminar on equity, diversity and inclusion which includes interactive sessions on orchestration of gender equitable discourses. Such an opportunity has potential to support TA's development of proficiency with facilitating small group discourses in ways that overcome (or at least) alleviate gender inequity.

Pedagogy: The role of student preparation. Students' prior and current experiences [e.g., in the classroom] shape the development of their science physics identity (Hazari et al., 2015; Hyater-Adams, 2018) and how such students frame science tasks to participate in epistemic discourses (Hutchison & Hammer, 2009, Wieselmann et al., 2019). This is true in a unique way for women in classrooms because of gender equity issues (Carlone, 2004). Students' physics identity has implications for [gender] equity (Hyater-Adams, 2018) as they learn. In the final analysis, learning is the shaping of students' experiences. These experiences are not only important in terms of sense-making to understand natural phenomena but also in learning how to equitably participate in sense-making.

Findings centering on orchestration of negative gender interactions emerging from this exploratory single case study highlights the need for physics departments to include gender equity awareness in physics curriculum. One specific recommendation is for an intervention in the form of a department-wide course centering on gender equity, diversity and inclusion in physics. Such a course would be categorized as required and designed for the freshman or sophomore years. As an example of a meaningful activity in such a course, students could work on building group norms and what constitute epistemologically productive interactions in their small group and make posters, embark on whole class presentations and discussion etc. In this way, they would have opportunities to reflect on their biases, their awareness of gender equity issues and identity/identities and how these can potentially influence their framing of doing science. Thus, students learning experiences will include *discourse socialization* (Ho, 2011) — how to equitably participate in small group discourses with a focus on gender (in)equity in this case.

Concluding Remarks

In this research, my goal was not to compare what women do versus what men do (not to essentialize gender). Rather, to explore gender dynamics since it is in the social interactions

(Vygotsky, 1979) that gender inequity is revealed. Also, the purpose of this research was not to determine and generalize whether or not SCALE-UP was free of gender inequity, but rather to understand the nature of the woman's experience in the small group within the SCALE-UP context. However, my findings suggest that negative gender dynamics are alive and well in this context despite its reliance on reform-based innovation. While studio physics has promise for increasing learning gains across race and gender, the findings suggest that small groups are not silver bullets (Blanchard, Southerland, & Granger, 2009) against gender biases and microaggressions. Awareness of negative gender dynamics in even one small group is a call for other larger scale studies to explore the regularity of such interactions. These findings also suggest that instructions in the SCALE-UP environment may need to integrate practices to help alleviate gender bias and micro-aggressions as visible in the small group explored.

In the small group I explored, it is remarkable that if Kay with her strong sense of socio-disciplinary agency in physics is being shut out, what does this mean for others? It means that alleviating negative gender micro-aggressions requires consistent self-reflection by students, instructors, physics departments, entire colleges, universities and society at large. Dismantling gender inequity in physics will take systemic and long-term approaches. My research offers the insight that carefully designing or structuring of small group is important, but it is insufficient to shield women from subtle negative gender interactions such as micro-aggressions. In fact, rather than hoping to shield them, discursive participants in small groups need to be supported to develop awareness of gender inequity and take responsibility by their commitment to engage in discursive interactions in such a way as to be gender equitable. Isaac embodies this goal, and the 'Davids' would need to develop a socio-disciplinary identity which approximates and even surpasses the 'Isaacs'.

Participants' awareness or (otherwise) of gender equity and their positioning of self and others during discourses in the small group influenced their individual epistemological framing but Interestingly, the nature of gender interactions did not totally shut out productive framing of tasks by the group as a whole. However, there was a mix of both productive and unproductive framing in and around discourses. In addition, in such episodes where Kay experienced negative gender interactions, she seemed to manage epistemic uncertainty and conflict better. In some of such situations, Kay negotiated gender performance and doing physics, even though generally Kay insisted on a socio-disciplinary identity, framed by her experience of micro-aggression in a previous course. So, this small group is important for understanding the nature of Kay's management of epistemic uncertainty and conflict as — not socialization, but a struggle to navigate negative gender experience in the small group. More research is needed to understand the factors that explain how the Kays seem to manage epistemic uncertainty and conflict better in small group physics discursive interactions.

In future work centering on gender dynamics, my research will focus on multiple small groups across a studio physics sites, and multiple studio physics sites. This current exploratory single case study has potential to serve as basis for a large-scale quantitative study in order to explore the generalizability of findings on the interconnection of gender dynamics, physics identity and epistemological framing across reform-based physics pedagogies.

APPENDIX A

CONSENT FORM

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title of Study: GENDER DYNAMICS IN SMALL GROUP WITHIN A STUDENT-CENTERED PHYSICS COURSE: AN EXPLORATORY SINGLE CASE STUDY

Principal Investigator: Mark Akubo

Date————————————

We invite you to participate in a research study at Florida State University.

You were selected as a possible participant because you are enrolled in a studio physics course and may be willing to participate in this study. We ask that you read this form and ask any questions you may have before appending your signature consenting to participate in the study.

This study is being conducted by Mark Akubo, (Doctoral Student) in the department of Science Education (College of Education), under the guidance of Dr. Sherry Southerland, Dr. Paul Cottle, Dr. Lara Perez-Felkner, and Dr. Ithel Jones.

Background Information:
The purpose of this study is to explore patterns of gender dynamics in sense-making in small groups of one woman and two men in studio physics and how such patterns may be related to the meanings they ascribe to the dynamics, tools, and roles in the studio physics context.
My study is guided by the following **Research Questions:**

1. What patterns of gender dynamics centered around the woman's participation emerge within the small group?
2. What meanings do the small group participants assign to these dynamics?

Procedures:
In order to address the goal of this research, data will be collected on participants. The collection of data will be in the forms of (1) audio-/video recording, (2) in-class work [individual and (group work on white board)], (3) individual and focal group interviews (4) Field notes. Micro audio tapes and video camera will be placed before each group in such a way that they do not obstruct participants' work. Recording will last the entire three hours of each class observed during eight weeks in the semester. The video camera will also focus on participants when they present their work to the entire class during a session.

Risks and benefits of being in the Study:
Participation in this study involves no known risk to you but has potential benefits to researchers, practitioners, and the education community as a whole. For instance, the equity question has implications for diversity and under-representation. Findings from this study may potentiate adoption or adaptation of principles and techniques such as targeted instructional moves to support diverse students in knowledge construction within various active learning contexts. There is the possibility that upon completion of this study, you become much more intentional or aware about your own positioning in knowledge construction within small groups focused on learning.

Confidentiality:
The data collected from your participation in this study will be accessible or available only to the researchers and the team of advisors for this study (Dr. Sherry Southerland,
Dr. Paul Cottle, Dr. Lara Perez-Felkner, and Dr. Ithel Jones). The data for this study will be kept private and confidential to the extent permitted by law. In any sort of report the researcher might publish, no information that will make it possible to identify a participant will be included. Tape recordings or videotapes will be used by the researcher for educational purposes only.
All participation-related documents will be de-identified (no names but codes identifiable only to the research team). Digital data will be stored in electronic format and stored in a repository (external hard drive) in the researcher's office cabinet. The hard drive will have a password. These original data will be stored for 5 years.

Compensation
Although you will receive no financial remunerations or compensations for participation in this research, your willingness to participate in the study is deeply appreciated.

Voluntary Nature of the Study:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University. As a participant, if at any point you decide or choose to discontinue participation, you can withdraw and ask that your data not be used with no penalty.

Contacts and Questions:
The principal investigator in this research is Mark Akubo. You may ask any question you have at any stage of the data collection process. You are encouraged to direct your questions to Dr. Sherry Southerland (ssoutherland@admin.fsu.edu 850-645-4667.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the FSU IRB at 2010 Levy Street, Research Building B, Suite 276, Tallahassee, FL 32306-2742, or 850-644-8633, or by email at humansubjects@fsu.edu
You will be given a copy of this information to keep for your records.
I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

_______________ _________________
Signature Date

_________________ _________________
Signature of Investigator Date

APPENDIX B

IRB APPROVAL MEMORANDUM—2017

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

Dear Mark Akubo
APPROVAL MEMORANDUM
Date: 7/12/2017
Dept.: SCIENCE EDUCATION
From: Thomas L. Jacobson, Chair
Re: Use of Human Subjects in Research
Students' Participation in a Scale-up Freshman Physics Course: Examining Support for the Development of Students' Epistemic Agency

The application that you submitted to this office in regard to the use of human subjects in the research proposal referenced above has been reviewed by the Human Subjects Committee at its meeting on 06/14/2017. Your project was approved by the Committee.
The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects. If the project has not been completed by 6/13/2018 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: Sherry Southerland, Advisor
HSC No. 2017.21038

APPENDIX C

IRB APPROVAL MEMORANDUM—2018

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

Dear Mark Akubo
RE-APPROVAL MEMORANDUM
Date: 6/4/2018
Dept.: SCIENCE EDUCATION
From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research
Students' Participation in a Scale-up Freshman Physics Course: Examining Support for the Development of Students' Epistemic Agency

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 5/8/2019, you must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Sherry Southerland, Advisor [ssoutherland@admin.fsu.edu]
HSC No. 2018.23628

APPENDIX D

IRB APPROVAL MEMORANDUM—2019

Florida State
UNIVERSITY

Office of the Vice President for Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 06/24/2019

To: Mark Akubo [redacted]

Address: [redacted]

Dept.: SCIENCE EDUCATION

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Students' Participation in a Scale-up Freshman Physics Course: Examining Support for the Development of Students' Epistemic Agency

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 06/22/2020 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is IRB00000446.

Cc: Sherry Southerland <ssoutherland@admin.fsu.edu>,
HSC No. 2019.28641

APPENDIX E

IRB: NO RENEWAL NEEDED NOTICE—2020

AA
Annette Allman <aallman@fsu.edu>
Tue 4/7/2020 12:25 PM
To: Mark Akubo

HRP-103 - INVESTIGATOR M...
366 KB

Show all 2 attachments (744 KB) Download all Save all to OneDrive - Florida State Students

Good Afternoon Mark,
Hope all is well your way. Yes, I can help you. Your study is in the HSRS system and it is a completely different system than RAMP. They do not talk to each other.

Therefore, if you want to renew your study, because you are still submitting subjects or have tasks to run subjects through; you have to submit your study in RAMP. That requires using a protocol template that is provided in the RAMP Library. You are also required to submit a HRP-212 form, which has duel purposes. We use the HRP-212 form for closure and continuing review. Fill out the HRP-212 and upload it into RAMP as a local site document.

If your study is left with only data analysis of de-identified data, you can close your study and continue to work on the analysis and/or manuscript writing as that is now considered Not Human Subjects Research any longer.

For your convenience, I have uploaded the Investigator's Manual that is used for RAMP submissions and the HRP-212 form. Fill out the HRP-212 form first, if you can check the first four boxes, this indicates you can close your study.

Let me know if you have any other questions.
thank you for contacting the Office for Human Subjects Protection.

Best,
Annette

...

APPENDIX F

SYLLABUS FOR PHY2049C

Questions and problem assignments

We will have written assignments and use the mastering Physics online problem system. Assignment due dates and times are absolute — no exceptions will be permitted.

Weekly quizzes

The Friday classes will be devoted to weekly quizzes that will assess your knowledge of the science we have covered up to and including that week's laboratory and mastering Physics activities. We will only count 13 of the 14 quizzes given this semester in your grade.

The quizzes will not be given any other time — that is, there will not be any "make-ups." If you anticipate missing any Friday classes, then you should move to a "traditional" section of PHY 2049C right now, before the semester gets going.

If you are more than five minutes late to the quiz (that is, you arrive any later than 12:25 pm), you will not be allowed to take to take the quiz and you will receive a grade of zero for that quiz.

The first quiz will be held on January 18.

Grading

I will be using a "traditional" grading scale:

A	93.0-100.0%
A-	90.0-92.9%
B+	87.0-89.9%
B	83.0-86.9%
B-	80.0-82.9%
C+.	77.0-79.9%
C	73.0-76.9%
C-	70.0-72.9%
D	60.0-69.9%
F	<60.0%

Academic Honor Code

Students are expected to uphold the Academic Honor Code published in the University Bulletin and the Student Handbook. The first paragraph is: The Academic Honor System of the University is based on the promise that each student has responsibility (1) to uphold the highest standards of academic integrity in the student's own work, (2) to refuse to tolerate violations of academic integrity in the University community, and (3) to foster a high sense of integrity and social responsibility on the part of the university community.

ADA Information

Students with disabilities needing academic accommodations should: (a) register with and provide documentation to the Student Disability Resource Center SDRC; b) bring a letter from the SDRC indicating you need accommodations. Please do this in the first week of class.

Class Schedule

January 7-11	Circuits
January 14-18	Circuits
January 21-25	Circuits
January 28-February 1	Circuits
February 2	White boards
February 4-8	Electric Charges and Forces
February 2	White boards
February 11-15	Electric Field
February 18-22	Gauss' Law
February 20	White boards
February 25-March 1	Electric Potential
March 4-8	Potential and Field
March 11-15	Magnetic Field, earth Magnetic Field lab
March 11	Whiteboards
March 13	Coil Magnetic Field Lab, White board
March 18-22	Spring Break
March 25-29	Magnetic Forces
April 1-5	Electromagnetic Induction
April 8-12	AC Circuits
April 15-19	Electromagnetic Induction, Diffraction, and Refraction
April 22-26	Electromagnetic Waves, Diffraction, and Refraction
April 29-May 3	Final Exam Tuesday April 30, 12:30-2:30

APPENDIX G

INTERVIEW PROTOCOL

Opening Question

1) Have you taken a studio physics course before? If positive, how did you decide to choose a studio physics class for the Electricity and Magnetism course this semester?

Introductory Question

(2) What were your expectations coming into the electricity and magnetism studio physics course?

Transfer Question

(3) What do you think about presentation of small group work to the entire class in this studio physics course?

Key Questions

(4) How did you take opportunities presented in your small group to contribute to making sense of the physics ideas and activities you worked on in the class?

(5) How did people view their colleague(s)' contributions or roles during the labs and white board activities? (You can refer to your own experience in your group or your observation of another group).

Specific Questions

6) In the third week of class, your groups were switched round. Flashing back at how you learned that week of Jan 23rd, what was different for each of you based on the switching of groups?

7) What do you think mattered in how you or your peers made sense of physics ideas in your small group to learn in this course (e.g., the whiteboard, group members)? For example, how did the interaction between you and a male or female member of your group influence how you took part in making sense of the physics ideas? how the participants were interpreting the goal of the activity and interaction.

Closing Question

(8) Were you to take a course in studio physics again, how would you suggest interactions need to go between the male and female members of your group in order to foster each member's participation in sense-making?

Final Question

(9) Is there anything else you would have loved us to talk about, but we did not?

APPENDIX H

CODING PROTOCOL 1: GENDER DYNAMICS

S/N	Types of Gender Dynamics	Examples
1	**Active Positive Gender Dynamics**: These entail clearly observable data on dynamics that have potential to support gender equitable participation in knowledge construction and discursive interactions.	leading peer conversations, set up of equipment, acknowledged peers' efforts or contributions, elaborating on a peer's explanation, offering constructive critique, etc.
1a	acknowledged peers' efforts or contributions	**Isaac:** "Thank you for bringing the wires"
1b	elaborating on a peer's explanation	**Kay:** O, he (referring to a peer) said that...
Ic	Offering constructive critique	**David**: And A is in series with B. But what does...? **Kay:** But see, it looks like this one is okay, (cutting in and pointing on the screen) because it says in series or in parallel. A is in series with B, and the system is in parallel with C. So, I think that one...
1d	mindful of other's sense of belonging	Uses "we/us" rather than "I/me" to refer to the group's work
1e	elicited (and so inclusive) of other's participation	**David**: Okay. What are we, what are we talking about? (shaking his head, looking at Kay) I am sorry. **Kay**: We are comparing 5 and 1.
2	**Active Negative Gender Dynamics**: These entail clearly observable data on dynamics that have potential to hinder gender equitable participation in knowledge construction and discursive interactions.	Refusing to engage in conversation during epistemic differences, denying the epistemic worth of a peer's ideas, observable verbal and/or physical aggression towards a peer,
2a	Refusing to engage in conversation during epistemic differences	**Kay**: Then, explain to me. **David:** No, (shaking his head and hands), not this.
2b	denying the epistemic worth of a peer's ideas	"I understand that.... You are telling me things that I already know. I get that." (shaking head).
2c	observable verbal and/or physical aggression towards a peer,	**Kay:** All you have to do is just say what you wanted to say (the look on her face grin). That may help than **yelling at me**: "no, no,no."
3	**Subtle Gender Dynamics:** They are characterized by not-so- clearly observable data such that the interactions are not obvious, that is, without deep reflection	fostering a peer's hesitation to make his/her voice heard, non-verbal/verbal ignoring a peer's contribution, biased validation of peers' contribution, fostering negotiation of gender and physics by the woman
3a	fostering a peer's hesitation to make his/her voice heard,	Frequent hedges (e.g., I think, hmm), critique as questions
3b	non-verbal/verbal microaggressions,	swiftly taking an item pencil, pen, from a peer during epistemic disagreement without courtesy
3c	ignoring a peer's contribution	determined in context
3d	fostering negotiation of gender and physics by the woman	determined in context
4	**Mixed Gender Dynamics:** Any combination of 1-3 above	Active positive and active negative, Active positive and active positive, Active Negative and active negative Active positive and subtle negative Active negative and subtle negative

APPENDIX I

CODING PROTOCOL 2: GENDER DYNAMICS

S/N	Codes	Examples
1	gender equity Due, 2014; Gonzalvez, 2014; Hazari & Beattie, 2015; Kittleson & Wilson, 2014	**"**I was in a group..., a table of all males. And trying to say anything, I would literarily be ignored sometimes. I would like come into this class and am like, am' going to fight, am going to literarily yell my ideas until they listen to me."
2	achievement Carlone, 2003; Andersson and Johansson, 2016)	**"**A(.)h for me personally, I can understand through the labs, but I can know what I need to do through things like the white boards. To be honest, for this class, you just need to like 'know what' to be able to pass the quizzes."
3	physics/science identity Carlone, 2006; Lock and Hazari, 2016; Pettersson, 2011	"For me, I am furthering with physics as my major. So, it is very important for me to like, understand what is going on."
4	Resources (tools, the TA) Hutchinson & Hammer, 2010	"I think the white board is a good thing for our group because it is a great way for us to illustrate our ideas together" "I think that another reason why the TAs where so helpful is that even if like if we got something and he (referring to Isaac) or they (pointing to Isaac and David) got something and I didn't, they can like understand everything and I can like raise my hand (raising her hand) and ask the TA real quick"
5	Learning (in Labs) Vygosky 1978, 1980	"I don't think the labs were so useful. I know the whole principle of studio is that you do hands-on, you play with stuff and you learn. You know what I think is better in comparison with the circuits? Watching a youtube video. I am dead serious (laughing)."
6	Roles (social participation, Vygosky 1978, 1980)	"I feel like ...We did not really have a conversation about who is doing what. It just happened every time. Like when I walked in, I got the materials, set it up, like got things set up, go grab the white board and like record it on there. And then, he (pointing to Isaac) works through everything, like clarifies everything before we turn in...."

APPENDIX J

EPISTEMOLOGICAL FRAMING CODING PROTOCOL

Episode	Patterns of Gender Dynamics	Meanings Attributed as revealing of each participant's framing of discourses during tasks			Predominant epistemological frames
		Kay	**Isaac**	**David**	
5	Subtle Negative	negotiating gender and physics	validation, positioning as data recorder	subtle dismissal of peers' epistemic contribution (explanation as not novel)	uncertainty, explanation, metacognition
6 Mixed	Active Positive	TA as resource, discourse as inclusion of peers	negotiating consensus, constructive critique	discourse as explanation	metacognition, explanation, uncertainty
	Subtle Negative	negotiating gender & physics "these guys are in series..."	negotiating competence (in relation to David)	subtly considered peers' explanation as offering no new epistemic contribution	
7	Subtle Negative	negotiating gender and physics by positioning David as more competent	self-positioning as recorder	discourse as explanation	metacognition, explanation, collaboration
8 Mixed	Active Positive	discourse as co-construction of ideas	TA as resources, discourse as entailing inclusiveness	no active participation	collaboration, uncertainty, mostly explanations,
	Active Positive	discourse as entailing inclusiveness	uncertainty, discourse as inclusiveness	uncertainty, positioning others as competent	
9	Subtle Negative	negotiating gender and physics	Self-positioning—data recorder Discourse as collaboration, validation	explanation, uncertainty	uncertainty, Kay's cognitive struggle, explanation
10	Active Positive	leading knowledge-construction,	Self-positioning—listener, data recorder	did not participate	metacognitive, uncertainty, explanations,

Episode	Patterns of Gender Dynamics	Meanings Attributed as revealing of each participant's framing of discourses during tasks			Predominant epistemological frames
		Kay	**Isaac**	**David**	
11	Active Negative	navigating uncertainty	knowledge-building as non-verbal participation during uncertainty	Navigating uncertainty by doing school: ("Tell me. What is wrong?" with negative affect and TA as hogged resource	navigating uncertainty
12 Mixed	Active Positive	navigating uncertainty through positive affect, self-confidence, & eliciting peer's participation	discourse as inclusive through cross-checking with peers	discourse as explanation with self-confidence in leading small group discourse	discourse as self-confident explanation mindful of inclusion
	Subtle Negative	negotiation of physics and gender			
13	Active Positive	navigating uncertainty through positive affect, through leading circuit-building with TA as a resource	navigating uncertainty, through coordinating knowledge-building in inclusive ways	navigating uncertainty but no room for mistakes while positive in affect, and inclusive, ("we have done some wrong connection")	discourse navigating uncertainty through equitable leadership
14 (F1)	Active Positive	discourse as co-construction of ideas, takes lead in building the circuits (self-positioning as competent)	coordinating knowledge-building,	navigating uncertainty, by positioning peer (Kay) as competent	discourse as navigating uncertainty through leadership and competent positioning of peers
14 (F2)	Subtle Negative	leading circuit-building, discursive inclusiveness & validating peers' ideas	self-positioning as data recorder	subtly discrediting peer's (Kay's) ideas, ["But his as correct: This was the right idea. Right?"] and contestation for leadership	

Epistemological Framing Protocol Continued

Episode	Patterns of Gender Dynamics	Meanings Attributed as revealing of each participant's framing of discourses during tasks			Predominant epistemological frames
		Kay	**Isaac**	**David**	
15 (F1)	Active Negative	discourse as negotiation— "Okay, I can redraw this." and consensus-building: "We will go back to it later".	discourse as self-positioning for consensus-building; "I don't want to move on without resolving this"	discourse as epistemic dismissal through negative affect: "we already said that it doesn't make a difference. Right? Like whenever it... Whatever, whatever..." (shaking his head in disagreement)	discourse as negotiation and self-positioning in the face of epistemic differences and conflict
15 (F2)	Active Negative	discourse as negotiation of gender and physics to navigate experience of negative affect—"All you have to do is just say what you wanted to say (the look on her face grin). That may help than yelling at me: no, no, no"	discourse as consensus-building ("So... If I can find something that we can agree upon"	discourse as epistemic dismissal through negative affect: "No, (shaking his head/hands, raising voice), not this." (Giggling), I understand that. You are telling me things that I already know. I get that. (shaking his head).	discourse as negotiation through consensus0building to overcome micro-aggression
16	Active Positive	navigating uncertainty, through positive affect, and leading knowledge-construction, with TA as a support	navigating uncertainty, through inclusive coordination of knowledge-building	navigating uncertainty through positive affect and inclusive language ["we have done some wrong connection")] but no room for mistakes	navigating uncertainty through inclusion and positive affect

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