Student views of what counts as doing physics in the lab

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Numerous studies have identified gender inequity in how students divide roles in lab courses. Few studies, however, have probed how these inequities impact women's experimental physics identity development. In this work, we used closed-response surveys to investigate which lab tasks students view as part of "doing physics" and how these designations varied by gender. In both courses, we found that most students viewed working with the experimental apparatus, taking lab notes, doing data analysis, and thinking about the physics theory behind the experiment as part of doing physics. Only 50% of students, however, viewed managing the group progress as part of doing physics. While men and women's views did not vary in the first-semester lab course, in the third-semester course women were more likely to view notes and managing as part of doing physics than were men. Given that previous research has indicated that women are more likely to take on managing and note-taking roles than men, our results suggest that women may be receiving less recognition as physicists from their peers, which may hinder their experimental physics identity development.

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I. INTRODUCTION

Lab is an important part of the physics curriculum where students can develop practical and technical skills such as instrumentation and data analysis [1, 2]. Physics labs are also one of the only places in the undergraduate curriculum where students can develop their experimental physics identities.

Previous work on science identity and physics identity has identified interest, perceived competence/performance, recognition from others, and seeing oneself as a physics person as important aspects of physics identity [3–6]. Unfortunately, compared to men, women tend to have a lower overall sense of physics identity [4, 6–8], have lower self-efficacy [9–11], and both perceive and receive less recognition, even as they perform equally well or better in a physics context [7, 12].

These concerns about women's development of physics identity are particularly salient in the lab. Many studies have identified inequities in how students divide up laboratory work along gender lines [13–17], even though women and men express similar preferences for laboratory tasks [18]. Quinn *et al.* found that men were more often the primary data collector and equipment manipulators for their lab groups than women in inquiry-based labs [16]. Doucette *et al.* similarly identified two gendered modes of work distribution in lab groups: secretary/tinkerer and Hermione/slacker [17]. The first mode is similar to Quinn *et al.*'s results, in which a man primarily manipulates the experimental apparatus (tinkerer) while a woman takes notes and fills out the group's worksheet (secretary). The second mode is characterized by a man who is unprepared and unengaged in the lab (slacker), forcing his woman partner to take responsibility for organizing the group and making sure the group completes their work (Hermione). In doing so, she must focus more on logistical and managerial tasks than engaging with the physics of the experiment. Doucette *et al.* argued that these secretary and Hermione roles actively inhibit women's opportunities for physics identity development.

Women's identity in the physics lab is further complicated by the inherent gendering of physics identity: women must navigate performing their gender as part of their identity within the physics lab [3, 19, 20]. Many of the skills valued by professional experimental physicists, such as manual labor and tinkering, are viewed as inherently masculine and antithetical to traditional femininity [21–25]. A lab identity consistent with femininity is likely to instead emphasize organizational, analytical, and collaborative skills [20], similar to the secretary and Hermione roles identified by Doucette *et al.* [17] and the gendered patterns of engagement observed by Quinn *et al.* [16].

This paper is part of a bigger project to further probe the impacts of these gendered notions of roles and identity development within the physics lab. As described above, recognition, both of oneself as a physicist and from others, is an important aspect of physics identity. The work a student does in the lab will impact how they view their own identity as a physicist and how others view them. Given the gendered notions of tasks such as note-taking and coordinating group logistics, we might expect that women receive less recognition as physicists than men because they disproportionately take on this work. On the other hand, self-expression can also be an important aspect of identity development [26], so for women who value note-taking and coordinating group logistics, taking on these roles may allow them to see themselves as physicists in roles that are compatible with their femininity.

An important first step to understand how student roles within the physics lab impact their identity development is to identify what lab work students value as part of doing physics. Thus, in this paper, we will address the following research questions:

1. What lab tasks do students view as part of doing physics, both before and after laboratory instruction?
2. How does this classification of lab tasks vary based on student gender?

II. METHODS

We studied students enrolled in two in-person laboratory courses at a large research university, Phys 1110 and Phys 2210. Phys 1110 is typically taken concurrently with calculus-based introductory mechanics, although the experiments include both mechanics and electricity and magnetism topics. The course included students from both engineering-track (primarily engineering and other STEM majors) and majors-track (primarily physics majors) courses. Women made up approximately 45% of the students in Phys 1110 (the engineering-track course was approximately 50% women, while the smaller majors-track course was approximately 30% women). The lab course emphasized student development of experimentation skills by supporting students' agency to design and carry out experiments in small groups [27–30]. Lab sessions met for two hours weekly and were divided into six two-week units throughout the semester. Each week each group was required to submit a single set of lab notes that detailed the decisions they had made in designing and carrying out their experiment, how they analyzed their data, and what conclusions they drew from their experiment.

Phys 2210 was a follow-up course taken concurrently with the third course in the introductory majors sequence (but not the engineering sequence), and was taken primarily by physics majors. Women made up approximately 30% of the students in this course. Students in Phys 2210 worked on a semester-long project in small groups in which they chose a topic, developed and conducted an experiment, and presented their results in a poster session at the end of the semester. As in Phys 1110, lab sessions met for two hours weekly and each group submitted a set of lab notes at the end of each session.

Students filled out a survey at the beginning of the course (pre) about group work preferences and attitudes to help the course instructors assign appropriate groups. They filled out a

TABLE I. Self-reported gender of survey respondents.

	Phys 1110	Phys 2210
Women	100	10
Men	124	17
Non-binary	3	0
Prefer not to disclose	12	1

similar survey at the end of the semester (post). For this study, we focused on student responses to the question, "Which of the following experiment tasks or roles do you think counts as doing physics? Choose all that apply.

(a) Setting up the apparatus and collecting data. (**Apparatus**)
(b) Writing up the lab procedures and conclusions. (**Notes**)
(c) Analyzing data and making graphs. **(Analysis)**
(d) Managing the group progress. (**Managing**)
(e) Exploring the theoretical aspects of the experiment." (**Theory**)

These answer choices were based on lab tasks identified in student interviews and prior observational studies [18, 31].

We collected matched pre and post survey responses from 239 students (65% response rate) in Phys 1110 and 28 students (56% response rate) in Phys 2210; these response rates fall within the range commonly reported in PER studies [32]. The breakdown of students' self-reported gender is shown in Table I. In our analysis of the relationship between student gender and perceptions of physics, we focused on comparisons between men and women. Despite our interest in the specific experiences of non-binary students, we were unable to include them in the gender analysis owing to the small number of them in our sample and maintaining anonymity.

The goal of our analysis was to identify large-scale trends in student attitudes rather than to quantify small differences across our data sets. As a result, we did not perform statistical analyses but instead used overlap in error bars to make claims about differences in student thinking. Given our small sample of students from Phys 2210 in particular, our analysis should be interpreted as identifying possible trends worthy of future investigation with a larger sample size.

III. RESULTS

Our first research question is about what lab tasks students viewed as part of doing physics and how these views changed after lab instruction. Across both courses, students overwhelmingly identified all roles except managing the group as counting as doing physics (see Fig. 1). This overall trend did not vary significantly between the pre and post surveys: for each of analysis, apparatus, notes and theory, most students indicated in both the pre and post survey that the task counted as doing physics. In contrast, only around half of the students identified managing as counting as doing physics at each time point and in each course. Thus, students seemed to

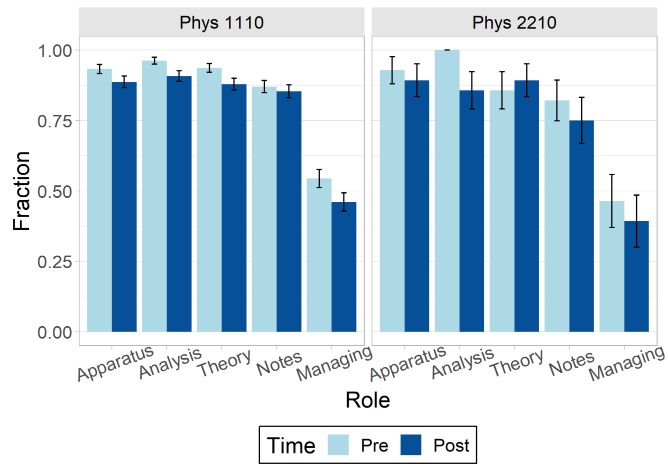


FIG. 1. Student views on what counts as doing physics, both pre and post, in Phys 1110 and Phys 2210. Error bars represent the standard error.

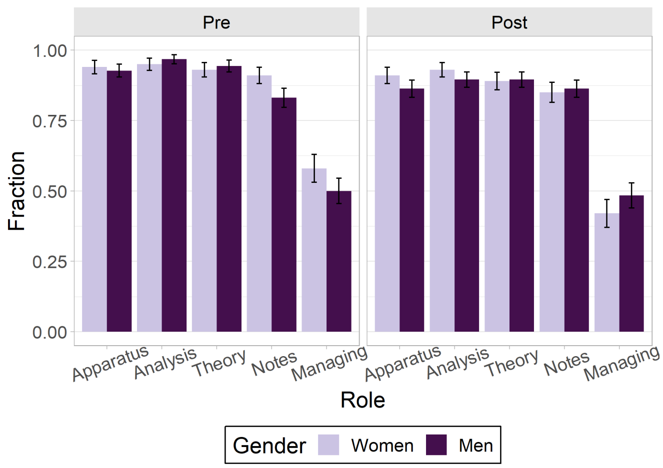
feel that most work done in their lab courses constituted doing physics, other than managing their groups. These views did not change on average for the classes from the beginning to end of the semester.

The second research question concerns how these views might vary based on student gender. In the first semester course, Phys 1110, there were no significant differences in student responses to what counts as doing physics between men and women either in the pre or post survey (see Fig. 2a).

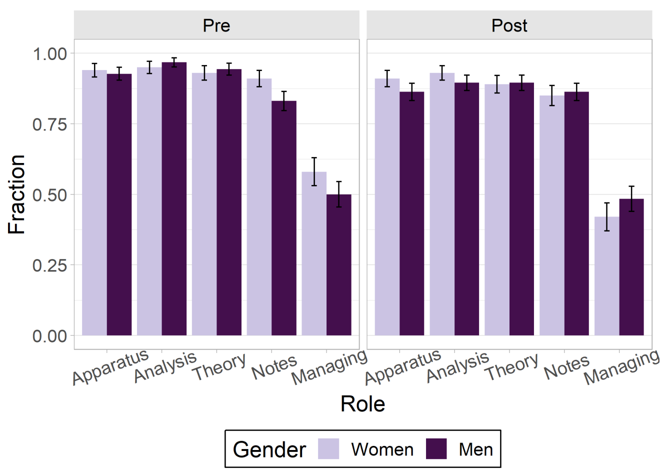
As in Phys 1110, we observed no gender differences in students' views in the pre survey for the follow-up course, Phys 2210 (see Fig. 2b). In the post survey, however, gender differences emerged in the note-taking and managing tasks. At post, women were more likely to include note-taking (90% of women) and managing (60% of women) tasks as counting as doing physics compared to men (65% and 24%, respectively). For the note-taking role, the emergence of the split in the post data was characterized by a slight increase in the number of women including notes and a slight decrease in the number of men including notes from pre to post. For managing, women's inclusion stayed consistent from pre to post, while the proportion of men including managing decreased from 41% at pre to 24% at post.

There is also a slight gender difference in Phys 2210 students' categorization of theory at the end of the semester. All of the women indicated that working on the theoretical aspects of an experiment counted as doing physics, while only 82% of the men did so. Because our sample size is small, it is difficult to determine whether this difference is meaningful, so in this paper we focus our discussion primarily on the larger gender differences for notes and managing.

One possible explanation for the difference in gender dynamics between the two courses is the population of students who took each course. Phys 2210 was comprised entirely of students in the majors introductory physics sequence (pri-



(a)



(b)

FIG. 2. Student views on what counts as physics in Phys 1110 (a) and Phys 2210 (b), split by gender. Error bars represent the standard error.

marily physics majors), while Phys 1110 included students in both the majors and engineering sequences. It is possible that the students in the majors sequence, who are primarily physics majors, view physics differently than those in the engineering sequence. When we disaggregated the majors-sequence students from the engineering-sequence students in Phys 1110, however, we observed no differences between these two student populations. Regardless of which sequence the students were enrolled in, there were no gender differences in their views of what counts as doing physics in Phys 1110.

IV. DISCUSSION

In this work we probed students' views of what lab tasks count as doing physics in two different lab courses. Unsurprisingly, students overwhelmingly included working with the apparatus, performing data analysis, and working on the theoretical aspects of an experiment as part of doing physics. Prior work has shown that students and professional researchers alike consider tinkering and "getting one's hands dirty" by working with the experimental apparatus to be key aspects of being an experimental physicist [17, 20–22, 25]. Other research has indicated that physics students also value data analysis skills and a firm understanding of theory, even within an experimental lab context [33].

Surprisingly, however, most students viewed taking notes as part of doing physics. Previous research has suggested that students and professional researchers exclude organizational, communication, and managerial skills from their definition of an experimentalist [17, 20–22]. At both the beginning and end of the semester, however, students indicated that taking notes counted as doing physics at similar rates to setting up the apparatus, performing data analysis, or investigating the physics theory behind the experiment. The consistency of this result across the semester for the Phys 1110 students was particularly surprising. These students would not have taken a college physics lab course prior to Phys 1110, so we would expect their pre survey responses to have been shaped by their prior experiences with lab and physics. Given that lab courses often involve filling out highly structured worksheets or lab reports rather than keeping an authentic lab notebook [34–38], we might have expected students to view this form of taking notes less as doing physics than the other roles prior to taking Phys 1110.

The consistently high ranking of lab notes as part of doing physics is likely a beneficial attitude for students to have. The American Association of Physics Teachers recommendations for laboratory instruction identify communicating physics as an important skill for students to develop [2]. Furthermore, research suggests that practicing authentic scientific writing in lab courses encourages students to think like professional scientists rather than just think like students completing schoolwork [35, 36, 39]. If students value communicating their experiment design and results as part of doing physics, then we would expect working on lab notes to enhance their development of experimental physics identity.

In contrast to the lab-notes results, the result that half of students did not consider managing their lab group as part of doing physics aligns with what we might have expected from the prior literature [17, 20–22]. For example, Doucette *et al.* reported that students who took on a managerial role within their groups (Hermiones) tended not to view their success as indicative of their physics abilities because it was tied to project management rather than hands-on tinkering [17]. This result is particularly concerning given that women are more likely to be pushed into managerial roles within lab courses to make up for "slacker" group-mates [17]. Because both men and women are less likely to see managing as part of doing physics, women who take on managing roles may be missing out on both recognition from their peers as physicists and seeing themselves as physicists within the lab.

This equity concern is exacerbated by the gender differences in student views at the end of Phys 2210, where women were more likely than men to view writing lab notes and managing the group as part of doing physics. Previous research has indicated that women are more likely to take on the work of managing their groups and writing lab notes to document their groups' progress [16, 17, 31]. Consequently, these women might be more likely to value this work as an important part of the experimental process and see it as part of doing physics. Men, who might have been less likely to take on these roles, may not have recognized notes and managing as contributing to the group's success and therefore been less likely to view them as part of doing physics.

If this gender difference in students' views of what counts as doing physics is being driven by who takes on what roles, then this split is particularly concerning for women's experimental physics identity development. Because women made up only 30% of students in Phys 2210, many of the women who take on these roles were in mixed gender groups. While some of the women who took on these roles might see them as doing physics, and consequently see themselves as experimental physicists, men with whom they work closely in their groups may be less likely to recognize them as experimental physicists if they do not view managing and/or notes as part of doing physics [21, 22]. Future work should investigate the link between seeing notes and/or managing as part of doing physics and taking on these roles within the lab.

Notably, this gender difference emerged only in Phys 2210. There are several differences between the populations of the two courses that may have contributed to the different gender dynamics at play. Phys 1110 included a mix of both majors-sequence (primarily physics majors) and engineering-sequence students and was the first physics lab course these students took in college. Phys 2210 contained only students from the majors physics sequence and was the third physics lab course these students took in college.

The different gender results in these two classes are not simply due to differences between the students in majors-sequence courses and engineering-sequence courses: Phys 1110 students who were enrolled in the majors mechanics course expressed similar views to those in the engineering mechanics course (see Sec. III).

The level of the course, however, could have contributed to this difference. Studies have suggested that students' attitudes and beliefs about experimental physics shift as students progress from first-year to beyond-first-year lab courses [40] and that these shifts can differ slightly for men and women [41]. It is possible that the timing of Phys 2210, as a sophomore-level course in the third semester of physics instruction, impacted men's and women's views differently than their first-year lab courses.

Another possible explanation is the different course structures. In Phys 1110, each lab session focused on a self-contained assignment for which students conducted an experiment and submitted lab notes. Although a subsequent session could build from the previous week's work, students generally did not have to plan ahead or ensure that their notes from one week would form the basis for their work in a future week. In Phys 2210, because groups engaged in a single project throughout the semester, students would have needed to make a plan at the beginning of the semester and ensure that each week they did work that was a logical continuation of their previous session and that moved them forward toward their overall goal for the semester. In this structure, having students write out clear lab notes that the group could refer to in future weeks was even more important for making progress than in Phys 1110. Similarly, groups also would have benefited more from having a group member manage the overall progress, making sure the group was on pace with their timeline and meeting deadlines [31]. As suggested above, if women were more likely than men to take on these roles, they may also have been more likely than men to value them as part of doing physics. It is unclear, however, how this course structure (but not Phys 1110) would have caused the number of men who viewed managing and notes as part of doing physics to *decrease* over the course of the semester. More work is needed to characterize how students form these views throughout a lab course.

V. CONCLUSIONS

We have identified that many students in two different lab courses did not view managing their group's progress as doing physics. Moreover, among a small sample of students working on a semester-long project, men were less likely to view writing lab notes and managing the group as part of doing physics compared to women. Given that women are more likely to take on managerial and note-taking roles than men [16, 17, 31], these views could have a significant negative impact on women's recognition as physicists by their peers and, consequently, their overall experimental physics identity development. Future work will expand this study to a larger sample of students as well as investigate how the roles taken by students impact their views on what counts as physics and how these attitudes impact physics identity development.

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