Unpacking Gender Differences in Students' Perceived Experiences in Introductory Physics

Lauren E. Kost, Steven J. Pollock and Noah D. Finkelstein

Department of Physics, University of Colorado at Boulder, Boulder, Colorado 80309 USA

Abstract. Prior research has shown, at our institution: 1) males outperform females on conceptual assessments (a gender gap), 2) the gender gap persists despite the use of research-based reforms, and 3) the gender gap is correlated with students' physics and mathematics background and prior attitudes and beliefs [Kost, et. al. PRST-PER, 5, 010101]. Our follow-up work begins to explore how males and females experience the introductory course differently and how these differences relate to the gender gap. We gave a survey to students in the introductory course in which we investigated students' physics identity and self-efficacy. We find there are significant gender differences in each of these three areas, and further find that these measures are weakly correlated with student conceptual performance, and moderately correlated with course grade.

INTRODUCTION

Our prior work has shown that a difference in male and female performance (a gender gap) on conceptual assessments persists despite the use of fully interactive engagement methods [1]. Further, this gender gap can be largely accounted for by differences in physics and mathematics background and prior attitudes and beliefs about physics [2]. We are now interested in how males and females experience the introductory physics course, whether there are differences by gender, and whether these differential experiences impact the gender gap in performance that we observe.

For several years an end-of-term survey has been administered to students in our introductory course. The content of the survey has varied, but some versions included questions about how much students enjoyed and how useful they found various aspects of the course (e.g. use of clickers, lecture presentation, homework). There were also questions about how comfortable students felt discussing physics with their peers, the professor, and the TAs. Contrary to our expectations, we found few significant gender differences on questions of enjoyment, usefulness, and comfort level. We then generated a new survey about student experiences in the course that probed areas identified from the literature as potentially varying by gender [3]. In this paper we present the results from our survey.

METHODS

The survey was issued to students in the first semester, calculus-based introductory physics course in the fall and spring semesters of the same year. The two courses were taught by different instructors, but the courses were identical in terms of curriculum; both used clicker questions and Peer Instruction [4] during the lectures and *Tutorials in Introductory Physics* [5] and Learning Assistants [6] during the recitation. The courses were slightly different in terms of the demographics of the students. While both courses had about 625 students, there was a higher percentage of females in the spring semester (29% versus 24%) and a higher percentage of declared physics majors in the fall semester (10% versus 2%). The Force and Motion Conceptual Evaluation (FMCE) [7] was used to assess students' conceptual understanding in both courses, and the scores (pretest, posttest and normalized gain) were not significantly different between the two semesters ($p > 0.05$). In Table 1 we also present the gender difference in students' overall grades in the course. In a previous paper [2] we reported that in no semester did we see a statistically significant gender difference in student grade, though males always earned slightly higher grades than females. Since that publication, we have observed two instances where there was a statistically significant ($p < 0.01$) gender difference in course grade. The survey results that we present here come from these two semesters.

TABLE 1. Comparison of Student Populations in the Fall and Spring Semesters. FMCE scores are not significantly different between these two semesters. Gender gap is M-F

	Fall Semester	Spring Semester
FMCE Pretest Average	31.9±1.1%	32.4±0.9%
FMCE Posttest Average	71.9±1.3%	69.1±1.2%
FMCE Pretest Gender Gap	14±2%	10±2%
FMCE Posttest Gender Gap	18±3%	11±3%
FMCE $<g>$	0.59	0.54
Gender Gap in Course Grades (GPA units)	0.28±0.1	0.26±0.1

The survey was administered to students online in the last few weeks of the semester. The students were awarded a small amount of extra credit for completing the survey. The completion rates were 82% and 67% for the fall and spring semesters, respectively. The survey questions, which probed areas that were identified from the literature as potentially influencing the gender gap, were both adapted from other instruments and generated by the authors. The first area investigated by the survey was students' sense of physics identity and belonging. Lave and Wenger define identity as, "the way a person understands and views himself, and is viewed by others," [8]. If learning physics is viewed as the process of becoming a physicist, then understanding whether students view themselves as a physicist and as someone who can do physics is crucial. Seymour and Hewitt [9] found that a prevalent reason for females leaving the sciences was that they rejected the career and lifestyle of scientists. Brickhouse et. al. found that middle school girls engaged in their science classes differently depending on their identities [10]. Both of these studies provide evidence that identity is important when considering student learning.

Another area we investigated was students' sense of self-efficacy in physics. Self-efficacy (SE) comes out of Bandura's social cognitive theory [11], and characterizes the beliefs that people have about their ability to complete a specific task. According to Bandura's theory, SE beliefs influence the choices that people make and the effort that they put forth to complete a task. SE has been shown to predict students' academic achievement in several disciplines [12]. There are four hypothesized sources of SE: mastery experience, vicarious experience, verbal and social persuasions, and emotional and physiological states [13]. Questions from the Sources of Self-Efficacy in Science Courses - Physics instrument [3] were modified and included in our survey. The questions we chose all probed students' emotional and physiological responses as a potential source of physics SE. Our survey contained 11 statements to which students responded on a 5-point Likert-scale from "strongly agree" to "strongly disagree".

RESULTS

We looked at gender differences in students' responses to individual questions, and in the average responses over groupings of similar questions. The results for individual questions are summarized in Table 2. The table contains the percentages of males and females that responded favorably to each statement. A favorable response could be "agree" or "disagree", depending on how the statement is phrased. Mann-Whitney U-tests [14] were carried out to compare males to females in each semester, as well as all students from the fall semester to all students in the spring semester. In Table 2, bold indicates significant male-female differences, and the final column indicates significant fall-spring differences.

TABLE 2. Percent Favorable on Each Statement. The first two columns report the percent of males or females who responded favorably to each statement. Bold percentages indicate that the difference between males and females is statistically significant (via Mann-Whitney test, p<0.05). p<0.05 indicates a significant difference between fall and spring.

Statement	Fall Semester M	Fall Semester F	Spring Semester M	Spring Semester F	All Students Fall vs. Spring
Physics Identity and Sense of Belonging					
I enjoyed physics this semester.	**42**	**19**	**75**	**58**	p<0.05
I feel like I could be a good physicist.	**54**	**22**	**57**	**30**	
I felt like I didn't belong in this class	**67**	**39**	**77**	**67**	p<0.05
It was easy finding friends in this course.	64	68	68	74	
Other students in this class were easy to relate to.	73	75	72	75	
I was different than most of the other people in this class.	36	45	44	50	
The professor of this course was easy to relate to.	**37**	**27**	89	89	p<0.05
Physics Self-Efficacy					
I was unable to think clearly when taking exams in this class.	**41**	**26**	40	30	
Physics makes me feel uneasy.	**53**	**21**	**58**	**29**	
I got really stressed when working on homework in this class.	**30**	**10**	28	16	
I worried about my ability to solve physics problems on exams	**31**	**13**	**36**	**18**	

We first look at those questions pertaining to students' sense of physics identity and belonging. As shown in Table 2, we find that of the seven questions about identity, three questions show gender differences in both semesters, three questions do not show gender differences in either semester, and one question shows a gender difference in one semester but not the other. Those questions that show no gender differences are about relating to other students in the class, such as, "It was easy finding friends in this course." The questions that *did* show gender differences were related to physics and doing physics, such as, "I feel like I could be a good physicist." Responses to the statement, "The professor of this course was easy to relate to," were different by gender in the fall semester, but not in the spring. Males were more positive than females about the professor in the fall semester, but males and females were equally positive about the professor in the spring semester. We note that the instructor in the fall semester had taught a large-enrollment introductory course only once prior to this semester. The instructor in the spring semester was a member of the physics education research group and has received numerous awards for his teaching.

In addition to looking at gender differences on individual questions, we can look at student responses averaged over several similar questions. Figure 1 shows the distribution of average scores on all seven of the identity questions for males and females. The difference between males and females is significant (via 2-tailed t-test, p<0.001).
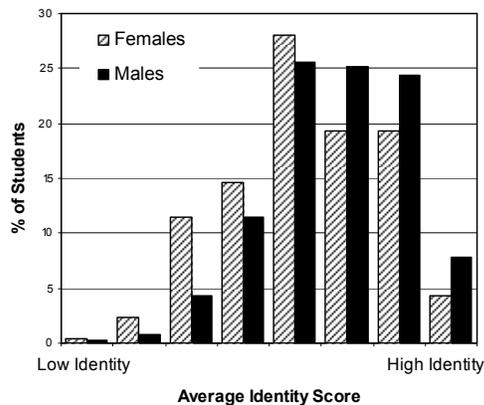

FIGURE 1. Histogram of Students' Average Identity Scores. Each student's score is the average of his/her responses to the seven identity questions. Males have significantly higher responses than females.

Figure 2 shows the distribution of average scores on all four of the self-efficacy (SE) questions for males and females. Again, the difference between males and females is significant (p<0.001). Females respond significantly less favorably on all four of

these questions in both semesters. Further, there are no differences between student responses in the fall and spring terms. We investigated the possibility that females report lower SE because they have lower exam scores. We find that even when controlling for exam score, females have significantly lower SE than males (via ANCOVA, p<0.001).
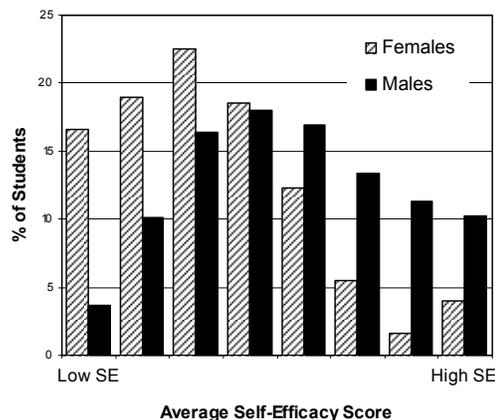

FIGURE 2. Histogram of Students' Average Self-Efficacy Scores. Each student's score is the average of his/her responses to the four self-efficacy questions. Males respond significantly higher than females.

We looked at correlations between these measures of identity and SE and student performance in the course, i.e. FMCE pretest, posttest, and gain scores and course grades. The correlations were similar for males and females and for the fall and spring semesters, so we report the correlations for all students together. As is shown in Table 3, most of the correlations are fairly weak. The highest correlations are between student SE and exam scores and course grade.

TABLE 3. Correlations between identity and SE measures and student performance. * indicates a statistically significant correlation, p<0.01.

	Identity	Self-Efficacy
FMCE Pretest	0.24*	0.44*
FMCE Posttest	0.24*	0.38*
FMCE <g>	0.20*	0.29*
Course Grade	0.32*	0.50*
Participation Score	0.02	0.04
Homework Score	0.16*	0.14*
Exam Score	0.36*	0.58*

We also carried out a regression analysis to see if the identity and SE measures were useful predictors of FMCE posttest score and course grade. Because of the moderate correlations between these measures and student performance, we know that they are

somewhat useful as predictors on their own, but we were interested in whether they contribute any predictive power beyond the FMCE pretest and standardized math test scores. We find that both measures are useful predictors of course grade, even after FMCE pretest score and math score are included in the model. However, the identity and SE measures do not help predict FMCE posttest score beyond FMCE pretest, math score[15], and CLASS [16] pretest score. Further, controlling for identity and SE does not further account for the gender *gap* in FMCE scores.

DISCUSSION

The results from our survey indicate that there are significant differences between males and females in terms of their responses to questions about their sense of physics identity and their physics self-efficacy (SE). It appears that while there are gender differences in both semesters on the identity questions, there are also differences between the fall and spring semesters. This is not the case with the SE questions; there are consistent gender differences in both semesters, and there are no significant differences between the fall and spring semesters.

There are several conclusions to be drawn from these results. First, females report less of a sense of physics identity than males. This, on its own, could contribute not only to the fewer number of females who go on to become physics majors, but also their lower performance in the course. Though identity didn't help to predict FMCE posttest score beyond the pre-measures that were already analyzed, we understand that females' sense of physics identity may have influenced their physics and mathematics background.

The large gender differences that we see on questions of SE, especially the questions that we chose which probed emotional responses to exams and homework as a potential source of physics SE, suggest that stereotype threat [17] could be affecting females in the introductory physics course. If this were the case, that females were underperforming on assessments (both exams in the course and the FMCE) because they were under a stereotype threat condition, there are potential interventions that could alleviate the threat [18].

The survey questions regarding SE only probed one source of SE. There are other sources of SE that we could also investigate, as well as measuring students' SE more directly. We also note that the survey was given to students towards the end of the semester, and according to Bandura's theory, SE is most predictive when assessed before the student attempts the task. In addition, we have some evidence (by comparing to CLASS results) that students' SE may shift over the course of the semester. Hence, in the future we will assess students' SE at the beginning of the course in order to get a better predictor of achievement and also to be able to examine whether there are shifts as students go through the introductory course.

In all, the results of our survey have made clear that while there are similarities in the reported experiences of males and females, there are also some important ways in which their experiences differ. As evidenced by the correlations and regression analyses, these measures of identity and SE are associated with student performance in the course. As such, identity and SE are potential targets of future interventions to address the disparity in performance, retention, and participation between males and females.

ACKNOWLEDGMENTS

REFERENCES

1. S.J. Pollock et al. *Phys. Rev. ST PER* **3**, 010107 (2007).
2. L.E. Kost et al. *Phys. Rev. ST PER* **5**, 010101 (2009).
3. H. Fencl & K. Scheel, *J. Col. Sci. Teach*. **35**, 20 (2005).
4. E. Mazur, *Peer Instruction: A User's Manual*, Upper Saddle River, NJ: Prentice-Hall, 1997.
5. L.C. McDermott & P.S. Schaffer, *Tutorials in Introductory Physics*, Upper Saddle River, NJ: Prentice-Hall, 2002.
6. V. Otero et al. *Science* **313**, 445 (2006).
7. R.K. Thornton & D.R. Sokoloff, *Am. J. Phys*. **66**, 228, (1998).
8. J. Lave & E. Wenger, *Situated Learning: Legitimate Peripheral Participation*, Cambridge: Cambridge University Press, 1991.
9. E. Seymour & N.M. Hewitt, *Talking About Leaving: Why Undergraduates Leave the Sciences*, Boulder, CO: Westview Press, 1997.
10. N.W. Brickhouse, et al. *J. Res. Sci. Teach*. **37**, 441 (2000).
11. A. Bandura, *Psych. Rev*. **84**, 191 (1977).
12. F. Pajares, *Rev. Ed. Res*. **66**, 543 (1996).
13. E.L. Usher & F. Pajares, *Rev. Ed. Res*. **78**, 751 (2008).
14. W.J. Conover, *Practical Nonparametric Statistics*, New York: John Wiley & Sons, Inc, 1999.
15. ACT-Math score was used.
16. W. Adams et al., *Phys. Rev. ST PER* **2**, 010101 (2006).
17. S.J. Spencer, et al., *J. Exp. Soc. Psych*. **34**, 4 (1999).
18. G. L. Cohen, et al., *Science,* **313***,* 1307 (2006).