Why Don’t Girls Think They’re Good at Physics? Recognition in a High School Classroom

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Abstract

Women, especially Black and Latina women, are marginalized in physics, including in high school classrooms. Recognition is one of the ways women and girls experience marginalization in physics. This dissertation is comprised of three distinct but related studies examining how students experience recognition in an AP Physics 1 classroom.

The first study is a mixed-methods study examining students’ sense of self-efficacy using a sequential explanatory design. This study first examined the relationship between students’ self-assessments and actual quiz scores and found no statistically significant difference between boys and girls in this class. I next used open-ended self-assessment prompts and semi-structured student interviews to identity classroom experiences that students felt contributed to or detracted from their sense of self-efficacy. While boys and girls talked about many experiences, such as the way labs in the course were structured, in very similar ways, only boys clearly discussed receiving consistent recognition from their peers, leading to the research questions in the subsequent studies.

The second study examined how students provided each other with recognition, what kinds of contributions they recognized, and how peer recognition interacted with students’ sense of physics identity using small group video and student interviews. Recognition fell into two major categories: explicit, where students directly recognized a peer, and implicit, where the recognition was provided indirectly. Explicit recognition was primarily connected to correct answers while implicit recognition was connected to a much broader range of contributions. During interviews, when students discussed their personal physics identity, they primarily discussed correct answers and explicit recognition they had received, suggesting that their personal identity was primarily connected to explicit recognition. When discussing their
conceptions of what it means to hold a physics identity, students referenced not only correct answers, but the much broader range of contributions connected to implicit recognition. They also described giving both explicit and implicit recognition. This suggests that students connected both categories of recognition to their conceptions of a physics identity.

Third, I analyzed exchanges in which students positioned each other in terms of physics ability without directly referencing physics using video of a mixed-gender group and an all-boy group. The mixed-gender group engaged in many of these exchanges and primarily used them when the girl contributed a correct answer with the boys taking authoritative positions. Rather than providing the girl with recognition, these exchanges served to devalue her contribution. The all-boy group, by contrast, only had one of these exchanges and neither was clearly established as more authoritative.

Together, these studies provide insights into the gendered dynamics of the recognition that students give and receive in physics classrooms with implications for instructional practice. There is a clear need for teachers to structure group work in ways that ensure all students are recognized by their peers for a wide range of contributions and to disrupt gendered patterns in the classroom.
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Chapter 1: Introduction

1.1 Rationale

Physics is a firmly male-dominated field, with women underrepresented not only among professional physicists, but at all levels of physics education. For example, the College Board reports that on the 2021 AP Physics 1 exam, less than 40% of the students taking the exam were girls and only 0.2% were non-binary (College Board, 2022). In 2020 only 25% of bachelor’s degrees and 21% of doctoral degrees in physics went to women (Women in Physics Statistics, 2023). One lens to view this problem through is physics identity, which describes being seen by oneself and others as the kind of person who does physics (Carlone & Johnson, 2007). Multiple studies have shown gender differences in student’s affiliation with a physics identity (Carlone et al., 2011; Hazari et al., 2010, 2013). Importantly, in other science disciplines, such as chemistry and biology, the differences in the affiliation with a relevant science identity reported by men and women is much smaller or even non-existent, consistent with other evidence that women experience less severe marginalization in other science disciplines and suggesting it is particularly important to examine gender equity in physics education (Hazari et al., 2013).

In science classrooms, students are constantly exposed to messages about what kind of person does science, whether they are capable of doing science, and whether their other identities are compatible with doing science (Brickhouse, 2001). These messages have important implications for equity in physics education (Malone et al., 2009). Many of these messages are delivered through classroom experiences, including peer interactions during small group work, and play an important role in students’ development of a science identity (Carlone et al., 2011). At the same time, many studies have documented gender differences in how students participate in small group work (Carlone et al., 2011; Doucette et al., 2020; Jovanovic & King, 1998; Jurik
et al., 2013; Patrick & Yoon, 2004; Wieselmann et al., 2021; Wieselmann, Dare, Ring-Whalen, et al., 2019).

Better understanding what students experience in the classroom, especially during small group activities, has clear implications for improving gender equity in physics education. However, much of the existing research focuses on undergraduate students (e.g., Doucette et al., 2020; Hazari et al., 2013) and middle school students (Wieselmann et al., 2019b). In addition, because identity depends on how an individual interprets their experiences as well as what those experiences are (Carlone & Johnson, 2007), it is crucial to not only study what happens in the physics classroom, but how students perceive their experiences. Many of the existing studies focus on surveys (e.g., Hazari et al., 2010; Mujtaba & Reiss, 2013b) or on the observable behaviors of students (e.g., Doucette et al., 2020; Patrick & Yoon, 2004) with few studies that connect the perspectives of students to how they act in the classroom.

The studies in this dissertation seek to address this gap in the literature to examine relationships between what students experience in the classroom and their affiliation with a science identity. These studies make use of student interviews in conjunction with other data sources to ensure that how students perceive their classroom experiences is included in the analysis. Findings from these studies can inform the use of instructional practices that promote gender equity in the physics classroom as well as provide new insights to inform future research.

1.2 Organization

This is a three-paper dissertation that contains five chapters. Chapter 1 describes the organization of the dissertation and provides a rationale for the three studies included. Chapters 2-4 each describe a single study, with a rationale, brief literature review, methodological
approach, and findings and implications specific to the study. Chapter 5, describes key findings from all three studies as well as implications for teaching and future research.

Chapter 2 describes the first study, which analyzed gender differences students’ self-assessments and actual assessment scores in a physics classroom, then combined the findings with student interviews about the kinds of experiences that contributed to their beliefs about whether they are good at physics. This study was published in Physical Review Physics Education Research in July, 2021.

The next two studies focus specifically on recognition, a decision informed by the findings of the first study. Both of these studies analyze student discourse of students working in small groups. Chapter 3 describes a study that used grounded theory to develop a framework for the forms that peer recognition can take during small group interactions. In addition, this study used student interviews to explore the relationship between these forms of recognition and students’ affiliation with a science identity. The study in chapter 4 used positioning theory to analyze brief exchanges in which students used contributions not directly related to science to position someone in terms of science ability within the group.
Chapter 2. Gender Differences in Classroom Experiences Impacting Self-Efficacy in an AP Physics 1 Classroom

2.1 Introduction

Physics is a firmly male-dominated field, with women underrepresented not only among professional physicists, but at all levels of physics education. For example, the College Board reports that on the 2018 AP Physics 1 exam, less than 40% of the students taking the exam were girls (College Board, 2018). And in 2017, only 21% of bachelor’s degrees and 20% of doctoral degrees in physics went to women and women were only 16% of physics faculty (Porter & Ivie, 2019).

Science identity, and physics identity more specifically, provides a powerful framework for understanding students’ experiences and their intentions to persist within a science field (Brickhouse et al., 2000; Carlone, 2004; Carlone & Johnson, 2007; Hazari et al., 2010, 2013). Identity can be described as whether an individual seems themselves as a certain kind of person (Gee, 2000), so someone with a science identity sees themselves as the kind of person who does science. In a large-scale survey, Hazari et al. (2013) found that a student’s sense of physics identity strongly correlates to their intention to persist in the field and college women, especially women of color, tend to report a weaker physics identity than men, even among students majoring in a field closely related to physics (Hazari et al., 2013).

Carlone and Johnson (2007) suggest science identity comprises the dimensions of competence, recognition, and performance. Each of these dimensions are influenced by both internal and external factors. Performance refers to the ways in which an individual is able to demonstrate competence in line with the norms of the field, such as their fluency in the language of science or the ways they interact with others. Recognition refers to the extent to which the
individual is viewed as a “science person” both by themselves and by others, including classmates, instructors, supervisors, and even those outside of the scientific field. Competence is the extent to which someone demonstrates skills and knowledge valued in the field; in educational settings, test scores and grades can be viewed as a measure of competence. Students’ beliefs about their ability to understand physics are also an important aspect of competence (Kalender et al., 2019b). The beliefs central to competence include self-efficacy, which describes an individual’s belief in their capacity to succeed (Bandura, 1977), and confidence, which describes an individual’s perceptions of their achievement (Covington Clarkson et al., 2017).

Students’ classroom experiences can impact their science identity development across all three dimensions (Carlone, 2003; Carlone, 2004). An important aspect of competence is self-efficacy and there is substantial evidence that women in introductory physics classes tend to have a lower sense of self-efficacy than their male peers (Jurik et al., 2013; Marshman et al., 2017; Marshman et al., 2018; Mujtaba, T., & Reiss, 2013a; Mujtaba & Reiss, 2013b; Nissen & Shemwell, 2016). Mujtaba and Reiss (2013a) and Marshman et al. (2018) found these gender differences in self-efficacy persist even between men and women with similar levels of academic performance.

Several studies found self-efficacy decreased for both men and women during an introductory physics course (Marshman et al., 2017; Nissen & Shemwell, 2016), however, in one study, women reported experiencing states of low self-efficacy during classroom activities more often than men and exhibited greater declines in self-efficacy by the end of the course than their male peers (Nissen & Shemwell, 2016). Also, women shifted toward a more fixed mindset (Dweck, 2008) view of physics, suggesting they developed a picture of physics identity as something innate, similar to Gee’s natural identities (Gee, 2000), rather than as something that
could be cultivated and developed. A growth mindset also tends to be correlated with a high sense of self-efficacy since it suggests the student believes they can improve through factors in their control, such as effort (Dweck, 2008).

Jurik and colleagues examined how self-efficacy impacts the ways students engage in the classroom (2013). They found that students with a higher sense of self-efficacy were more likely than their peers to verbally engage in the classroom, regardless of their gender. This suggests that development of a strong sense of self-efficacy can have important impacts on the ways that students behave in the classroom, as well as the kind of classroom culture that develops. These studies suggest that it is important to examine the interplay between students’ experiences in the classroom and the development of their sense of self-efficacy.

Confidence is closely related to self-efficacy and is often a precursor to a sense of self efficacy (Covington Clarkson et al., 2017). Confidence describes students’ perceptions of their achievement, rather than a more general sense of whether they are capable of success. While confidence can also contribute to the competence dimension of physics identity (Carlone & Johnson, 2007), it has not been examined as closely in physics classrooms as self-efficacy.

This study examines the impact of classroom experiences in high school physics on self-efficacy and confidence. Specifically, this study addressed three research questions:

1. In what ways do girls experience confidence in a physics classroom differently than boys?

2. What kinds of classroom experiences do students see as particularly important in developing confidence and self-efficacy?

3. In what ways do girls experience opportunities to develop confidence and self-efficacy differently than boys?
2.2 Study

2.2.1 Context

All data was collected in the AP Physics 1 classroom at a suburban high school with approximately 1600 students. 36% of the students in the course were girls and 31% of the students in the course were identified as Black, Indigenous, or people of color (BIPOC), while 56% of the overall school population were BIPOC. AP Physics 1 is offered as an elective and is primarily taken by high-achieving students in their senior year. Students’ only prior physics experience is typically a one trimester survey of basic physics required as part of the 9th grade science sequence. The only prerequisite for AP Physics 1 at the school is students must be enrolled in or have completed Pre-Calculus. The curriculum is adapted from the Modeling Instruction (Jackson et al., 2008) physics curriculum, a reformed instructional approach that relies heavily on guided inquiry.

AP Physics 1 is the only Advanced Placement (AP) course at the school in which girls are significantly underrepresented; in AP Calculus, a course that serves students at the same grade level and with similar academic interests as AP Physics 1, 47% of the students enrolled are girls. This suggests that girls in this school experience barriers particular to physics specifically and perhaps science in general which impact their decision to enroll in AP Physics 1.

2.2.2 Research Design

This study used a mixed method approach, following a sequential explanatory design (Creswell et al., 2003). Data was collected over the course of two school years.

2.2.2.1 Self-Assessments & Course Performance Data.

2.2.2.1.1 Participants. The quantitative data included all students enrolled in AP Physics 1 during both years of the study. The race and gender of students was collected from the
district’s student records system; this places an important limitation on the study as the district uses a limited number of categories for both race and gender. As a result, this study uses two sub-groups for gender: boy and girl. Another important limitation of this study arises from the limited scale of this study; during the two school years during which quantitative data was collected, a total of 92 students enrolled in AP Physics 1 at the target high school, with small sample sizes in some sub-groups; Table 2.1 describes the demographics of study participants. The participant demographics were similar across the two years of data collection.

2.2.2.1.2 Data Collection. This study measured confidence in order to examine students’ perceptions of their achievement. Data on students’ confidence and their actual performance was collected using in-class quizzes that students completed approximately once per week. The course uses standards-based grading, so for each standard on the quiz, students received a score on a scale of 1-5. Confidence was measured by asking students to predict the score they received on each standard on the quiz as part of a written self-assessment included at the end of each quiz.

<table>
<thead>
<tr>
<th>Race</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>43</td>
<td>23</td>
<td>66</td>
</tr>
<tr>
<td>Asian</td>
<td>11</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Black</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>American Indian</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>63</td>
<td>29</td>
<td>92</td>
</tr>
</tbody>
</table>
As part of the self-assessment on the weekly quizzes, students were asked to provide a written response to the prompt “If you believe you are at mastery, what strategies or actions helped? If not, what will you do to improve?” During the second year of data collection, these qualitative responses were recorded, along with the race and gender of the student and their average score and average self-assessment. While these responses were collected throughout year 2 of the study, they were not reviewed until after an initial analysis of the quantitative data.

2.2.2.2 Student Interview Data.

2.2.2.2.1 Participants. The final data source in this study was one-on-one interviews conducted with student volunteers during the second year of the study. A total of 10 students out of 52 enrolled in the course at the time volunteered to participate in the interviews; four of those students were girls and three of the students were boys of color, roughly mirroring the overall demographics of students in the study.

2.2.2.2.2 Data Collection. Interviews were conducted after the AP Physics 1 exam so that all standard course assessments were completed prior to the interviews. The interviews were conducted with student volunteers, so an important limitation is that the students who elected to participate likely had a positive relationship with the instructor and positive experiences in the course overall. Interviews were structured using open-ended questions. The interview questions are included in the Appendix A. All of the questions were intended to probe students’ sense of self-efficacy, the classroom experiences that impacted them, and their perception of a physics identity. The open-ended nature of the prompts provided insights into traits and actions the student associated with being good at physics, which can be assumed to be traits and actions the student associated with holding a physics identity, as well as the kinds of classroom experiences which had a lasting impact.
Interviews were conducted one-on-one between a student and the first author. The first author kept written notes during each interview and all interviews were recorded using an audio recorder and later transcribed. Interview transcripts included a student identifier to support the triangulation of results by comparing interview responses to students’ academic performance, confidence as indicated by self-assessments, and responses to open-ended self-assessment prompts.

2.3 Data Analysis

2.3.1 Quantitative Analysis

Quantitative results were analyzed using the CCL Confidence Achievement Window framework, proposed by Covington Clarkson et al. (2017), for considering the relationship between student’s confidence and their actual achievement. This framework, based on the Johari Window, categorizes students into four profiles as shown in Figure 2.1. The public and unknown profiles represent a high calibration between confidence and achievement, with the public profile indicating a student with both high achievement and high confidence, while the unknown profile indicates low confidence and low achievement. The hidden and blind profiles both represent poor calibration between confidence and achievement. The blind profile, called underestimating here, indicates low confidence and high achievement, while the hidden profile, called overestimating here, indicates high confidence and low achievement.
We averaged the actual and predicted scores for each student over the course of the school year and used those scores to place each student onto a CCL Confidence Achievement Window. An average score above 0.75 indicated the student had ratings of “Near Mastery” or “Mastery” for most standards and demonstrated the depth of understanding necessary to pass the AP Physics 1 exam, so we selected this score as the cutoff for high achievement and high confidence. We calculated the percentage of students in each profile and compared the distributions for boys and girls using Fisher’s exact test.

Since self-efficacy may shift during an introductory physics course (Marshman et al., 2017; Nissen & Shemwell, 2016), the authors determined the profile distribution for each assessment, basing each students’ profile only on their actual and self-assessment score for the individual assessment. The fraction of students in each profile was calculated by gender for each assessment in order to determine whether the distribution changed over the course of the school year.
2.3.2 Qualitative Analysis

The authors reviewed the interview transcripts to determine whether particular types of classroom activities and experiences were mentioned in multiple interviews or in response to multiple interview questions. Next, the authors reviewed responses to the open-ended assessments to identify types of classroom activities that were mentioned by many students. In the analysis of both the interviews and the self-assessments, the authors also noted whether a student described an experience or activity as having a positive or negative impact on their self-efficacy. The authors then compared responses to the interview questions to the responses to the open-ended self-assessment prompt to look for potential connections between the kinds of activities that students identified as memorable self-efficacy experiences in the interviews and the kinds of activities students described most valuable for their learning on their self-assessments.

2.4 Results

2.4.1 Quantitative Self-Assessments

Figure 2.2 shows a plot of students in a CCL Confidence Achievement Window identified by gender and Table 2.2 shows a distribution of students across each profile by gender. A Fisher’s exact test produced a p-value of 0.91, indicating there is no statistically significant difference in the distribution of boys and girls across the profiles, suggesting that students in the study demonstrated similar levels of confidence and achievement, regardless of their gender.
Figure 2.2 CCL Confidence Achievement Window by Gender

![Graph showing CCL Confidence Achievement Window by Gender](image)

Table 2.2 Percent of Population in Profile by Gender

<table>
<thead>
<tr>
<th>Profile</th>
<th>Boys (n = 63)</th>
<th>Girls (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underestimating (c, A)</td>
<td>14.29%</td>
<td>10.34%</td>
</tr>
<tr>
<td>Public (C, A)</td>
<td>55.56%</td>
<td>48.28%</td>
</tr>
<tr>
<td>Unknown (c, a)</td>
<td>20.63%</td>
<td>37.93%</td>
</tr>
<tr>
<td>Overestimating (C, a)</td>
<td>9.52%</td>
<td>3.45%</td>
</tr>
</tbody>
</table>

53% of students fell into the public profile and 26% of students fell into the unknown profile, indicating that most students had good calibration of their confidence. 13% of students fit the underestimating profile and 8% fit the overestimating profile, indicating under-confidence was slightly more prevalent than overconfidence among students in this study.
To examine whether the distribution of students in each profile changed over the course of the year, the authors determined the fraction of students by gender in each profile each standard. These results are shown in Appendix B. In general, during year 2, more students fit the underestimating and public profiles indicating higher achievement than in year 1. This is likely because year 1 of the study coincided with the first year AP Physics 1 was offered in the district, resulting in curriculum revisions between years 1 and 2 of the data collection when the course materials were refined to better align to the AP Physics 1 exam. One impact of these revisions is the sequence of content and the skills emphasized in some standards changed between years 1 and 2 of this study. In both years, there was no clear pattern in the fraction of students fitting each profile as the year progressed, indicating that there was not a clear change in student confidence as the course progressed in this study.

There were several topics that produced similar results in both years. First, in both years, large fractions of students fit the public profile, representing high confidence and high achievement, on the standards for constant velocity representations, projectile motion representations, balanced forces, and energy bar charts. Second, on the standards for Kirchhoff’s Laws and the standards associated with rotation, a relatively large proportion of students fit profiles associated with low confidence, with more girls than boys fitting this profile in year 2.

2.4.2 Qualitative Self-Assessments & Student Interviews

The open-ended self-assessment prompt and student interviews revealed four major experiences which students perceived as important for their confidence: lab activities, problem sets, peer interactions, and assessment feedback. Sample, illustrative quotes are included to provide rich information for the reader using student voices. A table of additional quotes providing evidence for these themes can be found in Appendix C.
2.4.2.1 Lab Activities. In both the interviews and the self-assessments, students consistently identified labs as having a positive effect on their self-efficacy and confidence. In this classroom, most topics were introduced through a guided inquiry lab known as a paradigm lab (Jackson et al., 2008). Students participated in a whole-class discussion to establish a guiding question, then worked in small groups to determine a procedure and collect data. Students then shared their results in a whole class discussion to identify key results. The teacher concluded these labs with a brief lecture connecting students’ results to the target physics concepts.

On the open-ended self-assessments, it was common for students to identify labs as helpful. The student interviews provided additional insights into the role of labs in students’ self-efficacy. Students saw guided inquiry and labs they perceived as connected to the real world as especially important to their self-efficacy.

2.4.2.1.1 Guided Inquiry. Several students referenced the guided inquiry labs typically used to start a unit in Modeling Instruction (Jackson et al., 2008), attributing their self-efficacy to their experiences discovering new concepts. For example, one girl described these labs as a source of science identity when asked about activities that made her feel good at physics: “I think the self-discovery thing, like when you figure it out yourself, that’s, like, always really good. Cause it makes you feel like you’re doing it yourself and you’re, like, this scientist that knows everything.”

While most of the students interviewed expressed a similar sense of ownership from discovery learning as a contributor to their self-efficacy, the open-ended nature of the guided inquiry labs also had a negative impact on some students’ sense of self-efficacy. During the interviews, several students mentioned labs as both a catalyst and an impediment to their sense of self-efficacy. One student who saw the hands-on nature of labs as making him feel good at
physics also described his discomfort with the limited instruction inherent in these labs when asked about activities that made him feel not very good at physics:

I'm very much a learner and worker who does well under instruction, so when I'm left to my own devices, it's more difficult for me to understand the concepts and stuff and lessons. So I would say in physics when I'm left to do a lab by myself, I don't tend to do as well.

These contrasting responses to guided inquiry labs, especially when both perspectives were expressed by the same student, suggest it is important to build a classroom culture and provide instructional scaffolds designed to help students manage their discomfort with the limited teacher direction during these activities.

Many of the students interviewed also had very specific memories of particular labs from very early in the year. When asked for a specific moment when she felt good at physics, one girl described her experience during a lab from the first day of the course:

It was the first lab we did, the buggy lab, that one. Like, all the numbers were just like fitting together and it was, it was like we were actually applying something from math and put, like, physics in the real world and the numbers were just coming together and clicking and I was just like, ‘I love physics, I’m gonna be so good at this!’

This student’s use of language about the content of the lab “coming together” or “clicking” was fairly common among students who referenced specific labs that contributed to their self-efficacy. This suggests the experience of developing a new idea prior to formal instruction over the topic helped students to feel a sense of self-efficacy.

All of the students who referenced a specific classroom activity as helping their sense of self-efficacy referenced something from the first half of the course, even among students who
had higher achievement during the second half of the course. This suggests that early experiences in the course laid an important foundation for students’ self-efficacy.

2.4.2.1.2 Real-World Labs. The sensation of seeing physics in the real world described by the girl who recalled the buggy lab also appeared to be important. Several other students emphasized the importance of directly seeing and experiencing physics in the lab as something that helped build their sense of self-efficacy. As one girl explained:

It’s like labs and being able to see stuff actually happen because sometimes it’s hard to learn for me when we’re doing, like, alphabet soup problems [problems with literal equations] or something like that. So I feel like when I’m actually able to see it that’s really helpful because sometimes it can be a little confusing.

Several standards included labs using web-based simulations or commercially recorded video. It was less common for students to reference these labs in their responses to the open-ended self-assessment prompts. In the interviews, several students described these labs as an experience where they felt low self-efficacy. When asked about a time he did not feel good at physics, one of the boys of color interviewed quickly named the unit on circuits and described the unit’s heavy reliance on a simulation as an important factor:

It was hard for me to understand and wrap my head around and I feel like it’s because we had this simulation and I was able to learn off that, but it was on a computer and I feel like it was cuz I never was actually able to see it and touch it.

The lack of self-efficacy students felt around circuits and other topics with computer-based labs suggests that the opportunity to manipulate equipment directly is important for students to develop a sense of self-efficacy. This is also reflected in the quantitative self-assessments where a high proportion of students, especially girls, fit the unknown profile with low achievement and
low confidence on the standard for Kirchhoff’s Laws in both years. In both years of the study, instruction relied heavily on a simulation, rather than real-world labs. While students did not discuss rotation during the interviews, the labs for these topics relied on video-based virtual labs and a relatively large fraction of students fit the profiles associated with low confidence on these topics, again reinforcing that it was difficult for students to build self-efficacy in topics with purely digital labs.

By contrast, students had relatively high confidence on the standards for constant velocity representations, balanced force representations, and energy bar charts. The labs for all of these topics utilized low-tech equipment such as meter sticks, stopwatches, and spring scales that are familiar to students and provide very direct, tactile experiences with the quantities being measured. Students also had relatively high confidence on the standard on projectile motion representations. While this topic was introduced through video analysis, students recorded their own videos and manually tracked the object of interest, which likely helped students connect the video analysis to their direct experience.

2.4.2.2 Problem Sets. On the written self-assessments, problem sets were another common activity students considered important to their self-efficacy. As is typical in Modeling Instruction (Jackson et al., 2008), problem sets emphasized students applying concepts they had developed during lab activities. Students worked on these problem sets in small groups with minimal prior instruction. In the interviews, students, especially boys, discussed particular aspects of problem sets that were important to their self-efficacy. Several boys saw the process of figuring out how to apply what they figured out in a lab to the written problems as important to their self-efficacy. One boy described his perception of this process when asked about the kinds of activities that make him feel good at physics:
I think when, not like the lab, but after a lab that we do. So, like, we do a lab that hammers at the different ways that physics works and we get a problem set, like, the day after. That it's the same--they’re not the same thing, but it's like the same concept. And then it's like I semi-understand what we did yesterday and then we practice it and all the sudden, I just really understand the problems.

Several boys also recalled a specific problem they had been successful at connecting to the previous day’s lab. As with students who recalled specific labs, students who referenced specific problems consistently spoke only about problems from early portions of the course, suggesting again these early experiences were important to students’ self-efficacy.

By contrast, only one girl talked about the transition from labs to written problems and, by contrast, interpreted the challenge of this experience as evidence she is not good at physics:

Some of the worksheets were...rough cause, you know, you do an experiment and you can see the physics and sometimes with the worksheets you look at it and it's like you can almost grasp it, but I don’t know what is happening here.

Similar to the students who saw guided-inquiry labs as a barrier to self-efficacy, this student interpreted the ambiguity and confusion she experienced on problems as evidence she is not good at physics, rather than as an expected part of the process.

**2.4.2.3 Peer Interactions.** Several of the boys interviewed talked about interactions with their peers while working problems as an experience that positively affected their self-efficacy. They described experiences where peers asked them for help or took their contributions seriously during small group discussions, pointing to these experiences both as moments that helped them feel good at physics and as evidence that their peers believe they are good at physics, such as the boy quoted here:
They think I’m okay and I know that cause maybe when they ask for your ideas like ‘okay, what do you think about this?’ giving the chance to tell them ‘I think we should do this or do that’ and also when they do listen to you with the suggestion it, means they’re like ‘okay, it’s probably right’

Interestingly, the only female student who brought up her peers asking her questions or soliciting her ideas believed that her peers overestimated her physics ability:

I think it's one of those things where I’m, like, generally, a smart person, so they’d like just assume that I kinda know what I’m doing, but, like, they’re all super good at physics so I think...I think they overestimate my abilities almost.

2.4.2.4 Assessment Feedback. During the interviews, feedback students received on assessments emerged as an additional experience that impacted their self-efficacy. Feedback was not mentioned by any students on the written self-assessments, but this is likely because the written self-assessments were only collected for students’ first attempt on each standard, so they had not received or used written feedback from the instructor on that skill. During the interviews, when asked whether their instructor believes they are good at physics, a number of students, especially boys, referred to the comments and grade on a quiz they had done well on. The boys interviewed typically focused on quizzes where they had done well, such as the boy quoted here: “Yeah, cause, if I have a good grade in the class and the teacher is the same teacher that marked it, so obviously the teacher would agree that I’m good in that class.” This response suggests boys saw demonstrating competence and external recognition as related.

Interestingly, several students, especially girls, focused on the kind of feedback the instructor wrote on assessments they had done poorly on as evidence their teacher believed they are good at physics. As one girls put it, :Whenever we take quizzes and your give the quizzes
back to us, you would write feedback on them and it was never anything like bad. It was always constructive and it was always helpful.” This suggests that some of the students interviewed experienced external recognition even when they do not demonstrate competence if the recognition is framed as a belief in the students’ ability to improve. It is worth note that every girl interviewed expressed this view, while the boys who focused on feedback from their teacher were in the minority.

2.5 Limitations

This study has several important limitations. First, while the intersections of race, gender, and other identities have important and unique impacts on the development of a student’s sense of science identity (Brickhouse et al., 2000; Carlone, 2004; Carlone & Johnson, 2007; Hazari et al., 2013), the very small number of BIPOC girls enrolled in AP Physics 1 at this high school preclude a meaningful consideration of the intersections of race and gender in this study. In addition, this study relied on a gender binary since the high school only reported gender as male or female in student records. It is also important that all of the students interviewed were volunteers, meaning that students who had positive experiences in the course were likely overrepresented in the interviews.

This study also relied on students’ memories and perceptions of their experiences in the class, which may not reflect what actually occurred in the classroom. For example, it is not clear whether the boys interviewed said more about peers asking them questions and listening to their ideas because they had more of those experiences than girls or because the girls interviewed interpreted those experiences differently, such as the student who thought her group overestimated her.
2.6 Discussion & Conclusions

This study found that both boys and girls not only had similar levels of confidence, but had confidence that was well-calibrated to their actual achievement. Since confidence is typically a precursor for self-efficacy (Covington Clarkson et al., 2017), this result stands in contrast with existing literature that found men had a higher sense of self-efficacy than women (Jurik et al., 2013; Marshman et al., 2017; Marshman et al., 2018; Mujtaba & Reiss, 2013a, 2013b; Nissen & Shemwell, 2016). Since this study did not directly examine self-efficacy, it is possible that while gender did not predict a students’ confidence, gender may have played a role in how confidence developed into self-efficacy.

These results do not show a clear decline in the proportion of students in profiles associated with low confidence, a contrast with previous studies that found college students’ self-efficacy declined during an introductory course (Marshman et al., 2017; Nissen & Shemwell, 2016). Rather, the distribution of students across profiles fluctuated throughout each year of data collection, suggesting students did not have a clear increase or decrease in confidence as the course progressed. While this may suggest the participants in this study did not experience the decline in self-efficacy seen in other studies, it is also possible that the relationship between confidence and self-efficacy shifted for students over the course of the school year.

These results raise the question of what classroom experiences contributed to students’ perceptions. In interviews, students referenced clear, specific memories of early experiences in the classroom that helped to shape their beliefs about their abilities in physics, suggesting that experiences early in the course played an important role in developing students’ sense of self-efficacy. It is therefore particularly crucial to ensure students have experiences such as learning
new concepts through guided inquiry that will contribute to self-efficacy early in the school year to provide a foundation for students’ physics identity.

Sense-making activities, especially guided inquiry labs and problem sets, played an important role for both boys and girls in not only developing a sense of self-efficacy, but in developing a physics identity as a whole. Both boys and girls reported experiencing competence by figuring out new concepts in the lab, which led to a sense of self-efficacy. Boys also reported experiencing competence and self-efficacy when figuring out how to apply concepts from the lab to problems. The interviews suggest students also saw guided-inquiry labs as an opportunity to engage in the performance dimension and act like a scientist, contributing to a robust science identity in addition to a sense of self-efficacy. This mirrors Carlone’s observations of girls in a physics classroom using a reformed curriculum (2004). Much like Modeling Instruction, the classroom observed by Carlone placed science as a process, rather than a set of facts, and emphasized students’ ideas and questions throughout the curriculum. This provided ample opportunity to engage in the performance dimension, leading some girls to develop a robust physics identity. In this study, guided inquiry labs in particular appear to have played a similar role in giving students the opportunity to see themselves as physicists.

There was, however, some tension in the ways students in this study experienced guided inquiry and problem sets. Even some of the students who saw guided-inquiry as important to their self-efficacy interpreted the confusion, mistakes, and ambiguity inherent in guided inquiry in ways that harmed their self-efficacy. In addition, only boys saw problem sets as contributing to their self-efficacy. The only girl who discussed the problems described similar frustrations to the ones students described during guided-inquiry, which hurt her self-efficacy. For girls in particular, these challenges may be actively threatening to their identity as a good student.
Girls often associate being a good student with behaviors like following directions, paying attention, and getting correct answers that are devalued during sense-making activities in approaches such as Modeling Instruction (Jackson et al., 2008), which can lead to students feeling frustrated and potentially rejecting a science identity. To minimize the negative self-efficacy impacts of sense-making activities, it is therefore crucial to normalize working through confusion and mistakes, reframing them as skills such as troubleshooting and solving problems. It is also important to recognize that asking students to engage productively in guided inquiry, problem sets with minimal instruction, and other reformed approaches involves attending to students’ identity development and the behaviors they connect to their student identity (Carlone, 2004).

Finally, students viewed labs they perceived as connected to the real world as especially important to their self-efficacy and confidence. In interviews, students saw arriving at new physics knowledge from a phenomenon they had directly observed and measured as a powerful experience that was important in developing a sense of self-efficacy. Students also described struggling to develop self-efficacy on topics where labs were primarily conducted using simulations or video since students saw these labs as less connected to the real world. It is therefore important when using digital labs to find ways to support students in drawing connections to the real world in order to support the development of student self-efficacy.

Identity formation is a social process (Brickhouse, 2001), so it is no surprise that students saw peer interactions as important to their sense of self-efficacy. It is not, however, clear why boys in this study consistently described peer interactions that supported their self-efficacy, while the only girl to describe similar interactions saw them as evidence she was fooling her peers, rather than an experience that contributed to her self-efficacy. Jovanovic and King (1998)
and Wieselmann et al. (2019a) both observed that in mixed-gender groups, girls’ ideas were often quickly dismissed by boys in the group, so it is possible that girls in this study had fewer experiences than boys where peers listened to their input. Wieselmann et al. (2019a) and Quinn, et al. (2020) also observed that during highly-structured activities, student participation was more equitable, though students were less likely to encourage behaviors that promote the development of a science identity. This suggests that it could be valuable to provide structures to group-work, such as roles, during otherwise open-ended activities to promote equitable participation and ensure that all students have the opportunity to experience positive recognition from their peers. It is also possible that girls experienced positive peer recognition, but interpreted those experiences differently than boys in the study. Patrick and Yoon (2004), in their observations of a group of eighth-grade students, found boys in the group tended to use their contributions to demonstrate competence to their peers, which suggests they may have been actively seeking external recognition from peers in the group. The girls observed, by contrast, appeared to be motivated by seeking understanding or wanting to appear conscientious through their contributions. If similar motivations were present in this study, it is possible girls were attending to peer recognition differently than boys.

In this study, girls viewed feedback on assessments where they scored poorly as evidence the teacher believed they are good at physics. This suggests that not only were students able to experience external recognition without experiencing competence, but the recognition and growth mindset messages in the feedback were more impactful than experiencing low competence. While recognition, competence, and performance are all important to a physics identity (Carlone & Johnson, 2007), students do not need to experience all three at once and a positive experience in one dimension may be more impactful than a simultaneous negative
experience in another. The ability of girls in this study to separate recognition and competence was rooted in a growth mindset (Dweck, 2008) since girls emphasized the feedback was evidence the teacher believed they could improve. This interpretation was likely influenced by growth mindset messages present in the classroom beyond the teacher feedback, such as a policy allowing retakes (Sun, 2019).

Students take messages about who is good at physics and what it means to be good at physics from their experiences in the classroom. These messages impact their confidence, self-efficacy, and their sense of physics identity as a whole. Understanding the messages students hear and how they impact students’ beliefs about their abilities is a stepping stone to designing classrooms where every student can see themselves as the kind of person who does physics.
Chapter 3. What Does it Mean to be Good at Physics? Peer Recognition in a High School Physics Classroom

3.1 Introduction

Physics is a firmly male-dominated field, with other genders underrepresented not only among professional physicists, but at various levels of physics education. At the high school level, less than 40% of the students taking the AP Physics 1 exam in 2021 were girls and only 0.2% were non-binary (College Board, 2022). Black, Indigenous, and other girls of color experience particularly significant marginalization (Hazari et al., 2013), indicating a need to consider the intersections of race and gender in addressing gender equity in physics.

One framework for examining marginalization is physics identity, defined as the extent to which an individual sees themselves as the kind of person who does physics (Carlone & Johnson, 2007). A physics identity can be both personal, which describes an individual’s affiliation with a particular identity, and normative, which describes a collective sense of what it means to be a particular type a person (Cobb et al., 2009). Normative identity plays an important role in shaping who has access to a physics identity since political, social, and cultural factors influence what we think it means to be a science person (Avraamidou, 2020). Carlone and Johnson (2007) propose a framework for personal identity with three dimensions: competence, performance, and recognition. Competence refers to demonstrating skill or ability related to physics and performance describes acting, speaking, and interacting in ways associated with physics by oneself or others. Recognition refers to being seen as the kind of person who does physics both oneself and by others.

An important part of developing a physics identity is being recognized by others as a science person (Archer et al., 2020; Carlone & Johnson, 2007; Hazari et al., 2017; Kalender et
al., 2019b). In several studies, boys were more likely to talk about receiving recognition from peers during small group work than girls (Stoeckel & Roehrig, 2021; Tonso, 2006), but it is unclear whether boys received more peer recognition or whether they perceived peer recognition differently than the girls in the study. These studies also do not address what constitutes peer recognition.

3.2 Literature Review

The recognition dimension of physics identity describes students being seen as the kind of person who does physics, both by others and by themselves (Carlone & Johnson, 2007). Recognition may play a particularly important role in equitable science instruction. For example, in a large-scale study, students who reported their high school physics teacher saw them as an exemplary physics student were more likely to major in a related field as an undergraduate (Hazari et al., 2017). However, women undergraduates majoring in STEM fields tend to report that others do not see them as science people (Kalender et al., 2019a). In a study of undergraduate engineering classrooms, even when women had significant opportunities to perform as a science person and demonstrate competence, they experienced less recognition than their male peers (Tonso, 2006).

Several studies have observed differences in the ways boys and girls engage in small group activities which could have implications for the opportunities students have to make contributions and receive recognition from peers (Jovanovic & King, 1998; Jurik et al., 2013; Patrick & Yoon, 2004; Wieselmann et al., 2019a; Wieselmann et al., 2019b). One common finding has been that boys are more likely to present ideas and suggestions when working in small groups, an important opportunity for students to receive recognition from their peers. Patrick and Yoon (2004) observed that boys often used their participation to demonstrate their
competence to peers while the girls in the study tended to participate to develop a deeper understanding, providing very different opportunities for recognition. Jovanovic and King (1998) and Wieselmann et al. (2019b) each observed several occasions in mixed-gender groups where a girl proposed an idea that was quickly dismissed by the boys in the group, communicating a lack of peer recognition to the girls in the group. These results make clear that recognition, and physics identity in general, is not only about individuals, but about how individuals and their environments interact (Kim & Sinatra, 2018). An important layer of this interaction is how a normative science identity is constructed within a classroom, since what students come to think of as a science person has important implications for who in the classroom has access to a science identity (Carlone et al., 2011).

An important gap in this literature is that while many studies agree that recognition is important, there is little effort to describe what recognition looks like (Kim & Sinatra, 2018). It is especially important to consider how context, cultural norms, values, and other social factors influence how recognition is both given and received (Avraamidou, 2020). A few studies have examined individuals’ perceptions of recognition in their physics education (Avraamidou, 2022; Wang & Hazari, 2018), but do not include direct observations of how students, teachers, and others interacted during events that resulted in recognition. Wang and Hazari (2018) proposed a framework of major ways that teachers can provide recognition to students, categorized as either explicit recognition, where teachers directly acknowledge students’ abilities, or implicit recognition, where teachers indirectly acknowledge students, then used student surveys and interviews to examine how students experienced those forms of recognition and how those experiences impacted their physics identity. Avraamidou (2022) applied these categories of explicit and implicit recognition to analyze the stories three women told about their journeys in
physics and examine how factors including race, economic background, and religion interacted with the recognition they experienced from a variety of sources. While these studies add important insights to a conceptualization of recognition, neither directly examined the particular ways that students are able to recognize their peers during classroom interactions.

This study examines three questions to clarify what constitutes peer recognition and how it relates to a physics identity:

1. **What are the ways that small groups in a high school physics classroom provide peer recognition within the group?**

2. **How do these forms of peer recognition reflect and contribute to the normative physics identity in a classroom?**

3. **How do these forms of peer recognition interact with students’ sense of personal physics identity?**

3.3 Theoretical Framework

In this study, I used an initial definition of recognition based on positioning theory. The central concept of positioning theory is that different participants in a social episode have access to different rights and obligations based on their social positions (Davies & Harré, 1990). From this lens, interactions revolve around establishing, affirming, or challenging the positions held by each participant and what is expected or allowed of someone in that position. These positions carry a moral weight in the sense that someone who adheres to the responsibilities and limitations of their position is seen as “good” by the participants.

Analyzing discourse through positioning theory requires attending to the three points of the positioning triangle shown in Figure 3.1: position, speech acts, and storylines (Davies & Harré, 1990). A position is a dynamically changing role that carries with it particular rights,
duties, and obligations. For example, a student who is positioned by their peers as a good physics
student may be seen as having an obligation to help their peers with a task and a right to
challenge the ideas stated by their group members. While identity certainly shapes the positions
available to an individual, it is important to note that a position can shift dynamically, in some
cases from utterance to utterance, while identity is typically seen as relatively stable (Kayi-Aydar
& Miller, 2018). In addition, a position is purely a social phenomenon; an individual cannot hold
a position without some form of interaction with others. Carlone and Johnson's (2007) view of
identity, however, includes purely internal experiences, such as how an individual perceives
themselves, that do not require social interaction. This means that while the identities someone
holds may influence the positions available to them, a position is not simply a particular way of
expressing an identity.

Storylines describe the larger social narratives that influence our beliefs about what
positions are available, who can occupy those positions, and what it means to hold those
positions (Davies & Harré, 1990). These are rarely directly stated during discourse, but play a
powerful role in interaction. For example, storylines that frame using tools as a masculine
endeavor (McGowan & Bell, 2020) give men more access to positions associated with
manipulating equipment and were enacted by students in several studies that found
undergraduate men used equipment more than women (e.g. Doucette et al., 2020; Quinn et al.,
2020).
Speech acts are the particular discourse moves that individuals use during an interaction (Davies & Harré, 1990). These may be as small as a single utterance or gesture. For example, when a student gives an answer, the teacher may use a simple speech act such as saying “correct” that simultaneously accomplishes multiple positioning moves. First, the teacher is positioning themselves as having the right and obligation to evaluate student contributions by virtue of their position as an expert on the course material. In addition, the teacher is positioning the student as a good student by indicating this was an appropriate answer to the question given in an appropriate manner at an appropriate time.

Positioning theory describes recognition as a speech act that positions someone as holding skill or expertise relevant to the particular context (Harré & van Langenhove, 1999). While positioning theory certainly allows for misrecognition, or negative judgements in which someone is positioned as lacking skills or expertise, in the context of physics identity, recognition is typically limited to positive judgements (Carlone & Johnson, 2007). In addition, while every speech act includes some form of positioning, not every speech act includes recognition since skills or expertise relevant to the context are only included in one of the many positions that may be at play within a conversation. Finally, this definition allows for both verbal and non-verbal recognition. For example, if a group of students are working on a problem and one suggests using a particular equation, which another writes down, the first student is
recognized as having presented a useful idea through the act of their peer preparing to make use of that equation.

Recognition may be implicit as well as explicit, as described by Wang and Hazari (2018) in a study of the ways that teachers provided recognition to students in a high school physics classroom. For example, if a teacher assigns students a challenging task with the clear expectation that students will successfully complete the task, that move positions the students as holding meaningful skill in physics, even if the teacher never directly communicates their confidence in students’ capabilities.

3.4 Study

3.4.1 Context

Data was collected in the AP Physics 1 classroom at a suburban, Midwestern high school with approximately 1600 students. The course is a year-long electives primarily taken by seniors intending to attend a four-year college. The curriculum is adapted from the Modeling Instruction (Jackson et al., 2008) physics curriculum, a reformed instructional approach that relies heavily on guided-inquiry and small group work. I collected data across two weeks in March and April. Since all students had been in the same section since September, they had well-established peer relationships. During the data collection, students worked in self-selected small groups of two to four students.

The year that data was collected, there was a significant drop in enrollment at the school for AP and other courses that offered college credit, including AP Physics 1. In previous years, AP Physics 1 typically had 40-50 students. During this data collection, AP Physics 1 had 11 students enrolled in the course. The demographics according to school records of students enrolled in the course are given in Table 3.1.
Table 3.1 Demographics of AP Physics 1 Enrollment

<table>
<thead>
<tr>
<th>Gender</th>
<th>Asian</th>
<th>White</th>
<th>Mixed</th>
<th>Black</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Girls</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>

3.4.2 Participants

This study focuses on interviews with six volunteers from the class, along with recordings of two small groups. The pseudonyms of the participants along with the race and gender they used to describe themselves and the portions of the data collection they participated in are in Table 3.2. One group was composed of Lucy, Bobby, and Kareem while the other included Nyan and Tyler. On some occasions, especially when one or more of these students were absent, these two groups worked together as a single group.

Table 3.2 Self-Identified Demographics of Study Participants

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>Race</th>
<th>Data collection participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alex</td>
<td>Boy</td>
<td>White</td>
<td>Interview</td>
</tr>
<tr>
<td>Bobby</td>
<td>Boy</td>
<td>Hmong</td>
<td>Small Group Video</td>
</tr>
<tr>
<td>Kareem</td>
<td>Boy</td>
<td>Asian &amp; Black</td>
<td>Interview &amp; Small Group video</td>
</tr>
<tr>
<td>Lucy</td>
<td>Girl</td>
<td>Hmong</td>
<td>Interview &amp; Small Group Video</td>
</tr>
<tr>
<td>Matthew</td>
<td>Boy</td>
<td>Black</td>
<td>Interview</td>
</tr>
<tr>
<td>Nyan</td>
<td>Boy</td>
<td>Karen</td>
<td>Interview &amp; Small Group Video</td>
</tr>
<tr>
<td>Tyler</td>
<td>Boy</td>
<td>White &amp; Black</td>
<td>Interview &amp; Small Group Video</td>
</tr>
</tbody>
</table>
3.4.3 Data collection

Students were recorded during small group work over the course of two weeks during March and April. I selected a set of dates that included a range of activities, including working problems collaboratively, completing card sorts, and conducting various types of labs. I placed a video camera and audio recorder at each lab table when students are working in small groups during these lessons and recorded notes describing the major activities in each lesson.

In addition, I conducted semi-structured interviews, including stimulated-response items, using the protocol in Appendix D, several weeks after the video recording was complete. Six students, including four from the small groups used in this study, volunteered to be interviewed. As part of the interviews, I asked students about the ways they gave and received recognition in the class as well as their perceptions of what constitutes competence in physics, including how they and their peers demonstrated physics competence. For the stimulated response portion of the interview, I selected a brief clip in which I believed the student was either giving or receiving recognition, then asked students to reflect on their perceptions of the event. I selected exchanges where both the student giving the recognition and the student receiving the recognition would be interviewed, then showed both students the same clip to get the perspective of both participants in the exchange. The exchanges used in the stimulated response interviews are listed in Table 3.3. The interview data includes audio recordings, transcriptions, and researcher notes recorded during and after each interview.
Table 3.3 Exchanges for Stimulated Response Interviews

<table>
<thead>
<tr>
<th>Student giving recognition</th>
<th>Student receiving recognition</th>
<th>Brief transcript</th>
</tr>
</thead>
</table>
| Alex                      | Matthew                       | 1. Matthew: If we need the radius to have units in meters, we have mass which would be recorded in kilograms times meters-squared per second-squared and then both of these divided by…  
2. Alex: I see what you’re saying |
| Kareem                    | Lucy                          | 1. Lucy: I was right  
2. Kareem: This was one way of thinking about it |
| Nyan                      | Tyler                         | 1. Nyan: (looking at Tyler) What would normal force be? Would that be gravity?  
2. Tyler: Yeah |

3.5 Data Analysis

I analyzed the data using an iterative approach based on grounded theory (Charmaz, 2014). First, I reviewed several videos of each small group to code moments that appeared to include peer recognition. For this stage, I looked for discourse moves where a student was positioned either as being good at physics in general or as having made a contribution that moved the group forward on their task. Because my research questions specifically address peer recognition, I only considered events where one student recognized another student, not events where the teacher provided recognition or where a student gave themselves recognition.

I next developed an initial set of codes for types of recognition by looking for similar forms of recognition in the events I had identified so far. I also reviewed the interview transcripts to develop a set of codes for the forms of recognition that students discussed during the
interviews. By comparing the codes I developed in my initial review of the videos with the codes I developed from the interviews, I was able to refine the video codes to ensure they included the forms of recognition students saw as important in the classroom.

Next, I shared my codes with another researcher who has experience teaching high school physics and is also studying recognition as a component of physics identity. We each applied these codes to the same video, then discussed our coding in order to ensure we had a common understanding of the codes and examined events that seemed to include peer recognition, but did not fit within any of the existing codes. I then revised the codes and worked with the other researcher to apply those codes to a new video, repeating this process until I reached a point of saturation, where after coding the same video the other researcher and I agreed on how to code the recognition events we identified and did not see a need for any additional codes.

3.6 Results

The final codes for forms of recognition fell into two categories matching those from Wang and Hazari (2018): explicit recognition and implicit recognition, suggesting these two categories of recognition are widely applicable. Explicit recognition describes codes where one student very directly positioned another as good at physics or having made a meaningful contribution to the group. Implicit recognition includes codes where a student was still positioned as good at physics or having made a meaningful contribution, but the recognition was not direct. A summary of these codes is in Table 3.4.
### Table 3.4 Codes for Recognition

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit recognition</td>
<td>Direct validation</td>
<td>Directly acknowledging the value of a contribution, such as agreeing with an answer</td>
</tr>
<tr>
<td></td>
<td>Directed question</td>
<td>Directing a question toward a specific individual in order to obtain information</td>
</tr>
<tr>
<td></td>
<td>General praise</td>
<td>Validation that is not tied to a specific contribution, such as “we’re so smart!”</td>
</tr>
<tr>
<td>Implicit recognition</td>
<td>Responding to contributions</td>
<td>Validating a question or idea by engaging with it in order to move forward on the task</td>
</tr>
<tr>
<td></td>
<td>Active listening</td>
<td>Observing while a peer moves forward on a task without providing feedback</td>
</tr>
</tbody>
</table>

#### 3.6.1 Explicit Recognition

The final codes in this study included several forms of explicit recognition that had significant overlap with the explicit recognition from teachers described by Wang and Hazari, (2018), suggesting that what explicit recognition looks like can have similarities across different contexts and that teachers and students can have similar speech acts available to them to provide recognition in spite of holding different positions within a classroom. These forms of recognition tended to function at a very short timescale, often in as brief a time as a single utterance. These forms of recognition also tended to respond to contributions that were seen as correct by other students, focusing on a particular way of being good at physics.
3.6.1.1 Direct Validation. The first and clearest was direct validation, where one student responded to a contribution from another by directly agreeing with the answer or stating the value of the contribution, closely mirroring Wang and Hazari’s (2018) code “addressing success” in which teachers responded directly to ways that students demonstrated competence in physics. This included both verbal and nonverbal moves, such as this exchange between Lucy and Bobby while working on a lab that required them to convert a measured mass in grams to a force in Newtons:

1. Bobby: It’s 1000 grams in Newtons it would be 10

2. Lucy: 10 Newton (writes “10” in the “Force” column of a data table on the group’s whiteboard)

During this very brief exchange, Lucy was holding the group’s marker and standing in front of the center of their whiteboard, giving her the most access to write on the board and positioning herself as the person who should evaluate whether a contribution made by her peers was worthy of including in the group’s record. Her gender contributed to her access to this position of authority in a mixed-gender group thanks to storylines that consider tasks like recording information a feminine task (Doucette et al., 2020). Lucy used the rights associated with her position through her speech act, which gave Bobby direct verbal validation by repeating his answer in order to express agreement, positioning Bobby as valuable to the group. Lucy reinforced the positioning in her speech act by writing Bobby’s answer on the whiteboard, adding it to the group record she was obligated to maintain.

During the stimulated response interviews, students indicated that events from this code were examples of peer recognition. In addition, when discussing the ways that students felt they had given and received recognition from peers during the course, several students described
experiences consistent with this code. For example, Alex responded “I give them positive affirmation like ‘yup yup I got the same thing’ or ‘you got it better than me’ ” when describing ways that he gives his classmates recognition.

3.6.1.2 Directed Questions. Another form of explicit recognition was directed answer-seeking questions. This code describes events where a student either referred to another by name or used body language such as directing their gaze to a particular person in order to obtain information they needed to move forward on a task. This code was used in instances where it appeared the person asking the question expected the person being asked to have a useful answer, thereby positioning them as someone good at physics, rather than a question that served other purposes, such as challenging an idea. This form of recognition overlaps with Wang and Hazari's (2018) code “addressing potential” in which a teacher expresses the expectation that a student will be able to demonstrate competence at physics in the future. For example, during a lab where each group needed to prepare a whiteboard with a graph of their data and an equation for their line of best fit, Nyan approached Lucy, who was working in a different group, made eye contact, and addressed her by name to ask how she had found the slope of her group’s line. By approaching Lucy specifically, Nyan positioned her as someone who he expected to know how to accomplish that task, even though he had not been at the table while the group calculated their slope to know who had found the answer. When Nyan approached the group, Lucy was once again holding the group’s marker and standing in front of the center of the group’s whiteboard, positioning her as the one who had determined whether the slope was correct, regardless of who had calculated the slope. Nyan was acting on a storyline that being able to evaluate whether the slope should be added to the group record included understanding how the group had arrived at that value.
Students also used directed questions as a tool to reengage a peer. For example, while working on a card sort with Tyler, Nyan at one point became disengaged and leaned away from the table, focused his attention on his phone. After matching a few cards on his own, Tyler pointed to a card in front of Nyan and said “I think we need some of these” while directing his gaze toward Nyan. Nyan immediately set his phone down, leaned toward the table, and turned his attention to the cards Tyler was gesturing toward. Nyan’s initial disengagement positioned him outside of the group, which Tyler could have accepted through a move such as simply taking the cards that were in front of Nyan. Instead, Tyler rejected Nyan’s positioning with his speech act and decision to simply gesture at the cards in front of Nyan. These moves positioned Nyan as someone who had the ability and obligation to contribute to Tyler’s efforts to complete the card sort activity, acting as a form of recognition. Nyan accepted this positioning by reengaging and making an effort to fulfill the obligations of the position Tyler had placed him in.

It was clear that students in this study saw asking these kinds of questions as a form of recognition. In his interview, when describing ways that he lets his peers know he thinks they are good at physics, Nyan listed “asking questions and stuff” as one of his approaches, a response echoed in several other interviews and further affirmed by the students who were shown this kind of question in the stimulated response portion of the interviews. Not all questions, however, served as recognition. In the interviews, students discussed some questions as a means of challenging a contribution someone had made to the group rather than a form of recognition. For example, Alex said that he knows his group believed he is good at physics because “they’re not always questioning whether or not I’m sure on something or that I did it correctly.” It was therefore crucial to carefully examine the intonation students used, the body language of the speakers, and the context of the question being asked in order to infer the purpose of the question.
within the conversation when using this code. Questions that had a rising or falling intonation seemed to indicate uncertainty and a desire for new information from the speaker and often led to the person being asked the question introducing new information to the conversation, leading us to code these as the directed question form of recognition. While the form of these questions varied widely, many started with words like “how”, “what”, and “why” then described a gap in the information the asker had. For example, while working on a lab, Tyler and Nyan had this exchange:

1. Tyler: How do we find $F_g$ [force of gravity]?

2. Nyan: $m$ times $g$

Tyler used a falling intonation at the end of his question in line 1, indicating uncertainty about the answer, and used the word “how” to specify what information he was missing and positioning Nyan as a potential source of this information. This question allowed Nyan to introduce new information to the group when he responded with the formula to calculate the force of gravity on an object, which the group had not been using prior to this point. Tyler’s body language also contributed to his positioning of Nyan as a potential source of information. Prior to the exchange, both students were standing in front of the whiteboard they were using to record their results, but Tyler was holding the group’s marker and writing on the whiteboard, positioning himself as the evaluator of what contributions were worth recording. As Tyler asked his question in line 1, he physically stepped out of this position by setting the marker down and stepping to the side of the whiteboard, leaving Nyan alone in front of the whiteboard with the marker in his reach and the opportunity to take up the position of evaluating what should be recorded.
Students also used questions to challenge ideas, express disagreement, and otherwise negatively position contributions. These questions were often used by the asker to introduce a new idea, rather than invite an idea from the person being asked. For example, while working on finding the equation for the line of best fit for their data, Kareem and Lucy had the following exchange:

1. Lucy: 50 grams equals one, over one Newton I don’t know
2. Kareem: Isn’t line of best fit y equals m x plus b?
3. Lucy: Yes
4. Kareem: So how, how is that?

While Lucy correctly stated the slope of the line in line 1, Kareem’s question in line 2 served to challenge the completeness of her answer, rather than seek new information. He used a closing intonation at the end of the question, positioning himself as certain of the answer, in spite of the hedging language. In addition, by beginning his question with “isn’t”, he positioned his response as contrasting with Lucy’s statement in line 1. He then used his question to introduce the idea that the equation for the line should have the form of \( y = mx + b \), emphasizing what Lucy’s contribution was lacking, positioning her contribution as incomplete and therefore less valuable through his speech acts. Importantly, Kareem’s speech acts failed to recognize that the slope Lucy had found would be used in place of the “m” in their final equation in the form of \( y = mx + b \), which could have been used to position Lucy as having made a contribution necessary to moving the group forward. By positioning Lucy in terms of what her contribution lacked rather than how it moved the group forward, Kareem enacted a storyline that the contributions of girls are inherently less valuable (Wieselmann et al., 2019b).
3.6.1.3 General Praise. The general praise code describes cases where students gave recognition that was not tied to a particular contribution. For example, at the end of an exchange where Tyler and Nyan worked to figure out the equation for the line of best fit for their data, as Nyan wrote the final equation on their whiteboard, Tyler clapped in celebration of completing the task. In another case, groups were working on a card sort to match cards that showed different representations of the same motion. After the teacher affirmed the correctness of some matches her group had made, Lucy turned to her group and said “We’re doing it right!” General praise tended to celebrate the group as a whole, such as through Lucy’s use of the pronoun “we” rather than “I” or “you”.

3.6.2 Implicit Recognition

Unlike explicit recognition, the final codes for implicit recognition in this study have very little overlap with the codes Wang and Hazari (2018) used to describe recognition from teachers. The exchanges where students demonstrated implicit recognition tended to be much longer than the exchanges with explicit recognition, sometimes taking as long as several minutes for a single example of implicit recognition.

3.6.2.1 Responding to Contributions. This code describes interactions where a student made a contribution, such as asking a question of the whole group or sharing an idea, and other members of the group validated that contribution by engaging with it as a means of moving forward. In the interviews, several students described this as a way they provide recognition to their peers. For example, Kareen said “We go off their idea. We start saying if ‘if this idea is right, how can this help?’ Try and discuss their idea, see how it will contribute to the problem.” in response to a question about how he let his classmates know he believed they are good at physics. Kareem and others who discussed this kind of contribution were describing speech acts
that treat the contribution as something the group should give serious consideration to, which, by extension, positioned the student who made the original contribution as someone who was good at physics. This kind of recognition occurred in the following exchange where Lucy, Kareem, and Bobby were trying to find the slope of a line of best fit, represented by m, for data they had collected:

1. Lucy: So it's 50 grams per Newton
2. Bobby: Well that's what I'm guessing because zero is no grams no force
3. Lucy: How to make that part m cuz it's in Newtons
4. Bobby: So it's one for one

In this exchange, Lucy proposed an incorrect value for the slope in line 1, which Bobby responded to by not only agreeing with Lucy, but by building on her idea and adding information, positioning Lucy as having made a useful contribution. Lucy then reciprocated that recognition in line 3 by asking a question to build on Bobby’s response. Lucy’s question sought additional information about Bobby’s contribution, focusing on the next steps the group should take in response to that contribution, which positioned Bobby as having moved the group forward. Bobby’s response in line 4 positioned Lucy as having asked a question worth engaging with by responding to the question with additional information to try and move the group toward their eventual answer.

Importantly, this form of recognition did not require students to demonstrate competence by sharing a correct answer, which fit with the ways students responded during interviews when asked what are some things a person who is good at physics does. For example, when Nyan described what he thought it meant to be good at physics, he said “Brainstorming. I think like sharing out ideas to each other even though it might not work.” Matthew responded to the same
prompt with “Questions is probably the most important thing. Whether it’s a question for understanding or a question to see if we’re doing this right or even just offering another way to do something. I’d say that’s the most important thing.”

There were few examples, however, of students describing this form of recognition as one they had received or these kinds of contributions as examples of ways they were personally good at physics. Nyan even went so far as to describe himself as bad at physics because “I tend to ask a lot of questions”, in stark contrast with the clear value Matthew placed on questions. There were no instances where a student who made a contribution that produced this form of recognition directly responded to the positioning their peers were engaged in, which suggests that the speech acts that accomplished this recognition were subtle enough that students may not have realized they were receiving recognition in those moments.

3.6.2.2 Active Listening. This form of recognition describes cases where one student seemed to accept another completing a task mostly independently. Avraamidou (2022) observed a similar kind of implicit recognition operating over an even longer scale when one of the women she interviewed described drawing recognition from the fact that her family never opposed her decision to study physics. We used this code when the gaze and body language of the student providing the recognition suggested they were engaged and attending to the work a peer was doing, but they did not offer verbal feedback or other input. For example, in one case Nyan and Tyler were working on a task to match cards that provided different representations of the same motion. There was a three-minute stretch where Nyan was confidently placing cards together in the center of the table and verbalizing his matches with phrases like “This one goes with that one”. Nyan’s placement of the cards in the center of the table where they were accessible to both students and verbalization of his answers positioned Tyler as a participant in
the activity, even if Tyler was not actively involved at this point. Tyler was leaning forward with his gaze following the cards as Nyan moved them, suggesting that he was paying attention to the choices that Nyan was making. In other exchanges, Tyler challenged Nyan, even when Nyan expressed confidence, indicating a storyline in which the position of an engaged member of the group includes the right to challenge contributions that are not correct or complete. By declining to act on that right, Tyler indirectly positioned Nyan as someone who was making valuable contributions to the group.

While I did not use any instances of active listening during the stimulated response interviews, during other portions of the interviews, students did indicate this could be a form of recognition. Alex described this kind of interaction in his interview when describing how his peers let him know that he is good at physics: “They trust that I did the right work and got the right answer.” As indicated by Alex, these instances of recognition seemed to occur when other members of the group expected the student being recognized either had the right answer or would be able to arrive at the right answer without help.

3.6.3 Experiencing Recognition

While students discussed both implicit and explicit recognition during the interviews, they primarily discussed explicit recognition when discussing themselves. For example, when asked how her classmates let her know she is good at physics, Lucy said “When I do something right, they’re like ‘oh, now I understand’.” Many students also specifically discussed receiving recognition for contributing correct ideas to their group, such how Kareem described how his group let him know he is good at physics: “When they try to use my idea as a point of which to begin to tackle the problem. And we would go off of that, see if it works, and if it does, it let me know that I made something useful toward the problem.” In both of these responses, Lucy and
Kareem described speech acts that would fall under the direct validation form of explicit recognition. By attaching explicit recognition to the ways they saw themselves as good at physics, students seemed to be connecting these forms of recognition to their personal physics identity. In addition, when describing ways that they were personally good at physics, students tended to describe knowing how to arrive at correct answers. For example, when Tyler described one way he is good at physics he said “It’s knowing what specifically to look for when encountering a problem. Knowing the exact model and how to apply it, really knowing what you need for the problem.” This indicates that students saw correct answers as closely tied to their personal identity. Since students primarily saw explicit recognition as important to their personal identity, this is likely a result of the kinds of contributions that led to explicit recognition in this study. Validating contributions was a way of positioning someone as good at physics by recognizing a correct answer while directed questions positioned someone as good at physics by recognizing they were likely to have a useful response. In both cases, the recognition students received was tied to their perceived ability to produce a correct answer. This connected students’ personal physics identity to storylines such as the “effortlessly clever physicist” which depict people who are good at physics as people who have a natural intelligence who are able to quickly and easily arrive at key answers or insights (Archer et al., 2020). Thanks in part to popular depictions of physicists, the “effortlessly clever physicist” is also often assumed to be white and male, which influences which students have access to positions associated with this storyline.

Students primarily discussed implicit recognition when talking about how they let their peers know they are good at physics, rather than when describing the ways they had been recognized. For example, Matthew described his group as an example of people in the class who are good at physics because of how they responded when a group member shared an idea: “we
go off that idea and try to see how much we can build off it. And just ask questions about it to see if there’s any inconsistencies on it, to really polish it.” All of the students who were interviewed described similar kinds of interactions as a way they let their peers know they think they are good at physics. Interestingly, Kareem seemed to see participating in this process as a barrier to contributing to a group. When asked whether he thinks his peers see him as someone who is good at physics, Kareem said “I have my times where I feel like I do contribute a lot, but most of the time, I feel like I’m going off of other people’s ideas and helping them fully explore it.” When he was positioned as good at physics by his peers building off his ideas, Kareem was able to experience recognition and develop a sense of personal physics identity. However, when he was on the other side of this process and positioning others as good at physics, he saw this as a barrier to his personal physics identity. This suggests that while Kareem saw building off the ideas of others as a way of giving recognition to the person who first proposed an idea, he felt that participating in the speech acts that positioned someone else as good at physics by engaging with their idea required that he simultaneously position himself as less valuable to the group.

Along with describing implicit recognition as how they recognize peers, during the interviews students discussed some of the varied contributions that could produce implicit recognition as ways their peers were good at physics. For example, when describing what it looked like when his classmates were good at physics, Nyan said “Brainstorming. I think like sharing out ideas to each other even though it might not work.” The ways students see their peers as good at physics indicate some of what students associated with a normative physics identity in this classroom, suggesting that students included skills like asking questions and sharing ideas in a normative identity even if they did not connect these skills to their personal physics identity.
It is also important to note that in most of the interviews, both students involved in the clips selected for the stimulated response portion of the interview had similar responses to the exchanges and agreed the clip showed an instance of one student giving the other recognition. Lucy and Kareem, however, responded very differently to this exchange:

1. Lucy: I was right

2. Kareem: This was one way of thinking about it

In her interview, Lucy saw Kareem as giving her recognition through direct validation since his statement positioned her answer as a valid one. Kareem, however, saw this same exchange as an example of him dismissing Lucy’s response. This matches other work that suggests that the way recognition is perceived by the recipient is deeply personal and may not always be consistent with the intent of the person providing the recognition (Avraamidou, 2020). In addition, in a later exchange from the same class period, Lucy and Kareem returned to discussing the same answer from Lucy that prompted this exchange, but with Kareem much more clearly dismissing Lucy’s response by commenting on a grammatical error and Lucy responding with frustration. It is unclear whether Lucy truly saw the selected exchange as an instance of recognition as she experienced it in the classroom or if something about the context of the interview led her to describe this interaction as a more favorable instance of recognition than she would have in the moment.

3.7 Discussion and Conclusion

While the forms of explicit recognition observed in this study had significant overlap with those described by Wang and Hazari (2018), the implicit recognition they described from teachers looked very different than the implicit recognition observed between students in this study. This is likely because how recognition is given and how it is perceived is deeply
influenced by a range of social positions (Avraamidou, 2020). Teachers occupy a particular position in the classroom, which comes with a set of rights and obligations for how they interact with students, opening opportunities for them to provide recognition through moves such as assigning challenging tasks to students. Students hold a very different position in a classroom than teachers and must find different avenues to provide recognition since they are not operating from any formally recognized authority or expertise. This reinforces the importance of examining recognition across a range of contexts and social positions to explore how the intersections of various social identities influence the ways individuals are able to give and receive recognition. For example, storylines that frame recording information on behalf of the group as a feminine task meant that Lucy’s gender gave her access to a position where she had the right and obligation to provide her peers with recognition by evaluating their contributions before adding them to their shared whiteboard. This position also gave her access to recognition from peers as other students directed questions about her group’s whiteboard to her.

The ways that students described their peers as being good at physics provides insights into the normative identity in this classroom. These students had a broad view of what it means to be good at physics that included not only finding the correct answers to problems, but skills like asking questions, suggesting ideas whether or not they were correct, and building on the ideas of others. Their personal identity, however, seemed primarily impacted by the explicit recognition they received. The ways students talked about being good at physics themselves was much narrower, focusing on correct answers, likely because those were the kinds of contribution that tended to receive explicit recognition. This has important implications for how other identities could impact who has access to a physics identity in the classroom. For example, in one study of small groups, boys tended to use their contributions to demonstrate their
competence while girls tended to use their contributions to deepen their understanding of course content (Patrick & Yoon, 2004). While the kinds of contributions girls made to their group are important to learning, the contributions boys made are more likely to result in the kinds of explicit recognition observed in this study. When explicit recognition is primarily tied to correct answers it also reinforces popular conceptions of a physics person tied to whiteness and masculinity, such as the “effortlessly clever physicist” (Archer et al., 2020).

It is important to note that during the interviews, students were able to recognize specific classmates for contributions like asking questions and posing ideas that elicited implicit recognition in the classroom. This suggests that while it was challenging for the students in this study to notice and explicitly respond to the value of these contributions in the moment, they were able to articulate the value of these kinds of contributions in a more reflective setting. In classrooms where these kinds of contributions are associated with the normative physics identity, giving students opportunities to reflect on the ways their peers are good at physics and share those reflections with peers could lead to explicit peer recognition for these kinds of skills, in turn helping students connect those kinds of contributions to their personal physics identity. It may also be useful for teachers to explicitly model the kinds of contributions they would like students to recognize from each other. For example, O’Shea (2016) developed a brief survey for students to complete after selected activities that named skills like “posing interesting questions” as important to physics learning in order to identify the kinds of contributions she saw as valuable and asked her students to give an example of how someone from their group had demonstrated those skills, giving students the opportunity to provide explicit recognition to their peers for contributions that are difficult to recognize in the moment.
Recognition can serve to reinforce or challenge existing power structures and dominant ideas about what it means to be a physics person. Examining the ways that students experience recognition not only provides insights into the ways students develop a physics identity, but provides the opportunity to intentionally expand the skills, abilities, and contributions that students receive explicit recognition for in order to expand the ways they see themselves as good at physics.
Positioning in Science Without Talking About Science

4.1 Introduction

When students learn physics, they are also learning what kind of person does physics and whether their identities are compatible with doing physics (Brickhouse, 2001). In other words, they are learning what it means to hold a physics identity and whether they are someone who can hold that identity. Unfortunately, multiple studies have shown gender differences in student’s affiliation with a physics identity (Carlone et al., 2011; Hazari et al., 2010, 2013), contributing to the underrepresentation of women in physics (Hazari et al., 2017). Carlone and Johnson (2007) describe a framework for physics identity composed of three dimensions: competence, performance, and recognition. Competence is the extent to which someone demonstrates skills and knowledge associated with science. Performance refers to the ways in which an individual behaves in the ways expected of a “science person”, such as their fluency in the language of science or the ways they interact with others in the field. Recognition refers to the extent to which the individual is viewed as a “science person” both by themselves and by others, including classmates and teachers. Hazari et al. (2010) added a fourth dimension of interest, which describes whether the individual has a desire to learn about and participate in a particular given discipline of science. While each of these dimensions include internal, individual experiences, they are also all heavily dependent on social interaction.

Given the social nature of physics identity, the ways that students interact when they are working in small groups has important implications for gender equity. Multiple studies have found that even when girls demonstrate competence in science and perform in ways expected of a science person, they receive less recognition than boys in the classroom, suggesting that how
recognition connects to other dimensions of a science identity has important implications for gender equity in physics (Kalender et al., 2019b; Tonso, 2006). Not only are women undergraduates less likely than men to perceive themselves as being recognized as a science person (Kalender et al., 2019b), a study of college students working in small groups found that women were less likely to receive peer recognition as good physics students than men, even when the women had equitable opportunities to demonstrate their competence or engage in performances associated with being a good physics student (Tonso, 2006).

4.2 Literature Review

Several studies have observed differences in the ways boys and girls engage in small group activities which could have implications for the development of students’ science identity (Jovanovic & King, 1998; Jurik et al., 2013; Patrick & Yoon, 2004; Wieselmann et al., 2019a; Wieselmann et al., 2021). One common finding has been that boys are more likely to present ideas and suggestions when working in small groups, an important element of Carlone and Johnson's (2007) performance dimension of identity (Jovanovic & King, 1998; Jurik et al., 2013; Patrick & Yoon, 2004; Wieselmann et al., 2019a). Jurik et al. (2013) found that student participation correlated with a high self-efficacy, regardless of the students’ gender, but boys were more likely than girls to have a high self-efficacy. The boys observed by Patrick and Yoon (2004) not only had a high self-efficacy, but often used their participation to demonstrate their competence to peers, sometimes even competing with each other. Jovanovic and King (1998) and Wieselmann et al. (2019a) each observed several occasions in mixed-gender groups where a girl proposed an idea that was quickly dismissed by the boys in the group, communicating a lack of peer recognition to the girls in the group.
The actions students take in a science classroom are also crucial to the development of a science identity (Brickhouse, 2001; Carlone, 2003). Multiple studies observed boys in mixed-gender groups spent more time manipulating materials while girls more often recorded results (Doucette et al., 2020; Jovanovic & King, 1998; Patrick & Yoon, 2004; Quinn et al., 2020). While Wieselmann et al. (2019a) observed girls manipulating materials as often as the boys, the girls tended to watch the boys use the materials first, then mimic their behavior. While the actions of the girls in these studies suggest they were not developing as robust a science identity as the boys, the actions of the girls were in-line with an identity as a good student (Carlone, 2003).

Multiple studies have found that girls are less likely to receive recognition than boys while working in small groups in science classrooms (Kalender et al., 2019b; Tonso, 2006). One layer of this may be students’ beliefs about what it means to be a science person and what a useful contribution to a group looks like. The performance dimension of a science identity includes performances not directly tied to competence in science such as how a person dresses and the ways they speak (Carlone & Johnson, 2007). Multiple studies have found students see these kinds of performances as important to being a science person, ranging from sixth-grade students who describe a scientist as someone “with big goggles and the hair” (Dare & Roehrig, 2016) to college students majoring in science who did not see themselves as science people because they did not wear the uniform of goggles and a lab coat (Nealy & Orgill, 2019). Many classrooms reinforce stereotypes of the “effortlessly clever physicist”, who is able to arrive at answers or key insights in physics quickly and with ease and is typically white and male, as the ideal physics person (Archer et al., 2020). These stereotypes of what it means to perform as a science person make a science identity particularly inaccessible to white girls and Black,
Indigenous, and other students of color who must contend with the expectation that scientists are white men in addition to stereotypes about how scientists speak, dress, and behave (Malone et al., 2009).

This study examines how students reference types of performance and competence that are not strictly tied to the academic requirements in a physics classroom to send messages to each other about what a physics identity is and who holds a physics identity. This study addresses two research questions:

1. **How do students use skills and actions not directly related to physics when positioning themselves and others in small groups?**
2. **What storylines shape the type and form of contributions that students see as valuable in physics classrooms?**

### 4.3 Theoretical Framework

In this study, we utilized positioning theory to examine how students recognized, or failed to recognize, each other as good science students during small group work. The goal of positioning theory is to comprehend how social structures are shaped through interaction (Davies & Harré, 1990). The theory is grounded in the idea that not every participant in a social episode has the same access to rights and duties to carry out specific kinds of meaningful acts. In many situations, the rights and obligations determine who is allowed to employ a particular discourse mode, such as providing instructions, assigning grades, or recalling a previous occurrence. Therefore, a key goal of positioning theory is to draw attention to behaviors that frequently relate to narratives or wider social structures, called storylines, that either encourage or discourage certain individuals or groups of individuals from saying particular things or taking certain actions during interactions. When students recognize each other during small group work, they are
positioning each other as good science students, though positioning theory also offers the opportunity to go beyond recognition and analyze instances where students are negatively positioned, such as when a student is positioned as a less valuable member of a group. In addition, the role of storylines in positioning theory provides tools to develop an understanding of what students associate with positions such as a good science student by analyzing their social actions.

Harré and van Langenhove (1999) use the word "position" to help draw attention to the dynamic components of interactions, as opposed to the way that the word "role" is used to emphasize the static, formal, and ceremonial parts. People assign positions to themselves and others by positioning moves, and each position carries with it a particular set of rights, obligations, and/or duties. Because of this, Harré (2012) defines a position as a collection of convictions about the obligations and rights of individuals to behave in particular ways.

Despite the fact that positions develop spontaneously through social encounters, they are not created voluntarily (Harré & van Langenhove, 1999). This is due to the fact that they emerge in accordance with narratives that are reenacted throughout conversations, implicitly or overtly connecting the past, present, and future (Slocum & van Langenhove, 2003). Conversation is considered to be a type of social contact, the results of which are likewise social, like interpersonal relationships. As a result, researchers must choose analytical notions that help expose conversation as an organized set of speech-acts, that is, as sayings and doings of different types that are classified according to their social force. Even if positioning changes simultaneously generate the opportunity for narratives to change and for new storylines to arise (Kayi-Aydar & Miller, 2018), these storylines are used to understand interactional episodes (Deppermann, 2015).
Table 4.1 *Grouping and Self-Identified Demographics of Study Participants*

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>Race</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bobby</td>
<td>Boy</td>
<td>Hmong</td>
<td>Mixed gender only</td>
</tr>
<tr>
<td>Kareem</td>
<td>Boy</td>
<td>Asian &amp; Black</td>
<td>Mixed gender only</td>
</tr>
<tr>
<td>Lucy</td>
<td>Girl</td>
<td>Hmong</td>
<td>Mixed gender only</td>
</tr>
<tr>
<td>Nyan</td>
<td>Boy</td>
<td>Karen</td>
<td>All boy &amp; mixed gender</td>
</tr>
<tr>
<td>Tyler</td>
<td>Boy</td>
<td>White &amp; Black</td>
<td>All boy &amp; mixed gender</td>
</tr>
</tbody>
</table>

4.4 Study

All of the videos used in this paper were recorded in an AP Physics 1 classroom at a large, suburban high school. The videos were recorded over eight class periods in March and April. The students had been in the same class all year and were working in self-selected groups on the days they were recorded. The curriculum for the course was adapted from Modeling Instruction (Jackson et al., 2008), an approach that relies heavily on guided inquiry and student-to-student discourse. For this study, we focused on two groups, one mixed gender group and one group of only boys with a total of five students. All students spoke English as their first language. During some lessons, these two groups combined into a single mixed-gender group. The participants are described in Table 4.1.

4.5 Data Analysis

We began by reviewing all the recordings of the selected groups to identify exchanges where the students used performances that were not directly related to science to position each other in terms of science ability. We specifically focused on exchanges that connected a student’s positioning in physics to the skill or behavior not required in physics, excluding exchanges where students discussed performances not required in physics without making
explicit connections to physics. For example, in a few of the included exchanges, students dismissed a written statement made by a peer because of errors in spelling or grammar, even though the teacher did not correct or comment on responses where students did not use formal academic English during class discussions or on assessments. In these cases, students made an explicit connection between whether a peer had used correct academic English and whether the peer had made a valuable contribution. In one of the excluded exchanges, a Karen student used a Hmong expletive, leading a Hmong student to ask who taught him that word. While the exchange has implications for who has access to certain language and how students navigated their ethnic identities in the classroom, none of the students involved made an explicit attempt to position themselves or another in terms of physics ability. Compared to more science-focused exchanges, the included exchanges tended to last longer and often included more emotional intensity, indicated by features such as students raising their voices, overlapping each other’s talk, and using large gestures.

After identifying exchanges relevant to our research questions, we transcribed them using symbols based on (Jefferson, 2004) and shown in Table 4.2. We then analyzed the transcriptions in several stages. In a preliminary read of the transcripts, we noticed that students frequently repeated a word, phrase, or grammatical structure used earlier in the exchange, a discourse move known as conversational repetition (Staats, 2008). Conversational repetition uses the form of a statement as a resource to convey meaning or draw connections (Juzwik, 2004). Analysis of conversational repetition is well-established in linguistic anthropology (Tannen, 1989) and has a long history of application in the analysis of classroom discourse more specifically (Wortham, 2003). Previous work in mathematics showed students used repetition as a tool to show relationships between ideas (Staats, 2018) and to facilitate collaboration (Staats, 2021). In this
case, our initial review of the transcripts suggested that students used conversational repetitions as a tool for positioning each other, making it relevant to our analysis. We color-coded instances of conversational repetition to visualize which students were being repeated and which students were doing the repeating over the course of each exchange, similar to Juzwik (2004). Next, we examined each transcript line by line to determine the social action and positioning the speakers were attempting in each utterance. This analysis included examining students’ use of conversational repetitions to analyze how the ways students repeated themselves and each other contributed to the positioning moves each speaker attempted. We then considered how the utterances combined into the positioning each student attempted in the larger context of the full exchange. Finally, we used our literature review and theoretical framework to identify unspoken storylines, especially relating to gender in a physics classroom, that shaped positioning during the exchanges.

4.6 Findings

After reviewing all eight small group videos, we identified seventeen exchanges that occurred while students were working in a mixed gender group that fit our criteria. When students were working in a group of only boys, however, we only identified a single exchange that fit our criteria. For this paper, we selected the three exchanges from the mixed gender group where the use of non-science performances was most prominent for in-depth analysis. We also included an analysis of the exchange we identified from the group of only boys.
Table 4.2 *Transcription Key*

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(.)</td>
<td>Pause</td>
</tr>
<tr>
<td>word</td>
<td>Elongation of preceding sound</td>
</tr>
<tr>
<td>WORD</td>
<td>Spoken loudly</td>
</tr>
<tr>
<td>↑,↓</td>
<td>Increase or decrease in pitch</td>
</tr>
<tr>
<td>((word))</td>
<td>Transcriber’s notes</td>
</tr>
<tr>
<td>?</td>
<td>Rising intonation</td>
</tr>
<tr>
<td>&gt;word&lt;</td>
<td>Talk is speeded up</td>
</tr>
<tr>
<td>[ ]</td>
<td>Overlapping talk</td>
</tr>
<tr>
<td>.</td>
<td>Closing intonation</td>
</tr>
<tr>
<td>Word</td>
<td>Emphasis</td>
</tr>
<tr>
<td>-word-</td>
<td>Spoken softly</td>
</tr>
</tbody>
</table>

Utterances that contain conversational repetition are color-coded. Each color indicates a set of related utterances.

4.6.1 *Exchange 1: “I said your English is terrible”*

In this exchange, transcribed in Table 4.3, Kareem, Lucy, and Bobby discussed the value of an answer to a problem Lucy had written, meaning that whether Lucy was positioned as a physics person was a central element of the exchange. The positioning was accomplished, however, without directly addressing the physics content of Lucy’s answer, instead focusing on grammar and recollection of past events. The group was working on a problem where they were asked to rephrase the question “What would happen to the force of gravity if Earth were twice as big?” in at least two different ways to make it less ambiguous and put their answer on a whiteboard. Prior to the transcription, Lucy had written “What would happen to gravity on Earth if had double mass?” on the whiteboard. Kareem commented on her grammatical error in the phrase “if had double mass” before he and Bobby turned to each other and began discussing a
second possible answer. When Lucy re-entered the conversation at the start of the transcript, Lucy and Kareem shifted from discussing the grammar of her answer to debating the content of what Kareem said earlier, each attempting to position themselves as the one who recalled correctly, which Kareem connected to being a good science student. Finally, the exchange ended with Kareem positioning Lucy as less intelligent based on the grammar of her written statement.

4.6.2 Analysis of Exchange 1

In this exchange, the science content of what Lucy wrote on the whiteboard played a minimal role in Lucy’s attempt to position herself as important to the group. Her emphasis on “right” and use of a closing intonation without a justification to reinforce her claim suggest she expected the group to agree with her written statement. It is also important that this utterance occurred after a relatively extended exchange about answers besides Lucy’s written statement.

<table>
<thead>
<tr>
<th>Exchange 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lucy: I was right you can double the mass.</td>
</tr>
<tr>
<td>2. Kareem: I NEVER SAID IT WAS WRONG [I SAID IT WAS]</td>
</tr>
<tr>
<td>3. Lucy: [YOU SAID] [IT WAS]</td>
</tr>
<tr>
<td>4. Kareem: [I JUST SAID] IT’S ONE WAY OF [THINKING ABOUT IT] ↓</td>
</tr>
<tr>
<td>5. Lucy: [CHECK THE RECORDING OF IT] ((pointing at voice recorder)) check the recording ↓</td>
</tr>
<tr>
<td>6. Kareem: You can yeah↑ I just literally said this is one way of thinking about it</td>
</tr>
<tr>
<td>7. Lucy: You literally said it was not right</td>
</tr>
<tr>
<td>8. Kareem: No I said your English is terrible ((laughing on last word))</td>
</tr>
</tbody>
</table>

Note. Utterances that contain conversational repetition are color-coded. Each color indicates a set of related utterances.
where the boys in the group turned toward each other while Lucy remained silent, positioning Lucy as an outsider to the group both through their gaze and through their apparent dismissal of Lucy’s contribution. In line 1, Lucy attempted to reassert her position as an important member of the group by drawing the attention of her group members with her statement and redirecting the conversation back toward the value of her written statement.

Kareem rejected Lucy’s positioning as important to the group by framing the conversation around whether Lucy could accurately recall his earlier comments and otherwise positioning himself as more intelligent without ever challenging the science content of her written statement. In lines 4 and 6, Kareem’s insistence that Lucy’s written statement was “one way of thinking about it” positions Lucy as having given an incomplete answer that lacked nuance. In addition, at line 8, when Kareem commented on the grammar of the written statement, Kareem is again positioning Lucy as less intelligent by focusing on her use of academic English.

Throughout the exchange, Lucy rejected Kareem’s negative positioning and insisted on the value of her contribution. In lines 3 and 7, Lucy used conversational repetition of Kareem’s previous lines as a way to emphasize her different recollection of the earlier conversation, turning his words into a tool for her to resist his positioning. In line 5, she referenced the voice recorder on the table to reinforce her positioning of Kareem as an unreliable narrator of the earlier conversation by suggesting there was tangible evidence to support her recollection.

Throughout the exchange, both Kareem and Lucy positioned Kareem as a leader of the group. Kareem initiated each shift in the focus of the exchange, beginning with line 2 when he framed the exchange as about what he had said. In line 4, he introduces the additional framing of suggesting Lucy’s answer was incomplete before finally introducing the relevance of Lucy’s grammar in line 8. Lucy followed Kareem in these shifts, consistently seeking his approval that
her written statement was right to position her as important to the group. In addition, Lucy at
several points utilized repetition of Kareem’s utterances, suggesting that Kareem literally set the
tone of the exchange. In lines 2 and 6, Kareem introduced a grammatical structure which was
then repeated by Lucy in lines 3 and 7 respectively, but Kareem only repeated Lucy when
continuing repetitions of a structure he introduced first. Kareem also raised the volume of his
voice at line 2, raising the intensity of the exchange, which Lucy mirrored in line 3. Finally,
while Bobby had been an active participant in the conversations leading up to this transcript,
neither Kareem nor Lucy engaged with him during the exchange, suggesting that the primary
issue was Kareem’s evaluation of Lucy’s written statement, positioning Kareem as the arbiter of
whether Lucy had made a valuable contribution.

4.6.3 Exchange 2: “You were wrong about this and you’re wrong about your body”

During this exchange, transcribed in Table 4.4, the mixed-gender group was working on
individual papers to solve a word problem that asked them to calculate the mass of an object. The
exchange began with Lucy attempting to position herself as a physics person by sharing her
solution with Nyan, which he dismissed, establishing Lucy’s competence in physics as a key
question in the exchange. Shortly before the transcription began, Nyan and Lucy briefly
disagreed on their interpretation of what they needed to solve for. Nyan then left the table to
retrieve his calculator while Lucy finished the problem using her own calculator and began
explaining her answer to Bobby. The transcription began as Nyan returned to the table,
interrupting Lucy’s explanation. As Nyan rejoined the conversation, Lucy and Nyan both
attempted to position themselves as more expert than the other. Initially, the physics problem
was the central issue in their positioning and, even when Nyan accepted that Lucy had the
correct answer, he stated his agreement in a way that reinforced his positioning as more
competent. However, both students quickly expanded their positioning to include who had authority on whether Nyan coughed or sneezed, with Nyan dismissing Lucy for using a typical social convention in response to a sneeze. By the end, Lucy explicitly tied Nyan's ability to accurately interpret a physics problem to his ability to accurately describe his own body.

Table 4.4 Positioning Based on Knowledge of Past Events

<table>
<thead>
<tr>
<th>Exchange 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nyan: for RE:AL ((sitting down at the table)) (. grams right?</td>
</tr>
<tr>
<td>2. Lucy: I I I just did the math ((Lucy pushes her paper toward Nyan))</td>
</tr>
<tr>
<td>3. Nyan: okay (. kg (. hold on ((Nyan holds up a finger to Lucy and types in his calculator))</td>
</tr>
<tr>
<td>4. Lucy: -watch you be wrong Nyan- ((Lucy retrieves her paper from in front of Nyan))</td>
</tr>
<tr>
<td>5. Nyan: you say a prayer about that? doubtful. heh heh [okay]</td>
</tr>
<tr>
<td>6. Lucy: [okay] that took that took a [long]</td>
</tr>
<tr>
<td>7. Nyan: [you’re] right. you look for kg right? kilograms cause gravity is kg (. boom. ((sneezes or coughs)) dang</td>
</tr>
<tr>
<td>8. Lucy: bless you</td>
</tr>
<tr>
<td>9. Bobby: [that means]</td>
</tr>
<tr>
<td>10. Nyan: [I didn’t] even sneeze</td>
</tr>
<tr>
<td>11. Lucy: that was a sneeze</td>
</tr>
<tr>
<td>12. Nyan: that wasn’t a sneeze that was a [cough]</td>
</tr>
<tr>
<td>12. Lucy: [that was] a sneeze</td>
</tr>
<tr>
<td>14. Nyan: that wasn’t</td>
</tr>
<tr>
<td>15. Lucy: that was a snee:ze</td>
</tr>
<tr>
<td>16. Nyan: ((sneezes or coughs)) that was a cough</td>
</tr>
<tr>
<td>17. Lucy: that was a cough before it was a sneeze</td>
</tr>
<tr>
<td>19. Lucy: you were wrong about this ((points at paper)) and you’re wrong about your body ((points at Nyan))</td>
</tr>
</tbody>
</table>
Note. Utterances that contain conversational repetition are color-coded. Each color indicates a set of related utterances.

4.6.4 Analysis of Exchange 2

This exchange began with Nyan positioning himself as the arbiter of the value of Lucy’s contribution and included him positioning Lucy as a less valuable member of the group, similar to Kareem’s positioning in exchange 1. Nyan initially did so by positioning himself as highly competent. In lines 1-3, Nyan did not make any direct comment about whether he believed Lucy’s work was correct or adequate, but firmly insisted on completing the problem himself and responded to Lucy dismissively, such as in line 3 with his use of the phrase “hold on” and holding up a finger without shifting his gaze away from his own paper. Lucy again attempted to resist this negative positioning, such as in lines 4-6, when Lucy attempted to position Nyan as less competent by expressing doubts about his ability to complete the problem accurately. Nyan calmly rejected that positioning by insisting on his confidence that he could complete the problem.

Again similar to exchange 1, Nyan ultimately accepted Lucy’s answer, but did so in a way that undermined her attempt to position herself as a competent physics student. This began in line 1 when Nyan returned to the group without acknowledging that Lucy was already explaining her solution to Bobby, positioning the work Lucy had done as not worth his attention. In line 7, he acknowledged Lucy was right, but reinforced his positioning as more competent by explaining the answer to Lucy. In addition, finishing the utterance with “boom” using a closing intonation implied that he did not expect Lucy to have anything to add, implicitly positioning her as less competent than him.
Nyan then positioned Lucy as having an inaccurate understanding of reality, which began the portion of the exchange in lines 10-17. This phase of the exchange began with Nyan dismissing Lucy for saying “bless you” in line 8, a speech act that is typically considered a polite response to someone sneezing. By using a repeated phrase without offering additional evidence, each student positioned themselves as having a clear, inarguable perception of whether Nyan had sneezed or coughed, even as the other continued to argue. Similar to Kareem in exchange 1, Nyan introduced the phrases “sneeze” and “that was a cough”, which then appeared in Lucy’s utterances as conversational repetitions, again very directly setting the terms and structure of the rest of exchange.

The exchange culminated in Lucy connecting that debate to the earlier positioning about competence in science with her final line “You were wrong about [the problem] and you’re wrong about your body”, suggesting that someone who did not initially understand the problem correctly could not be trusted to give an accurate recounting of events. Lucy emphasized the connection she saw between Nyan’s knowledge of his body and knowledge of physics with multimodal conversational repetition within this utterance, similar to that described by Staats (2018, 2021). Across the two phrases, Lucy mirrored not only her grammatical structure, but also repeated her gesture and emphasis. In addition, Lucy’s insistence on positioning Nyan as less competent in physics even after he accepted her answer was correct reinforces that Nyan accepted her answer in a way that Lucy experienced as dismissive and as positioning her as less competent.

4.6.5 Exchange 3: “We are keeping you in check”

The exchange in Table 4.5 included Kareem, Bobby, and Lucy. They were working on a shared whiteboard on a problem about a ball attached to a string and spinning in a vertical circle.
They were tasked with describing the motion of the ball if the string broke at a particular point in the ball’s path. Kareem took a dominant position in the group, tending to initiate and lead the group for much of the interaction prior to this exchange. As in the previous two transcripts, Kareem accepted Lucy’s answer as correct, but did so in a way that undermined her positioning as a competent science student. In this exchange, Kareem and Lucy also explicitly discussed their roles and responsibilities as members of the group, with Lucy explicitly positioning Kareem in a role similar to the “slacker” described by Doucette et al. (2020) as typically a man paired with a woman who avoids contributing to the group, instead relying on his group mates to ensure the task is complete. Kareem, in response, positioned himself as keeping Lucy “in check”, with the responsibility of ensuring she did not do the problem wrong.

**4.6.6 Analysis of Exchange 3**

This exchange began and ended with disagreement about the positions Kareem held relative to Lucy. In line 1, Lucy positioned Kareem as a “slacker” who did not contribute to the group with her question “why don’t you do some work though?”, a sentiment she repeated and expanded to include Bobby in line 16. Kareem rejected that positioning from Lucy, instead explicitly positioning himself as someone with the right and responsibility to evaluate Lucy’s contributions by responding “I’m keeping you in check” in line 2. In line 17, Kareem utilized conversational repetition, repeating his earlier phrasing to describe his positioning within the group, and expanded his positioning to include Bobby as holding the same right and responsibility to evaluate Lucy’s answers by shifting his pronoun choice from “I” in line 2 to “we” in line 17.

Unlike exchanges 1 and 2, Lucy declined to directly resist the positioning attempted by Kareem. In line 3, Lucy directed the conversation back to the problem. In addition, by saying “I
don’t know what I’m doing”, Lucy expressed a need for Kareem and Bobby to engage with the problem in order to help her move forward in solving it, positioning them as people capable of contributing to the group. Her use of conversational repetition connected lines 1 and 3 reinforced

<table>
<thead>
<tr>
<th>Exchange 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lucy: <em>I don’t know</em> why don’t you do some work though?</td>
</tr>
<tr>
<td>2. Kareem: I am (.) I’m keeping you in check</td>
</tr>
<tr>
<td>3. Lucy: <em>I don’t know</em> what I’m doing</td>
</tr>
</tbody>
</table>
| 4. Kareem: ((reading the problem)) Suppose the string breaks at point P (.).
  Suppose the string breaks at point P (.).
  >When describing the motion of an object (.) you can (.)
  >you need to discuss what happens to the position the velocity and the acceleration of the object (.) tell the story of the motion of the ball from the time the string breaks until the ball reaches the ground ((stops reading)) What? 6.2 desmos |
| 5. Lucy: ↑Wouldn’t the acceleration (.). the acceleration and the velocity stay the same. |
| 6. Kareem: Eemm: ↑Wouldn’t it? |
| 7. Lucy: -It’s like constant ↓It’s going in a straight line. |
| 8. Kareem: Yeah: ↑but it’s also saying you cannot hit the ground so that has to change at one point. |
| 10. Bobby: [Well the acceleration is constant] |
| 11. Kareem: [>Well it says] tell the story of the motion of the ball (.). from the time ↓the string breaks until it reaches the ground. so? it has to go back <down> to ↑this has to be changing. |
| 12. Lucy: Oh: ↑This is the ball. |
| 13. Bobby: If (.). ↑if the acceleration is constant ↓it doesn't mean the velocity will change. |
| ↑This is what are you saying. |
| 14. Kareem: Yeah? (.). so? that won't work anyways ((all laugh)) |
| 16. Lucy: ↑you guys don't even do anything. |
| 17. Kareem: What? ↑We're keeping you in check (.). so you don't get the wrong answer. |

Table 4.5 Positioning Based on Gendered Roles
Note. Utterances that contain conversational repetition are color-coded. Each color indicates a set of related utterances.

that her utterance in line 1 was about Kareem and Bobby choosing not to contribute, rather than suggesting they lacked the ability to contribute. Kareem responded to this positioning by engaging with the task and reading the problem his group was working on aloud in line 4.

In addition to introducing explicit discussion of positioning, Lucy was able to frame the discussion about the physics concepts in the problem. In line 5, she introduced the idea that some features of the motion must stay the same, which in line 7 she described as those features remaining constant, shifting to more formalized, physics-specific language to describe the same concept. Bobby then utilized conversational repetition to reinforce and build on her idea in lines 10 and 13, positioning Lucy as having made a contribution worth engaging with and building on. Kareem challenged Lucy’s contention in line 8 by stating “it has to change”, in direct contrast to Lucy’s assertion that features of the motion should be constant, but that idea was only repeated by another student in line 13 when Bobby used conversational repetition to challenge Kareem’s assertion by contrasting it with Lucy’s. Kareem attempted to reposition himself in an authoritative role in line 11 by re-reading portions of the problem, but, while Lucy’s response in line 12 suggests this repetition clarified an element of the problem for her, Bobby responded in line 13 by reiterating the idea that some quantities must be constant and challenging Kareem’s earlier statement.

In line 14, Kareem seemed to accept that his contribution would not be accepted by the group, but did so in a way that returned to his attempts to position himself with authority. His use of “Yeah? So?” at the opening of that utterance implied that while he agreed with Bobby’s
challenge, he positioned Bobby as not having made a meaningful contribution. Lucy then returned to her earlier explicit discussion of positions in line 15, challenging the authoritative position Kareem attempted to take.

4.6.7 Exchange 4: “I can’t read clocks”

In the exchange in Table 4.6, Tyler and Nyan were working in their own in a single-gender group. While both boys participated in multiple exchanges centered around non-science performances on the few days they joined the others in a mixed-gender group, this was the only instance of them participating in this kind of exchange when in a single-gender group, in spite of spending more time working in a single-gender group. This exchange occurred during a card sort activity on angular kinematics. They had a set of cards with different representations of the motion of an object moving in a circle and needed to match cards that had different representations of the same motion. Prior to the beginning of the transcript, Nyan had been taking the lead in completing the card sort. The exchange began when Nyan was examining the motion map shown in Figure 4.1 (Milliano, 2021), which uses dots to show the position of an object at several points in time with arrows in between the dots to show the direction of motion, and trying to decide whether the object was moving clockwise or counterclockwise. Tyler and Nyan then debated which direction is clockwise, until Tyler attempted to position Nyan as someone who did not belong in AP Physics due to his inability to read clocks, a positioning that Nyan flatly rejected by refusing to engage further in the positioning and disengaging from the activity. The exchange concluded with Tyler seeking Nyan’s input, repositioning him as a valuable member of the group and reengaging Nyan in the activity.
Table 4.6 Positioning Based on Ability to Read Clocks

<table>
<thead>
<tr>
<th>Exchange 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nyan: ((holding a card)) is this going isn’t this way not clockwise? this is counterclockwise right?</td>
</tr>
<tr>
<td>2. Tyler: that’s clockwise. ((moves finger clockwise over a card))</td>
</tr>
<tr>
<td>3. Nyan: no this is clockwise ((moves finger counterclockwise over a card))</td>
</tr>
<tr>
<td>4. Tyler: no it’s not</td>
</tr>
<tr>
<td>5. Nyan: going this way is clockwise isn’t it ((moves finger counterclockwise over a card))</td>
</tr>
<tr>
<td>6. Tyler: no it’s not ha</td>
</tr>
<tr>
<td>7. Nyan: word to my mo\textup{\textasciitilde}ther (. ) cuz look this one ((points at a card))</td>
</tr>
<tr>
<td>8. Tyler: ((sweeps arm behind Nyan, points toward clock)) look look at that clock</td>
</tr>
<tr>
<td>9. Nyan: word to my mother bro always a troll I can’t read clocks. ((leans back, picks up phone))</td>
</tr>
<tr>
<td>10. Tyler: oh you’re in AP Physics then</td>
</tr>
<tr>
<td>12. Tyler: alright we need one of these go with it too I think ((taps card in front of Nyan, Nyan puts away phone and leans in))</td>
</tr>
</tbody>
</table>

Note. Utterances that contain conversational repetition are color-coded. Each color indicates a set of related utterances.
4.6.8 Analysis of Exchange 4

This exchange began with Nyan positioning Tyler as a good physics student by seeking his input. Just before this transcript began, Tyler had been leaning forward and watching how Nyan moved the cards, but not providing any input or suggestions, positioning Nyan as capable by tacitly accepting his answers. In line 1, Nyan directed a question about which direction is clockwise toward Tyler, positioning him as someone with useful information. In line 2, Tyler accepted that positioning with a direct, authoritative response. In line 3, Nyan rejected the positioning he had initiated of Tyler as competent by challenging Tyler’s assertion. Nyan also utilized multimodal conversational repetition by mirroring not only Tyler’s wording in the previous line, but also mirroring the gesture Tyler had used, emphasizing his disagreement with Tyler’s statement.

During this exchange, both students made use of conversational repetition of the other, avoiding positioning either student as the one setting the structure of the exchange. In lines 2 and 3, Nyan repeated a phrase and gesture that Tyler had first introduced, but in lines 7 and 8, Tyler repeated Nyan’s use of the word “look” and gesture to draw attention to a particular piece of evidence for which direction was clockwise. In addition, in line 8, Tyler exaggerated his repetition of Nyan using a much larger pointing gesture and using the word “look” twice, giving additional emphasis to his use of the clock, rather than a card in the activity, as evidence. By taking turns shaping the grammatical structure of the exchange, neither was positioned as the primary authority in the group.

Nyan ultimately accepted Tyler’s answer about which direction is clockwise but did so in a way that positioned Tyler negatively. In line 9, Nyan described Tyler as “always a troll”, positioning Tyler as someone who had behaved disrespectfully. In the same utterance, Nyan also
said “I can’t read clocks”, implying he accepted Tyler’s justification for which direction is clockwise while positioning Tyler’s knowledge as unimportant to him. Nyan followed this line by positioning himself outside of the group by leaning away from the table and shifting his focus to his phone, leaving Tyler to continue alone after Nyan had previously placed most of the cards so far. This positioned Tyler as someone Nyan did not wish to work with.

Tyler did not engage directly with Nyan’s positioning and instead attempted a negative positioning of Nyan, but Nyan successfully rejected Tyler’s positioning move. In line 10, Tyler’s utterance “oh you’re in AP Physics then?” positioned Nyan as someone who does not belong in AP Physics, implying that general knowledge such as the ability to read analog clocks is an important indicator of someone’s ability to succeed in physics even though the skill was not directly required or utilized in the course. Nyan’s response in line 11 of simply “yup” with a closing intonation closed off this avenue for positioning by acknowledging the reality that Nyan was both enrolled in AP Physics and unable to read analog clocks without engaging in any argument about whether those two things should be simultaneously true.

Unlike the exchanges from the mixed-gender group, this exchange closed with both students positioning the other as an important part of the group. In line 12, Tyler positioned Nyan as someone with knowledge necessary to the task by focusing on cards that had a physical proximity to Nyan and by using phrasing that invited Nyan to offer ideas. Nyan responded by putting his phone away and leaning over the cards to reengage with the task, indicating that in this case he accepted Tyler’s positioning move and positioning Tyler as someone he was once again willing to work with.
4.7 Discussion

These exchanges suggest several elements are part of the storyline the students in this group used to determine who was a valuable member of the group. Importantly, in all three exchanges from the mixed-gender group, Lucy presented a correct answer to her group, yet was positioned as less valuable to the group by her peers even as the boys in the group accepted Lucy’s answers as correct. A study of college students found that women were less likely to receive peer recognition as good physics students than men, even when the women had equitable opportunities to demonstrate their competence or engage in performances associated with being a good physics student (Tonso, 2006), and these exchanges illustrate one form this can take. In each exchange, Lucy demonstrated competence and engaged in performances that would typically be associated with being a good science student by offering correct answers to her group, but other storylines still lead to her contributions being dismissed by the boys in her group. In each exchange, this dismissal turned the conversation toward performances that were not directly related to physics, such as accurately describing a past event, and positioned Lucy as less competent than her peers. While Nyan also dismissed Tyler’s answer in the exchange from the all-boy group, the exchange ultimately concluded with each making a move that positioned the other as a valuable member of the group, which did not occur in the exchanges with the mixed-gender group. This reinforces the urgent need for teachers to closely attend to the storylines of what it means to be a science person in their classrooms as competence at the course content is not adequate for all students to have access to the position of a good science student.

During these exchanges, several gendered storylines shaped the positions available to each student. The first was a storyline that allowed the boys to adopt an authoritative position
over Lucy. In each of the exchanges from the mixed-gender group, one of the boys in the group positioned himself as the arbiter of the value of the contributions made by Lucy, the sole girl. In addition, the boys evaluating Lucy’s responses established the parameters and tone of the exchanges through conversational repetition with Lucy taking up structures and phrases introduced by her peers, but the boys evaluating Lucy’s answers primarily repeating structures and phrases they had introduced. By contrast, when working in a group of only boys, each had moments where he repeated the other, meaning both helped to shape the structure and parameters of the exchange. While students did not explicitly discuss gender during these exchanges, this implicit hierarchy aligns with storylines that place science as a masculine endeavor where men are expected to take the lead (Brickhouse, 2001).

There were also gendered storylines about the kinds of roles students were expected to adopt through their positioning. In exchange 3, it is especially clear that Lucy saw the boys in her group as fulfilling the “slacker” archetype Doucette et al. (2020) described when she declared “you guys don’t even do anything.” As the “slacklers”, Kareem and Nyan adopted a position consistent with the “effortlessly clever physicist” (Archer et al., 2020). Archetypically masculine, the effortlessly clever physicist is able to arrive at the answers to problems easily and quickly (Archer et al., 2020). By relying on Lucy to maintain a record of the group’s work, Kareem and Nyan distanced themselves from the process represented in that record, instead emphasizing their competence by evaluating the answers of others.

Lucy, meanwhile, tended to fulfill a position often associated with women and girls where she took on disproportionate responsibility for completing the work while other members of the group were less engaged (Doucette et al., 2020). In each of the exchanges, Lucy was responsible for keeping a record of the group’s work and presented ideas that were most crucial
to moving the group forward. While Lucy’s control of the group’s record gave her more access
to key information than her peers, allowing her to present crucial ideas, similar to a student in
Staats (2018), it also positioned her as what Doucette et al. (2020) call the “secretary”, or a
student who is responsible for keeping a record, that is particularly associated with girls and
women. The secretary may also be positioned as less valuable due to a perception they are a
passive participant even when they make meaningful contributions (Staats, 2023), much as Lucy
was devalued in these exchanges in spite of making key contributions.

The simultaneous positioning of Kareem and Nyan as determining what counts as a
meaningful contribution and Lucy as holding disproportionate responsibility without authority
that arose from the combination of these storylines limited the recognition Lucy received for her
competence. For teachers interested in promoting equitable group work, it is important to
consider how to disrupt these storylines that are often at play in science classrooms to expand the
roles that are available to each student and limit access to positions that reproduce problematic
patterns. The positions observed in these exchanges emerged organically, which several studies
have found most commonly occurs in relatively unstructured group activities (Doucette et al.,
2020; Quinn et al., 2020; Wieselmann et al., 2019b). Teachers can disrupt these kinds of
positions by structuring the ways students collaborate during small group work, including by
providing students with formal, explicit roles that guide students to interact in ways that promote
effective, equitable collaboration (Cohen & Lotan, 2014).

Notably, at no point did Lucy passively accept the negative positions her peers attempted
to place her in. Throughout these exchanges, Lucy used conversational repetition to emphasize
her disagreement with the statements she echoed and forcefully insisted on the value of her
contributions and, by extension, her value to the group. Her vehemence in these exchanges
suggest that she recognized the competence at physics she was demonstrating and she believed her peers should recognize it, as well. The emotional intensity in these exchanges emphasizes the effort Lucy engaged in to seek recognition for her competence.

Interestingly, during the science portions of these exchanges, there are moments where the boys in the group engaging in practices such as seeking alternative explanations and asking questions that are explicitly called for in frameworks including the Next Generation Science Standards (NGSS Lead States, 2013). However, they engaged in these behaviors in a way that positioned Lucy as less valuable to the group. It is crucial for teachers to consider how to teach students to engage in these practices in ways that do not negate the value of the contribution that is being questioned.

These findings reinforce the urgent need for teachers to closely attend to the storylines of what it means to be a science person in their classrooms as competence in the science required for the course is not adequate for all students to have access to the position of a good science student. During these exchanges, gendered storylines shaped the roles and positions available to each student. In each of the exchanges from the mixed gender group, one of the boys in the group positioned himself as the arbiter of the value of the contributions made by the sole girl in the group. While students did not explicitly discuss gender during these exchanges, this implicit hierarchy aligns with storylines that place science as a masculine endeavor where men are expected to take the lead (Brickhouse, 2001). Lucy, meanwhile, tended to fulfill a position where she had disproportionate responsibility for completing the work while other members of the group were less engaged, also observed by Doucette et al. (2020) as a position disproportionately held by girls. In each of the exchanges, the girl was responsible for keeping a record of the group’s work and presented ideas that were crucial to moving the group forward. In several
exchanges, it was clear that the girl saw the boys in her group as fulfilling the “slacker” archetype Doucette et al. (2020) describe as often paired with a girl who took on disproportionate responsibility with declarations like “you guys don’t even do anything.” The simultaneous positioning of the boys as determining what counts as a meaningful contribution and the girl as holding disproportionate responsibility without authority that arose from the combination of these storylines limited the recognition the girl received for her physics ability. For teachers interested in promoting equitable group work, it is important to consider how to disrupt these storylines that are often at play in science classrooms to expand the roles that are available to each student and limit access to roles that reproduce problematic patterns.

The lack of exchanges we were able to identify from the all-boy group reinforces the importance of gender in these exchanges. On several occasions, the boys from this group joined the mixed gender group and participated in exchanges that dismissed a contribution made by the girl based on some factor besides the physics of her contribution, showing they were willing to participate in these kinds of exchanges. However, when working separately in a single gender group, these same boys had only a single exchange where they connected something beyond science competence to science ability. In addition, neither Tyler or Nyan directly engaged in the others’ attempted negative positioning, suggesting they did not feel a need to justify the value of their contributions or their presence in the group to the same extent that Lucy did. It is also noteworthy that both Tyler and Nyan positioned the other as a desirable group member at the end of the exchange, given them an opportunity for recognition following the negative positioning that was not granted to Lucy in any of the exchanges we analyzed.
4.8 Conclusion

In this study, we found that students used skills and behaviors not directly related to science to position each other as less competent in physics, reproducing gendered patterns that contribute to the marginalization of girls and women in physics. In each of the exchanges we analyzed from a mixed-gender group, the contributions of a girl were positioned as less valuable by the boys in her group even as they avoided directly challenging the science content of her contributions. While two boys also used similar kinds of positioning moves to dismiss an answer due to performances not directly related to science competence, this exchange concluded with both boys being positioned as valuable group members by the other. By analyzing the positioning students engaged in during these exchanges, we were able to gain insights into the storylines besides competence in science that shaped these interactions. There is a clear need for teachers to consider how to disrupt the presence of these storylines in order to design and facilitate group work where all students have their contributions recognized as valuable by their peers.
Chapter 5. Overall Conclusions, Implications, and Key Findings

5.1 Key Findings

This dissertation includes three studies that explore different aspects of students’ perceptions of what it means to be good at physics, whether they are good at physics, and how those perceptions affect gender equity in physics education. The first study (Chapter 2) examined students’ confidence by analyzing how their self-assessments compared to their actual performance on in-class quizzes. In contrast with existing literature (e.g. Jurik et al., 2013; Marshman et al., 2017; Marshman et al., 2018; Mujtaba, T., & Reiss, 2013a; Mujtaba & Reiss, 2013b; Nissen & Shemwell, 2016), this study found no statistically significant difference between how boys’ and girls’ self-assessments compared to their actual performance on the assessments. This study also included interviews with students to examine what classroom experiences impacted their sense of self-efficacy. Regardless of gender, students described activities where they had to figure out physics concepts, such as guided inquiry labs or problems they had to discuss with their peers prior to seeing worked examples, as both helping and hurting their sense of self-efficacy. The process of figuring out these concepts themselves gave students a sense of ownership of their learning that contributed to their sense of being good at physics. The mistakes, struggles, and other challenges that are an expected part of this process, however, got in the way of feeling good at physics.

In this study, there were important gender differences in how students discussed being recognized as a physics person. First, when discussing whether their teacher saw them as good at physics, boys typically discussed assessments where they had high scores. Girls, however, focused on the feedback their teacher gave them on assessments where they had done poorly as evidence their teacher saw them as good at physics. Boys also discussed being recognized by
their peers through experiences like their peers asking them questions or taking their ideas seriously. The only girl to discuss these kinds of experiences, however, described these experiences as evidence her peers made assumptions based on her performance in other courses rather than that evidence they recognized her as being good at physics.

These findings in chapter 2 add to a body of literature indicating that understanding recognition is an important part of addressing gender equity in science (e.g. Hazari et al., 2017; Kalender et al., 2019; Tonso, 2006). In spite of the importance of recognition, there is little existing literature describing what recognition looks like (Kim & Sinatra, 2018). This motivated the study in Chapter 3, which is an analysis of small group video in a physics classroom to identify what forms peer recognition takes and interviews with students to understand how peer recognition impacted their sense of physics identity. Similar to previous work looking at the ways teachers recognize students (Wang & Hazari, 2018), this study found that recognition between students may be explicit, in which students directly acknowledge a peer’s competence in physics or the value of a contribution to the group, or implicit, in which this acknowledgement is made indirectly. In this study, explicit recognition primarily acknowledged right answers, while implicit recognition acknowledged a range of contributions, including questions and sharing ideas whether or not they were correct.

In interviews about their perceptions of what it means to be good at physics, when students discussed their peers or general descriptions of what it means to be good at physics, students described a range of competencies, including those that received implicit recognition, suggesting that implicit recognition was tied to their understanding of what it means to be a physics person. When discussing themselves, however, they primarily focused on the
competencies that received explicit recognition, suggesting their sense of whether they were a physics person was largely shaped by explicit recognition.

In analyzing the video for the study in Chapter 3, I observed a number of exchanges were observed where students used skills or actions not directly tied to science ability to send messages about whether someone was good at physics. For example, in one exchange students discussed the grammar of a statement written on the group’s whiteboard, connecting it to whether the written statement is a useful contribution to the group. Thus, the study in Chapter 4 is an in-depth analysis of several of these non-science exchanges with science positioning from two different small groups, one all boys and the other a mix of boys and girls. While the mixed gender group had a large number of these exchanges, often including boys from the other group, the all boy group only had one. In the mixed gender group, these exchanges often served to diminish the value of a contribution made by the lone girl, even though her contribution that had accurate physics. This suggests one mechanism for prior findings that girls receive less peer recognition than boys even when the demonstrate competence and engage in science performances to the same extent as their peers (Tonso, 2006). These exchanges in the mixed gender group also enforced gendered roles, with the girl taking responsibility for recording the group’s work and driving the task forward while the boys assumed authority to evaluate the quality of her work.

5.2 Conclusions Across the Three Studies

Each of these studies suggest that students had internalized the archetype of the “effortlessly clever physicist”, which is someone who easily arrives at answers and insights and is often associated with whiteness and masculinity (Archer et al., 2020). The struggle, confusion, and other challenges students are expected to experience during guided inquiry became a barrier
to students’ self-efficacy because it did not fit with the archetype of a physics person who is able to easily get to the correct answer. This perception was reinforced by the explicit recognition that students received, which primarily acknowledged correct answers. Students’ experiences receiving explicit recognition in turn shaped their perceptions of how they personally were good at physics, aligning their personal identity to the effortlessly clever physicist. When students embrace this narrow view of what it means to be a physics person, it affects who has access to a physics identity and how students interpret expected challenges that come with learning physics.

However, even when students applied this narrow view of physics identity to themselves, they expressed a broader view of what it means to be good at physics. The same struggles that made their learning of physics far from effortless gave students a sense of ownership over their knowledge and students experienced recognition through messages that their teacher believed they could improve when they had done poorly on an assessment. The implicit recognition that students gave each other and the ways they described their peers as being good at physics also reflected a broad view of what it means to be good at physics.

5.3 Implications Across the Three Studies

An important challenge for teachers is helping students develop a broad view of how they are good at physics is ensuring that students receive explicit recognition for the wide range of skills they bring to the physics classroom. In the reflective setting provided by an interview, students were able to make specific statements about the ways their peers were good at physics beyond the archetype of the effortlessly clever physicist. In the moment when students are experiencing a struggle in the classroom or when a peer asks a valuable question, it can be challenging for students to see the value in what is happening, let alone recognize their peers and themselves for the physics competencies they are using. Giving students opportunities to reflect
on the ways that they and their peers are good at physics, and to share those reflections with each other, is one avenue to ensure students receive explicit recognition for a broad range of ways of being good at physics and expand their view of how they as an individual are a physics person. One strategy is to follow some activities, especially rich activities with multiple approaches, with a whole-class discussion where students brainstorm skills their group needed to complete the task, then reflect on which of those skills they demonstrated during the activity (Cohen & Lotan, 2014). Another strategy is to provide students with a broad list of competencies relevant to physics, such as asking good questions or making interesting connections, then asking students to share an example of a peer who demonstrated one or more of those competencies in a recent lesson (O’Shea, 2016). Expanding what it means to be a physics person in turn expands who has access to that identity in the classroom and beyond.

Teachers should also directly challenge the perception of the effortlessly clever physicist, explicitly building a classroom culture where students see struggle as an expected and desirable part of the learning process. This will support students in developing a sense of science identity from classroom activities where they experience struggle. For example, activities such as guided inquiry labs or doing problems prior to worked examples have a mixed impact on students’ science identity in this dissertation. Students recognized that during those activities, they were figuring out new physics concepts, giving them a sense of ownership over their learning that contributed to their self-efficacy. However, many of the same students who said these activities helped their self-efficacy also said the mistakes, confusion, and other struggles that are a natural element of these activities had a negative impact on their self-efficacy because of how those experiences conflicted with their perception of the effortlessly clever physicist. One strategy is to open class by discussing where in the learning progression the class is and what students can
expect based on that. For example, when doing the lab that introduces a new concept, students can expect lots of confusion, uncertainty, and maybe some frustration. The impact of those feelings can be less significant if students know from the beginning of the activity that these kinds feel and experiences are expected and normal. Another strategy is to place explicit value on mistakes through activities like mistakes whiteboarding (O’Shea, 2012) where to go over problems, each group prepares a whiteboard with their solution, but must include at least one intentional mistake. During a whole class discussion, other students must then identify the mistake and explain to the group how to correct it. With this approach, the mistakes students make while working the problems are framed as a valuable resource for the discussion rather than a cause for concern.

The studies in this dissertation also reinforce the importance of structuring groupwork in order to support gender equity. Similar to other studies (e.g. Doucette et al., 2020; Quinn et al., 2020; Wieselmann et al., 2019), the unstructured nature of the small group activities in this dissertation enabled students to fall into gendered roles, such as a girl recording information and taking responsibility for moving the group forward while boys take an authoritative role evaluating the work of girls. While this dissertation also shows that the unstructured, open-ended nature of activities such as guided inquiry labs are important to students’ sense of self-efficacy and affiliation with a science identity, teachers can use strategies such as formalized group roles to structure the ways students collaborate without diluting the open-ended nature of the activity.

5.4 Future Directions

The studies in this dissertation point to several directions for future study. First, examining gender equity in physics requires considering intersections of gender with other identities, including race (Avraamidou, 2020). The small number of the participants in these
studies limited the breadth of intersections between gender and other identities that were possible to examine. These studies also only include students who self-identified as cisgender, so do not provide any insights into how trans and non-binary students experience recognition in physics classrooms. Finding ways to examine the questions in this dissertation through a more intersectional lens and with participants with a broader range of gender identities is an important part of understanding how students are marginalized in physics classrooms and how to design physics classrooms where all students have access to a physics identity.

In addition to examining the experiences of students with a greater range of identities, it would be beneficial to explore recognition in a wider range of contexts. All of the data for this dissertation was collected in the same classroom at the same high school. Future studies should include students in other grade levels and physics courses beyond algebra-based AP Physics to see whether recognition operates in similar ways across grade levels. In addition, since all three studies examined a classroom led by the same teacher using the same core instructional approach, there remain important questions about how the curriculum impacted students’ sense of physics identity which can only be explored by examining a range of different physics classrooms. There are also contextual factors like the size of the school, the number of students in a class, the demographics of the school and the classroom, and the larger culture of the school that almost certainly impacted the ways students interacted with each other in these studies. In the small group studies in chapters 3 and 4 of this dissertation, the fact that only two girls were enrolled in the course and only one consented to participate in the studies meant it was impossible to examine a group of all-girls, a variation that would be especially valuable in future studies. Studying these issues in a wider range of settings could give a broader view of what recognition looks like and how it interacts with students’ sense of physics identity.
Collecting data at different time points in the school year could also provide useful insights into how students’ understanding of what it means to be a physics person evolves during a physics course. All student interviews and small group video in this dissertation were collected late in the school year, when students had well-established peer relationships and significant experiences shaping their views of what it meant to be a physics student in this classroom. Future studies should collect similar data at several different points in the school year to compare how students recognize each other and how they discuss their own physics identity as the year progresses.

Future studies should also consider the role and identity of the teacher. These studies found evidence that choices made by the teacher, such as what kind of feedback to write on assessments, impacted students’ beliefs about whether they are a physics person and the culture of the classroom built by the teacher likely impacted what students believed it means to be a physics person. Studies that consider the teacher in their analysis could provide insights into what kinds of moves contributed to or detracted from a classroom where students were able to see themselves as physics people. In addition, the teacher in all of these studies was a white woman. Simply being a woman in a position of expertise and authority in a typically male-dominated field likely impacted the way gender appeared in the classroom. Studying classrooms with teachers of other genders could give deeper insights into how the gender of the teacher impacts student interactions. In addition, just as it is important to consider the intersections of students’ various identities, it is also important to consider the intersections of teachers’ identities. In particular, given the ways physics is associated with whiteness, it could be powerful to examine the role of race in student interactions in classrooms with teachers who have a range of racial identities.
Finally, understanding why issues of gender equity are especially pronounced in physics requires understanding what is different about physics classrooms. Conducting similar studies on recognition, disciplinary identity, and related questions not only in other science disciplines, such as biology, chemistry, and earth science, but in other high school subjects such as social studies, English language arts, world language, mathematics and others, could lead to a more refined understanding of what about physics classrooms contributes to such significant marginalization along gender lines.
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Appendix A: Self-Efficacy Data Collection Tools

Figure A.1 Sample Self-Assessment

Self-Assessment
What score do you think you earned for each learning target on this quiz?

BFPM.1 I can draw properly labeled and qualitatively accurate system diagrams and free-body diagrams that show all forces acting on a system.

<table>
<thead>
<tr>
<th>Mastery (Nailed it!)</th>
<th>Near Mastery (I think I’m close)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Mastery (I need to work on some pieces)</td>
<td>Developing (I need a lot of work)</td>
</tr>
</tbody>
</table>

If you believe you are at mastery, what strategies or actions helped? If not, what will you do to improve?
<table>
<thead>
<tr>
<th>Question</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you think you are good at physics? How do you know?</td>
<td>Competence (Carlone &amp; Johnson, 2007)</td>
</tr>
<tr>
<td>3. Do you think your classmates or lab group members think you are good at physics? How do you know?</td>
<td>Recognition (Carlone &amp; Johnson, 2007)</td>
</tr>
<tr>
<td>4. Do you think your teacher believes you are good at physics? How do you know?</td>
<td>Recognition (Carlone &amp; Johnson, 2007)</td>
</tr>
<tr>
<td>5. Do you think physics is something you could learn to be better at? How do you know?</td>
<td>Growth mindset (Dweck, 2008)</td>
</tr>
<tr>
<td>6. Tell me about a time when you felt really good at physics.</td>
<td>Identify impactful classroom experiences</td>
</tr>
<tr>
<td>7. What kinds of activities or experiences help you feel good at physics?</td>
<td>Identify impactful classroom experiences</td>
</tr>
<tr>
<td>8. Tell me about a time when you did not feel very good at physics.</td>
<td>Identify impactful classroom experiences</td>
</tr>
<tr>
<td>9. What kinds of activities or experiences make you feel not very good at physics?</td>
<td>Identify impactful classroom experiences</td>
</tr>
<tr>
<td>10. Do you act differently in classes you feel good at than in classes you don’t feel good at? How so?</td>
<td>Does confidence influence engagement?</td>
</tr>
</tbody>
</table>
### Appendix B: Profile Distribution by Topic

#### Table B.1  Year 1 Profile Distribution by Topic

<table>
<thead>
<tr>
<th>Topic</th>
<th>Underestimating (c, A)</th>
<th>Public (C, A)</th>
<th>Unknown (c, a)</th>
<th>Overestimating (C, a)</th>
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</thead>
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<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
<td>Girls</td>
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<td>Constant velocity calculations</td>
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<tr>
<td>Energy bar charts</td>
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</table>
### Table B.1 Year 1 Profile Distribution by Topic Continued

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<tr>
<th>Topic</th>
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<th>Public (C, A)</th>
<th>Unknown (c, a)</th>
<th>Overestimating (C, a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
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<td>Girls</td>
</tr>
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<td>Conservation of energy</td>
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<td>Coulomb’s Law</td>
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<td>11%</td>
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<td>44%</td>
</tr>
<tr>
<td>Kirchoff’s Laws</td>
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<td>13%</td>
<td>16%</td>
<td>12%</td>
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### Table B.2 Year 2 Profile Distribution by Topic

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Table B.2 Year 2 Profile Distribution by Topic, Continued

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<td>Constant acceleration representations</td>
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<tr>
<td>Ohm's Law</td>
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104
<table>
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<tr>
<th>Topic</th>
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<td>12% 50%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>Angular acceleration calculations</td>
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<tr>
<td>Torque representations</td>
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<td>50% 40%</td>
<td>17% 30%</td>
<td>33% 10%</td>
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<tr>
<td>Conservation of angular momentum</td>
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<tr>
<td>Newton's 2nd Law for rotation</td>
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<td>24% 33%</td>
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### Appendix C: Additional Student Interview Quotes

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<thead>
<tr>
<th>Theme</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Labs: Guided-Inquiry</strong></td>
<td>If you’re doing a lab and you’re doing the theory so it's not just the teacher just tells you this is what’s gonna happen when you do this, you actually carry out the lab and you see what actually happens and it's easier to remember that, so I think the labs help a lot.</td>
<td>If I don’t understand the physics then it’s hard for me to catch along with the activities. I think the labs; I think what really helps on labs is knowing what I’m looking for and having an idea of how to get it there.</td>
</tr>
<tr>
<td><strong>Labs: Real-World Experiences</strong></td>
<td>The labs, they always helped. Like doing everything hands-on gave a better understanding, like when we did the marble activity with the horizontal and vertical velocities, that helped gain an understanding.</td>
<td>I like doing, like the physical, actually doing the experiments, but then actually be able to sit down and write down how that connects to physics definitely helps. Cause then you get the action and….I dunno, I’m a very visual learner so writing stuff down helps a lot. It makes a lot more sense when we're doing a lab and I can actually see this is what physics is like in the real world.</td>
</tr>
<tr>
<td></td>
<td>I think for the labs, early on for the labs, like the ones that we did hands-on, I would be the one that would lead them and I would, like, tell my group what to do. I think when we started to do the ones on the computers for like rotation, I was a little bit more confused. [I felt bad at physics during] some of the computer labs. Not the hands-on ones, but the ones where we get, like the videos, and when you’re supposed to record the data and I get confused about what am I supposed to be recording and then...I just kind of, like, get lost and then after the class period it's just like “well, I didn’t learn anything today” and that was not very good.</td>
<td></td>
</tr>
<tr>
<td>Theme</td>
<td>Boy</td>
<td>Girls</td>
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<td>------------------</td>
<td>----------------------------------------------------------------------</td>
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<tr>
<td>Problem Sets</td>
<td>Especially for the projectile one when we had to calculate the</td>
<td>So when we do the mistakes</td>
</tr>
<tr>
<td></td>
<td>horizontal and linear movement and all that, so there was one time when</td>
<td>whiteboarding [student-led discussion of problem sets], I feel</td>
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<tr>
<td></td>
<td>my group were like totally lost about the whole thing but I just found a</td>
<td>that being able to find those</td>
</tr>
<tr>
<td></td>
<td>way to put...to solve it and I actually got the right answer you got, so</td>
<td>mistakes is a crucial part of knowing how to do physics and knowing</td>
</tr>
<tr>
<td></td>
<td>I think I feel good about that.</td>
<td>how to do it correctly and we did some of the packets that you gave us,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>it was practice problems and that helped a lot with being able to do</td>
</tr>
<tr>
<td></td>
<td></td>
<td>it without any guided help.</td>
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<tr>
<td></td>
<td></td>
<td>Oh, I remember, so there was a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[problem set] that, I think, it was projectile motion and it was</td>
</tr>
<tr>
<td></td>
<td></td>
<td>comparing different graphs and it was an alphabet soup problem</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[problem with literal equations]…When I look at it, I was like &quot;well</td>
</tr>
<tr>
<td></td>
<td></td>
<td>this is just algebra” and it just made a lot more sense. I started</td>
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<td></td>
<td>plugging variables together, substituting and then I was like the</td>
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<td></td>
<td></td>
<td>only one in the class that got it, and then...you were going around,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>like, helping people, but no one was still getting it. By the time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>you got to our group, I wasn’t done yet, but I was almost there and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>then, that was like the one time that I was like I actually understand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>this. That was a long time ago.</td>
</tr>
<tr>
<td>Theme</td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Peer Interactions</td>
<td>Well, in class, most people would, at least early on in the class, not so much like now, people would ask me how to, for help. Like, neighboring tables would ask me or [my lab partner] or when we were in our groups for labs, I would be the one that would run the lab cause, I guess I was the only one that paid attention even though I really wasn’t. I'm never shut down by my lab group, they accept ideas. So it really shows that they're confident in me and my abilities.</td>
<td>I think always coming back to making sure we understand everything. [describing feedback she found helpful]</td>
</tr>
<tr>
<td>Assessment Feedback</td>
<td>I’m probably better than [my classmates] at physics and most times I know cause after a test or something the difference in the results from the test. I guess you grade our quizzes, that you can see I do get [mastery and near mastery] usually, so...I think that is really how you know if I’m good at physics or not. Well, I feel like [my peers] do think I’m good at physics because I’ll help them with some things and I would get [mastery] on the quizzes for some of the, like, pretty easily most of the time. She offers constructive criticism when needed and it’s really helpful when trying to understand what I did incorrectly on quizzes and labs. So I believe that feedback really shows that my teacher believes that I can do the course. There’s notes on our quizzes and always there’s feedback I can build upon. I usually don't study much for these quizzes and I do quite well, like easy [mastery].</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D: Stimulated-Response Interview Protocol

1. Who in our class do you think is good at physics? Why do you think that?

2. What are some things that you think it means to be good at physics?

3. What are some of the things that you think are useful contributions to group work?

4. When you are working in small groups, what are some of the ways you let your classmates know when you think they are good at physics or have made a useful contribution?

5. Do you think your classmates see you as good at physics or as someone who makes useful contributions to the group? How do you know?

6. What are some of the things your classmates do that let you know when they think you are good at physics or you’ve made a useful contribution to your group?

Stimulated Response

7. Do you think <student> was making a useful contribution here? What were they contributing?

8. Do you think the other students saw <student> as good at physics or making a useful contribution in this clip? How do you know?

9. What skills do you think <student> was being recognized for here? How do you know?

10. How do you think your group members saw your contributions in this clip? Why do you think that?