Who Becomes a Physics Major? A Long-term Longitudinal Study Examining the Roles of Pre-college Beliefs about Physics and Learning Physics, Interest, and Academic Achievement

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Abstract. In this paper, we examine the correlation between students' beliefs upon entering college and their likelihood of continuing on to become a physics major. Since 2004, we have collected CLASS survey and self-reported level-of-interest responses from students in the first-term, introductory calculus-based physics course (N>2500). Here, we conduct a retrospective analysis of students' incoming CLASS scores and level of interest, comparing those students who go on to become physics majors with those who do not. We find the incoming CLASS scores and reported interest of these future physics majors to be substantially higher than the class average, indicating that these students enter their first college course already having quite expert-like beliefs. The comparative differences are much smaller for grades, SAT score, and university predicted-GPA.

Keywords: Interest, Beliefs, Epistemology, Learning Physics, Physics Major, CLASS, Undergraduate education.
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INTRODUCTION

Who becomes a physics major? Are we simply selecting our majors from a narrowly defined group exhibiting particular characteristics upon entering college? Or are we drawing majors from a broader distribution of students by developing their beliefs about and interest in physics as they become more knowledgeable about physics through their college experience? Is it possible to predict who is likely to become a physics major? Answers to these questions are important in guiding departmental and national efforts to increase the number and quality of physics majors.

Here, we examine three potential predictive factors: students' beliefs about physics and learning physics (as measured by the CLASS survey), students' level of interest, and students' academic achievement. Prior studies of student CLASS scores across introductory and upper-level physics courses have demonstrated correlations between students' beliefs and their choice of major [1-3]. Looking across physics courses, Gire et al. [3] found that incoming first-year physics majors (N=15) had expert-like beliefs similar to those of students measured in upper-level courses. An earlier study [4] examined the relation between student interest and their future career prospects and found that students' positive interest in physics was associated more strongly with future pursuits in physics (whereas negative interest was attributed to factors of course implementation). In this study, we expand on this prior work. We include multiple years of incoming students, retrospectively identify those who actually end up majoring in physics, and simultaneously examine several possible characteristic traits of future physics majors.

Through this work and future efforts, we seek to identify characteristics commonly exhibited by future physics majors upon entering college and to examine their relative importance and their malleability post high-school. Our ultimate goal is to provide data that will guide educational efforts to produce large numbers of the most capable physics graduates.

STUDY DESIGN

In this longitudinal study, we first collected student survey responses within their first week of their first college physics course, waited several years, and then identified those students who ended up majoring in

physics. Over 6 terms (Fall 2004 to Spring 2007), we administered an online pre-survey during the first week of each of the two introductory, calculus-based physics courses at University of Colorado (Phys I and Phys II). This pre-survey included the Colorado Learning Attitudes about Science Survey (CLASS-Physics) [1] together with some supplemental background and interest questions describe below.

The CLASS survey provides a measure of student beliefs about physics and learning physics. It consists of 42 statements to which students respond using a 5-point Likert scale. Complete details of the design, categorization, validation, and scoring of the CLASS are reported by Adams et al. [1]. Briefly, the student's 'Overall' % favorable-belief-score is equal to the percentage of statements for which his/her response agrees with that of practicing physicists.

In addition to these statements, the surveys starting in Fall 2005 also included a supplemental question:

Currently, what is your level of interest in physics? (very low, low, moderate, high, very high)

We purposely use a vague question as opposed to a question that is a more specific measure of interest, such as whether students would like to learn more physics. This approach was taken in an effort to measure students' composite affective response towards physics. The student's answer naturally depends upon the range of factors relevant to how she personally identifies what makes something interesting.

Finally, all surveys included two questions which together allow us to identify students who, at the start of their first college physics course, identified that they "intend" to major in physics (*Intended Majors*):

What is your current declared major? (selection)

If you plan to change your major, please choose the major you intend to switch to: (selection)

Table 1 summarizes the courses surveyed, showing the number of enrolled students, the number for which we have survey responses along with the number of students who, at this early stage, indicated that they intended to major in physics. For the Phys II courses, we restrict our examination to only those students for which this was their *first* physics course at CU.

We matched these pre-college-physics student survey results to university student records as of Nov 2009. For each student, these records provided: (1) several measures of student achievement prior to college, including SAT scores and Predicted GPA (a university-calculated measure which predicts students' college GPA based on high school performance measures); (2) student course grades in Phys I and Phys II; and (3) subsequent student course, grade, and declared major history.

TABLE 1: Students surveyed at START of their first college physics course

Students in Phys I (Calc-based)				
	Enrolled	**w/ pre CLASS**	***Intended* physics major**	***Actual* physics major**
Fa04	583	489	42	12
Sp05	523	414	13	1
Fa05	600	389	30	9
Sp06	534	386	16	1
Fa06	611	495	34	14
Sp07	566	402	15	6
All	**3417**	**2575**	**150**	**43**
Students in Phys II (who did NOT take Phys I at CU)				
	Enrolled	**w/ pre CLASS**	***Intended* major**	***Actual* major**
Fa04	57	52	9	3
Sp05	40	33	1	0
Fa05	53	50	8	2
Sp06	29	16	0	0
Fa06	50	47	10	4
Sp07	31	27	2	0
All	**260**	**225**	**30**	**9**

From these records, we identified current physics majors (*Actual Majors*) as students who either had already earned a degree in physics, or were enrolled as a physics major, had completed >14 credit hours in physics, and had completed the first-term of junior-level E&M. Table I shows the dramatic reduction from those "intending" to major in physics as they enter their first college course, to those who actually end up majoring in physics.

RESULTS AND DISCUSSION

With these data, we conduct a retrospective examination of three areas with potential to influence student's decisions to major or not major in physics: (1) students' beliefs about physics and learning physics (CLASS scores), (2) students' interest in physics, and (3) students' achievement.

Incoming Students' Beliefs

As shown in Figure 1, we find a broad distribution of CLASS scores for the general population of 1st-semester physics students, ranging from quite novice-like beliefs (scores <60%) to expert-like beliefs on par with graduate students and physics faculty. However, we note the striking difference between the general distribution found among these students (largely engineering students), and those students declaring intention to major in physics at the start of this first

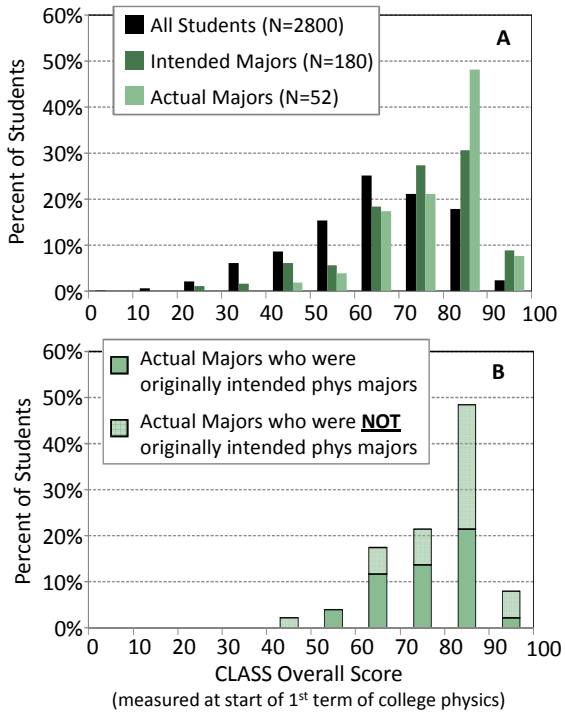

FIGURE 1. Distributions of observed CLASS 'Overall' % favorable scores for students at the start of their first college, calculus-based physics course. Panel A shows distributions for all students (N=2800), those stating an intention to major in physics at the start of the term (N=180), and those who actually major in physics (N=52). In panel B, the distribution from the "Actual Majors" graph indicates the fraction who were and were not originally in the "Intended Majors" group.

course. These "intended" majors hold much more expert-like beliefs as measured by the CLASS – an average score of 73.5 ± 1.2% versus 64.7 ± 0.3% for the overall population (Table 2). The distribution for students who actually end up majoring in physics is even more expert-like (average score of 78.3 ± 1.4% with over 50% of the majors starting college physics with CLASS scores exceeding 80%).

These data have several implications. First, the data indicate that our majors are drawn from the pool of students who enter college with expert-like beliefs about physics and learning physics. This finding provides a strong argument for significant efforts towards developing more expert-like beliefs among students in the K-12 system. These results also suggest that a student's score on the CLASS survey as they enter college may be informative to departmental efforts to recruit majors. Finally, the CLASS score would be a valuable addition to any model seeking to *predict* the likelihood that a student would major in physics in the future.

We see a sharp decline between the number of students intending to major in physics at the start of

TABLE 2: Measures from 1st semester of college physics

	All students	***Intended* majors**	***Actual* majors**
# of students w/ CLASS*	2800	180	52
CLASS Overall Score (Pre)$	64.7 ± 0.3	73.5 ± 1.2	78.3 ± 1.4
Level of interest (Pre) (1=very low, 5=very high)	3.7	4.6	4.5
Course Grade	2.7	2.7	3.0
Avg SAT	1246	1271	1290
Avg Predicted GPA	3.2	3.1	3.2

*Total number of students with other measures available varies for level of interest (N=1808), Avg SAT (N=1891), Avg Predicted GPA (N=2297). $Standard error on the mean shown.

their first course (N=180) and those who actually major in physics (N=52). In addition, only 48% of the "actual" majors were originally "intended" majors. However, we see in Figure 1B that the 52% of students who make the decision to major in physics at a later time still come from the group of students who enter college physics with very expert-like beliefs.

Incoming Interest in Physics

Similar to CLASS score data, we find a broad distribution of students' self-reported level of interest for the general population of 1st semester physics students, with an average of 3.7 out of 5 (5="very high interest"). Again, we observe a striking difference between this broad distribution for the general population, and the distributions for the subset of students in the "intended" and "actual" physics majors. These subsets almost universally declare a high or

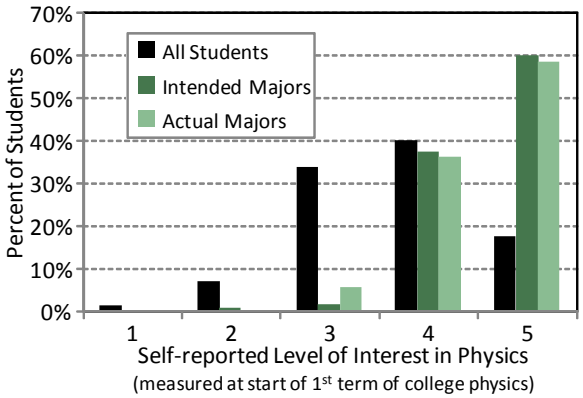

FIGURE 2. Distributions of students' self-reported level of interest in physics at the start of their first college, calculus-based physics course. Shown for all students, those intending to major in physics, and those who ended up actually majoring in physics (N=1808, 115, 36 respectively).

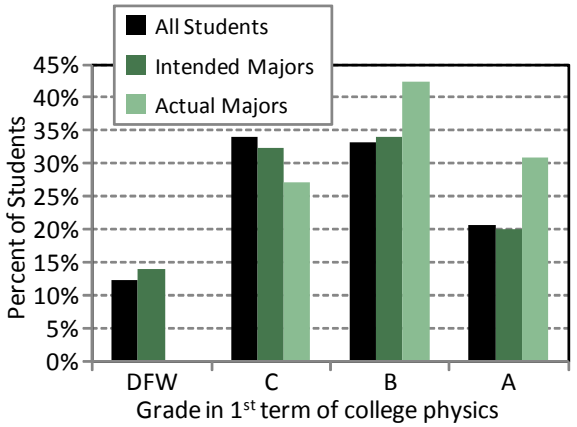

FIGURE 3. Distributions of students' course grades in their first college, calculus-based physics course. Shown for all students, those intending to major in physics, and those who ended up actually majoring in physics (N=2800).

very-high interest in physics at the start of their first term of college physics (avg 4.6 and 4.5 out of 5).

As previously reported [5], there is a correlation between student CLASS scores and students' self-reported level of interest. For these data, R^2 is 0.23, suggesting that 23% of the variance in CLASS scores is explained by students' reported level-of-interest. While this is a high correlation for educational data, it also indicates that by no means are these two measures redundant. Thus, students' self-reported level of interest in physics would also be a valuable addition to a model seeking to *predict* the likelihood that a student would major in physics in the future.

Student Achievement

Finally, we examined the seemingly-logical suspicion that student achievement – in terms of physics grades or general academic excellence – would be a predictor of who becomes a physics major. In Figure 3, we see that the distribution of grades in the first term of college physics is very similar when comparing the "intended" physics majors to all students. The lack of DFWs among the "actual" majors is an unsurprising selection effect. The distribution of ABCs for the "actual" majors includes a few more students getting As and Bs (average grade 3.0) compared to all students (average grade 2.7), but does not show the substantial differences observed in the measures of student beliefs about or interest in physics. Thus, 'grade-at-the-end-of-first-term-physics' would provide only modest improvements in a predictive model flagging potential future physics majors.

From Table 2, we see that other measures of student achievement – SAT scores and university's predicted GPA – also show little to no relationship with becoming an "actual" physics major.

CONCLUSIONS

We find a student's beliefs about and their interest in physics when they enter college to be strongly correlated with whether or not they will end up a physics major. College can be students' first serious exposure to physics – an opportunity to generate interest and develop expert-like beliefs about physics in students who may have the capacity to be outstanding physicists, but enter with little experience and novice beliefs about physics. However, these data highlight that our introductory college courses (at least at CU) are not succeeding at interesting and developing this population to major in the discipline.

For departments engaging in efforts to recruit and develop more majors, these data point to several approaches that may benefit their efforts: (1) reaching out to students with expert-like beliefs and interests in the freshmen year (about 85% of "intended" majors switch out of physics), and (2) including significant efforts to attend to students beliefs and interest in these first-year courses (on average student beliefs about physics typically decline substantially over the first term physics course) [6]. The PER community is researching how to develop expert-like beliefs.

Finally, these data also suggest that to increase the number of majors requires attention to improving students' experiences with physics in K-12 with particular attention to developing more students with expert beliefs and interest in physics prior to college.

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REFERENCES

1. W.K. Adams, K.K. Perkins, N. Podolefsky, N.D. Finkelstein and C.E. Wieman *Phys. Rev. ST Phys. Educ. Res.* **2**, 010101 (2006).
2. K.K. Perkins, W.K. Adams, N.D. Finkelstein, S.J. Pollock, & C.E. Wieman, *PERC Proceedings 2004.*
3. E. Gire, B. Jones, and E. Price. *Phys. Rev. ST Phys. Educ. Res.* **5**, 010103 (2009).
4. Briggs, B.H.. *Physics Education, 11*, 7, 483-487, (1976).
5. K.K. Perkins, M.M. Gratny, W.K. Adams, N.D. Finkelstein and C.E. Wieman, *PERC Proceedings 2005.*
6. Redish, E., Saul, J.M. and Steinberg, R.N. *American J. of Physics*, **66**, 212-224 (1998).