Physics Career Intentions: The Effect of Physics Identity, Math Identity, and Gender

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Abstract. Although nearly half of high school physics students are female, only 21% of physics bachelor's degrees are earned by women. Using data from a national survey of college students in introductory English courses (on science-related experiences, particularly in high school), we examine the influence of students' physics and math identities on their choice to pursue a physics career. Males have higher math and physics identities than females in all three dimensions of our identity framework. These dimensions include: performance/competence (perceptions of ability to perform/understand), recognition (perception of recognition by others), and interest (desire to learn more). A regression model predicting students' intentions to pursue physics careers shows, as expected, that males are significantly more likely to choose physics than females. Surprisingly, however, when physics and math identity are included in the model, females are shown to be equally likely to choose physics careers as compared to males.

Keywords: career choice, gender, math, identity, survey
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INTRODUCTION

Physics continues to lag behind the other sciences in terms of the representation of females. While the fractions of biology and chemistry bachelor's degrees earned by females are 59% and 49%, respectively [1], only 21% of physics degrees are earned by females [2]. An often espoused reason for this participation gap is gender differences in mathematics since mathematics is substantially used in physics. However, females earn 40.6% of bachelor's degrees in mathematics and statistics, indicating that mathematics is not a deterrent in and of itself [1].

Most females choose not to pursue a physics career before beginning college. To attract more females into physics careers, it is optimal, then, to focus on high school or earlier. In fact, most female physicists report that they first became interested in physics while in high school [3]. Fortuitously, almost half of high school physics students are female [4]. In order to take advantage of this opportunity, an improved understanding of the factors that affect students' career decisions while they are in high school is required. We use an identity framework to guide our understanding of these factors.

Identification with physics and math may be expected to influence a student's choice to pursue a physics career. Our identity framework is based on that of Carlone and Johnson [5] as modified by Hazari et al. [6]. Carlone and Johnson used the dimensions of performance, competence, and recognition to characterize the science identities of practicing scientists [5]. Hazari et al. added the dimension of interest in order to extend this theoretical framework to describe the physics identities of students [6]. In order to describe the dimensions of identity that may impact the choice of a physics career, we focus on both physics and math identities of students. While the relevance of physics identity is clear, math identity is also included because of the considerable use of math in physics [7].

Figure 1 shows a schematic of the four dimensions of the theoretical framework. Both physics and math identity contain these dimensions, and these two constructs may overlap. Performance consists of students' self-perceptions of their abilities to do well on subject-related tasks such as exams, while competence consists of students' self-perceptions of their ability to understand the subject. Recognition includes whether teachers, parents, and friends see the student as a "physics person" or "math person." Finally, interest includes students' desires to learn more about the subject. Important to consider is that these identity dimensions are not independent of one another. We also note that physics and math identities are only a part of students' broader personal and social identities [8].

In this work, we investigate the influence of students' physics and math identities on their choices to pursue physics careers. First, we describe the data and identity constructs arising from the data. Then, we compare the identity measures by gender and domain (math/physics) and perform a regression analysis to study the relationship between identity and physics career intentions. Finally, we summarize the importance of our findings.

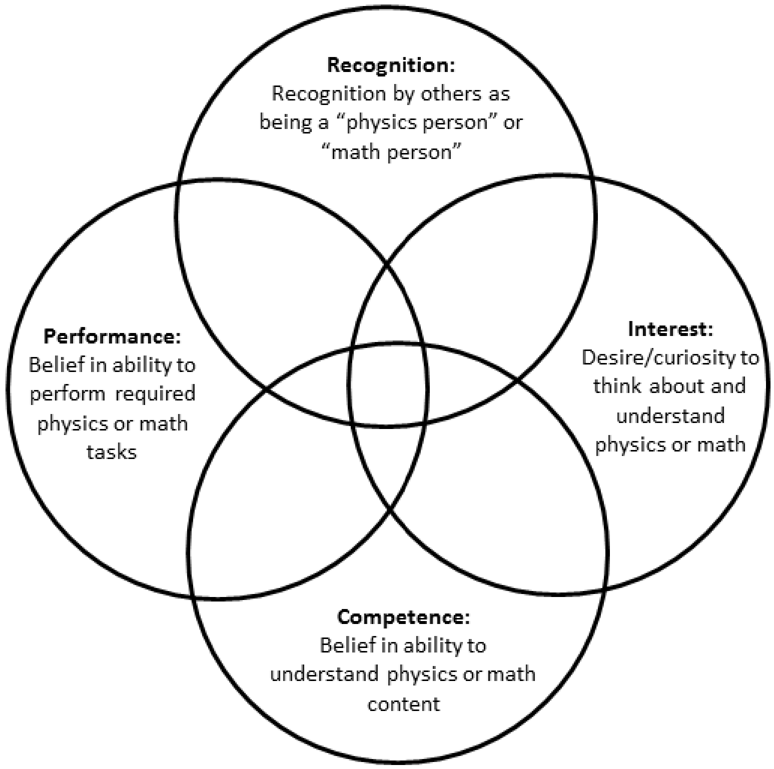

FIGURE 1. Schematic of identity framework. Adapted from [6].

METHODS

The data used in this study was drawn from the Sustainability and Gender in Engineering (SaGE) Project, a large-scale survey administered to a nationally representative sample of students enrolled in introductory English courses at 50 colleges and universities. The survey included questions about career goals, high school experiences, and sustainability. Students were surveyed during English courses in order to sample a broad range of students, including those with a strong interest in engineering and science as well as those with no interest. First-year college students were surveyed because they have recently made their initial career decisions and because they are able to recall their high school experiences. During the fall of 2011, 6,772 surveys were returned. This represents a student response rate of approximately 41%. The institutional response rate was 100% - every recruited college/university administered and returned surveys.

This paper focuses on survey questions related to career choice and physics and math identities. The question about career choice asked students to "Please rate the current likelihood of your choosing a career in the following." Choices included math, science, and engineering careers. This analysis only uses students' responses to the choice of physics. Responses to this question were on a Likert-type scale ranging from 0 being "not at all likely" to 4 being "extremely likely." For the identity questions, students were asked "To what extent do you disagree or agree with the following statements." The responses were on a Likert scale from 0 being "strongly disagree" to 4 being "strongly agree". The questions were asked in parallel for physics and math. Questions spanned the four sub-constructs of the identity framework.

We conducted factor analyses to verify that the identity items aligned with the four dimensions in the framework. For both math and physics, three factors were obtained: performance/competence, recognition, and interest. Note that the factor analysis revealed that performance and competence formed a single factor thus reducing the number of identity components to three. Six variables (three for physics identity and three for math identity) were then constructed from the responses to the identity items. The variable "performance/competence" is composed of responses to "I am confident that I can understand this subject in class," "I am confident that I can understand this subject outside of class," "I can do well on exams in this subject," "I understand concepts I have studied in this subject," "Others ask me for help in this subject," and "I can overcome setbacks in this subject." Recognition is composed of responses to "My parents/relatives/friends see me as a physics/math person" and "My physics/math teacher sees me as a physics/math person." Interest is constructed from "I am interested in learning more about this subject" and "I enjoy learning this subject."

We first compared the three identity dimensions (performance/competence, recognition, and interest) by gender and between math and physics using Wilcoxon tests. Additionally, we performed regression analyses to investigate the influence of math and physics identities on the intention to pursue a physics career.

RESULTS AND DISCUSSION

The results show that our identity framework can, in part, explain the physics gender gap and indicates the dimensions on which to focus in order to increase the representation of females in physics. Table 1 shows the mean values for the performance/competence dimensions for both physics and math broken down by gender, along with the significance of the differences between mean values. The significance is calculated using the Wilcoxon rank-sum test for gender differences and the Wilcoxon signed-rank test for differences between math and physics. Males have higher self-perceptions than females in both the physics and the math performance/competence dimensions. Note that students' self-perceptions may differ from actual grades or exam scores. In contrast to the reported self-perceptions here, previous research found no gender difference in mathematics performance at the high school level and found that the gender differences in science at the twelfth grade level are small [9]. Additionally, Table 1 shows that both males and females have higher self-perceptions of performance/competence in math than in physics.

Tables 2 and 3 show the results for the recognition and interest dimensions, respectively. Similar to the performance/competence dimension, males report more recognition and interest than females report for both subjects. Recognition and interest also show the same trends as performance/competence in the comparison between math and physics. Students report more recognition in math than in physics indicating that they, on average, feel more recognized as "math people" than "physics people". Additionally, students report more interest in math than physics. Finally, the gap between physics and math identity dimensions is larger for females than for males indicating that females may experience a starker contrast between the two subjects than males do. The identity dimensions reflect the same trends as students' career choices both in terms of gender differences and subject differences, as more students obtain bachelor's degrees in math than in physics [1].

TABLE 1. Wilcoxon tests for Performance/ Competence dimension. ***: $p < 0.001$.

	Male	Female	Sig.
Physics	2.02	1.44	***
Math	2.34	2.14	***
Sig.	***	***	

TABLE 2. Wilcoxon tests for Recognition dimension. ***: $p < 0.001$.

	Male	Female	Sig.
Physics	1.57	0.95	***
Math	2.08	1.73	***
Sig.	***	***	

TABLE 3. Wilcoxon tests for Interest dimension. ***: $p < 0.001$.

	Male	Female	Sig.
Physics	1.87	1.23	***
Math	2.01	1.79	***
Sig.	***	***	

To further explore the connection between physics career choice and physics and math identities, we performed two regression analyses. Table 4 shows the two models, Model I which includes only gender and the other control variables (parental education level, race, and ethnicity) and Model II which includes the math and physics identity dimensions in addition to the control variables. While Model I only explains 3% of the variance in intent to pursue a physics career, Model II explains 30% of the variance. Model I shows, as expected, that males are more likely to choose a physics career than females. However, in Model II, gender is no longer a significant predictor. Rather, the strongest predictors are physics recognition and physics interest. Thus, when students feel recognized as "physics people" or are curious to learn more about physics, they are more likely to pursue physics careers. Physics performance/competence was not found to be significant and, hence, was not included in Model II.

Math interest is also positively related to physics career choice. This was the only dimension of math identity found to be significant. Overall, math identity has a relatively small effect on physics career choice. One possible reason may be that students do not see a strong connection between the way math is used in math contexts and how math is used in a physics context.

Finally, there was one gender interaction effect. Physics recognition was shown to have more of an

TABLE 4. Regression model predicting intent to pursue a physics career. **: $p < 0.01$; ***: $p < 0.001$; ns: not significant

Parameter	Model I (N=4083) Estimate	Model I (N=4083) Std. Error	Model I (N=4083) Signif.	Model II (N=2953) Estimate	Model II (N=2953) Std. Err.	Model II (N=2953) Signif.
Intercept	0.83	0.06	***	-0.02	0.07	ns
Controls						
Parental Education		Included			Included	
Race and Ethnicity		Included			Included	
Gender (0 = Male, 1 = Female)	-0.31	0.03	***	0.06	0.05	ns
Identity						
Physics Recognition				0.22	0.03	***
Physics Interest				0.26	0.02	***
Math Interest				0.06	0.01	***
Interaction: Phys. Rec. × Gender				-0.09	0.03	**
Adjusted R^2	0.03			0.30		

impact on males than on females. This means that females may need to perceive higher levels of recognition than males require in order to consider physics careers. In summary, physics interest, math interest, and particularly physics recognition account for the gender gap between males and females in choice of a physics career.

CONCLUSION

Our identity framework provides an explanation for the gender gap in the choice of a physics career, as gender is not a significant predictor of physics career choice when physics and math identity dimensions are included in the regression. The results suggest that strategies aimed at improving female representation in physics should emphasize physics recognition and interest rather than performance/competence, although these dimensions are not entirely independent of one another. Males report higher physics recognition and interest than females, and this difference accounts for much of the gender gap. Additionally, females may require a higher perception of recognition than males in order to choose physics careers. Hazari et al. showed that specific high school teaching strategies can positively impact physics identity [6]. Future work should include investigating which strategies specifically affect recognition and interest. This work has potential to influence not only female representation, but also the number of students choosing to pursue physics careers overall.

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