

Gender Differences in the High School and Affective Experiences of Introductory College Physics Students

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Differences in the persistence of males and females studying physics have been a topic of concern for physics education researchers for decades. Although gender differences in average physics course grades have diminished¹ females continue to lag considerably in terms of persistence. The largest percentage drop of females studying physics occurs between high school and college². This is problematic since many female physicists report that they became attracted to physics and decided to study it further in high school according to the International Study of Women in Physics³. Even though high school may be the most important time to attract females, it is also the time when most females begin to opt out. The National Science Foundation reports that although half the students taking one year of physics in high school are female, females are less likely than males to take a second or Advanced Placement (AP) physics course⁴. In addition, the percentage of females taking the first physics course in college usually drops to between 30 and 40%⁵. Thus, the high school physics course that females take is a crucial time to engage them so that they will continue with physics study.

The purpose of this study was to explore the gender differences found in the high school physics experiences and background of students in introductory college physics courses. Using existing data from a project entitled “Factors Influencing College Science Success (FICSS)”, we determined how the earlier experiences of males and females who took introductory college physics differed. With the support of other findings in the literature, we hope to begin to parse out the factors that might have led to differential persistence levels for males and females studying physics after high school and even begin to perceive the difference in how males and females approach learning physics. Specific questions we endeavor to answer for students in introductory college physics are: How does male and female academic preparation differ? What is the difference in their high school physics experiences in terms of pedagogy and content? Do they have different learning or study strategies? Is there a difference in their outside-of-class experience and affective support?

FICSS Methodology

The FICSS study, funded through the Interagency Educational Research Initiative (IERI) and administered through the National Science Foundation (NSF-REC 0115649), focused on identifying predictors of success in college science through a large-scale survey of introductory science students across the US. The methodology was that of an epidemiological survey where the researchers relied upon the natural variation in the experiences, background, and decisions of the sample science students. In this case, the students were attending introductory physics classes at randomly selected universities. The FICSS survey consisted of 66 items⁶. The survey questioned students about the content, pedagogy, and assessment methods of their last high

school physics course, the levels to which they took mathematics and sciences in high school, how they performed in those classes, and their demographic information. The survey avoided asking opinion or attitude questions and focused on factual recall questions (e.g. how many labs per month?) and degree-of-experience rating questions (e.g. rate your high school physics course on a scale of 1 to 5, “1” being “few topics in depth” and “5” being “many topics in little depth”). As expected, for many straightforward factual questions, such as the number of labs, demonstrations, and projects, no gender difference was found. However, since students were reporting the experiences, there is some ambiguity as to whether the experiences reflect what actually happened in the classroom or students’ perceptions of what happened. In either case, the gender differences are interesting and relevant. The sample of students who took high school physics consisted of 1986 students, 1199 male and 787 female, from 54 first-semester introductory college physics courses at 35 randomly selected four-year colleges and universities⁶.

In order to determine whether the experiences reported by males and females were significantly different, we ran t-tests for parametric variables (normally distributed continuous variables) and Mann-Whitney tests for non-parametric variables. The significant gender differences found in academic preparation, high school physics experiences, outside experiences, and affective support are discussed below.

Academic Preparation

Are there gender differences in the academic preparation of students who take introductory college physics? Table I lists the academic areas for which significant gender differences were found. The results indicate that although females significantly outperformed males on their last English, math, and science high school grades, males outperformed females on the mathematics section of the SAT. There was no significant gender difference found for students’ last high school *physics* grade. There were also no significant differences found for enrollment in higher-level high school mathematics, such as calculus and Advanced Placement (AP) calculus. However, males were significantly more likely than females to have taken an AP physics course in high school.

Table I. *Significant gender difference tests (T and Mann-Whitney) and standardized mean differences for academic preparation of introductory college physics students.*

Factors	Sig.	Effect Size ^a
Last high school mathematics grade	***	+ 0.25
Last high school English grade	***	+ 0.42
Last high school science grade	**	+ 0.14
SAT mathematics score	***	- 0.24
AP physics enrollment	***	-
2 or more years of high school phy.	***	-

*p<0.05 **p<0.01 ***p<0.001

^a Cohen’s d effect size, no effect size reported for non-parametric variables

Females seem to be entering college physics courses with an equally competitive, or even more competitive, background than males. However, they represent a smaller number of the students in such courses. Perhaps the female students with a less-than-stellar high school background were more apt to avoid college physics than their male counterparts due to a lower level of confidence in their own abilities. This, in part, might explain the differential drop in

persistence of males and females from high school to college physics. The significantly lower SAT math scores of females in this study are not surprising since the SATs have consistently been found to under-predict the achievement capabilities of females⁷. Finally, although females are just as likely as males to have taken one high school physics course, we found them less likely to have enrolled in AP physics or in two years of high school physics. This result is supported by national data on high school course enrollment⁸. Thus, females might be taking the earliest opportunity to opt out of physics without substantial detriment to their admission to good colleges and scholarship opportunities since taking one high school course in physics (not necessarily AP) has become a fairly standard requirement.

High School Physics Experiences

Are there gender differences in the high school physics experiences of students who make it to introductory level college physics? Table II lists the high school physics experiences for which significant gender differences were found. They are grouped into three categories for discussion:

- Category 1 - On average, females reported spending more time studying and reading the textbook in their high school physics class and also perceived that solving calculation problems had a greater role in the class.
- Category 2 - Males reported more frequently understanding concepts before doing high school physics labs, having labs address beliefs they had about the world, and participating in physics-related community projects. There was also some gender difference in the reporting of select teacher characteristics.
- Category 3 - Females reported more than males that their last high school physics course leaned towards a “memorization of facts” focus rather than an “understanding of topics” focus and that test questions were drawn from the homework and/or required memorization. They also perceived more lecturing and that their high school physics class would not help as much in college.

Category 1 results are well supported by the literature on gender differences in diligence towards schoolwork. At the secondary level, males have been found to be less committed to working hard on schoolwork⁹ and lag behind females in reading and writing skills¹⁰. Females have reported spending more time doing homework and were less likely to come to class without completed homework¹¹. Females have also been found to “settle down to the task in hand more readily”⁹. These gender differences in diligence and focus would explain the differences we found in reading of the textbook, studying physics outside of class, and doing calculation problems. In addition, females have been found to have less confidence and prior experience in physics^{12,13,14} than males and subsequently may have relied more heavily on studying, reading, and practicing problems for that reason as well.

The prior experience differences may also have influenced female understanding in their high school physics class. Category 2 illustrates this possible experiential difference since males in introductory college physics reported more frequently understanding concepts before doing high school physics labs, having labs address beliefs they had about the world, and participating in physics-related community projects. These results are of particular concern since females have been found to relate to and understand physics better when it pertains to the broader world and “life” contexts¹⁵, which they may not be getting sufficient exposure to either before or during their high school physics class. For example, females are less likely to have tinkered with mechanical and electrical devices (e.g. car jack, cart, wheelbarrow, bow and arrow, bicycle, rope

and pulleys, car, radio, tv, motor, circuits)¹³. Thus, it is important for high school physics to try to address some of these contextual experience deficits. In addition, males found their high school physics teacher's methods of explaining and maintaining interest far more effective than females did whereas females perceived their teachers to be more knowledgeable. It is likely that the high school teachers were a little more successful in engaging male students through their efforts since engaging female students may have been a much harder task. Not only do females have less contextual experience with physics, several studies have found that females actually become disinterested in traditional physical science topics much earlier than high school^{13,17}. Thus, high school physics teachers have the onus of reversing any previously established lack of experience *and* interest. Females have also been found to be less comfortable with using technical language¹⁵, which combined with their lack of experience and confidence, might lead to their perceiving their teacher (who uses technical language and has experience) to be more knowledgeable than the males perceive her/him to be. However, it has been found that in student evaluations of teaching, students cannot accurately assess the instructor's knowledge of the subject whereas they can accurately assess other attributes such as the clarity of an instructor's explanations and the instructor's helpfulness¹⁶.

Table II. *Significant gender difference tests (T and Mann-Whitney) and standardized mean differences for high school physics experiences of introductory college physics students.*

Factors	Sig.	Effect Size ^a
Category 1		
Minutes studying/working on physics daily	***	+ 0.29
Minutes reading textbook daily	***	+ 0.21
Problems with calculations per week	***	+ 0.16
Category 2		
Understanding concept before lab	**	- 0.15
Labs addressed a belief about the world	***	- 0.18
Physics-related community project work	***	- 0.27
Physics teacher's ability to explain problems	*	- 0.11
Physics teacher's ability to maintain interest	*	- 0.11
Physics teacher's knowledge of physics	*	+ 0.11
Category 3		
Learning req.: (1) Memorize (5) Understand	**	- 0.15
Test questions from homework	**	+
Test questions required memorization	***	+
Frequency of teacher lecturing	**	+ 0.13
Points high school phy. will help in college	***	- 0.24

*p<0.05 **p<0.01 ***p<0.001

^a Cohen's d effect size, no effect size reported for non-parametric variables

In category 3, females reported more frequently than males that their last high school physics course leaned towards a "memorization of facts" focus and that test questions were drawn from the homework and/or required memorization. These trends indicate that females may have been relying more on rote learning strategies in their high school physics class such as memorization rather than appealing to conceptual understanding or reasoning. Williams¹⁸ found that introductory physics students who had high levels of "communication apprehension" were

more prone to rote learning like memorization and that females had significantly higher levels of such “communication apprehension”. Cavallo et al.¹⁹ found that females shifted towards more rote learning strategies, such as memorization, by the end of a physics course whereas males shifted to more meaningful strategies. Indeed, females have been found to resist taking on an active identity (in an Active Physics curriculum) because it was risky and they did not want to tarnish their “good student identities”²⁰. These results are of particular concern to high school physics teachers since high school physics may be the first and last opportunity to engage females in meaningful physics learning. Females also reported having a high school physics class with significantly more lecturing. Perhaps they perceived more lecturing (less student engagement) because they were paying more attention (more “on-task”) or perhaps they were actually less engaged than the males as indicated by some Category 2 results. Finally, females were less confident regarding how much high school physics would help in college. Their earlier perception that their HS physics course transferred less depth of understanding, as well as the well-documented confidence deficit females have with regard to their own physics-related abilities, are likely contributors to this effect.

Outside Experiences and Affective Support

Are there gender differences in the outside-of-class experiences and affective support of students who make it to introductory level college physics? Table III lists the areas for which significant gender differences were found. Males reported deriving their physics knowledge more from out-of-school experiences such as hobbies, reading books/magazines, media (e.g. TV, internet), and jobs. Males also perceived gaining greater knowledge from in-school experiences such as physics courses. Females reported significantly more home environment support of science and encouragement from their mothers, fathers, siblings, and science teachers whereas boys reported at a higher rate that no one encouraged them.

Table III. *Significant gender difference tests (T and Mann-Whitney) and standardized mean differences for outside of class experiences and affective support of introductory college physics students.*

Factor	Sig.	Effect Size ^a
Physics courses impact on knowledge of phy.	***	- 0.18
Hobbies impact on knowledge of phy.	***	- 0.26
Book/magazine impact on knowledge of phy.	***	- 0.16
Media impact on knowledge of phy.	***	- 0.25
Jobs impact on knowledge of phy.	***	- 0.16
Family attitude - science is for a better career	***	+
Home environment supportive of science	***	+ 0.21
Mother encouraged to take science	***	+
Father encouraged to take science	**	+
Sibling(s) encouraged to take science	**	+
Science teacher encouraged to take science	***	+
No encouragement	***	-

*p<0.05 **p<0.01 ***p<0.001

^a Cohen’s d effect size, no effect size reported for non-parametric variables

The results indicate that compared to the females, the males across-the-board perceived possessing greater knowledge of physics from their experiences. There are two possible issues

of concern here: perhaps females had fewer physics-related experiences and therefore perceived having limited knowledge, or perhaps females actually knew as much as males but had lower confidence levels with regard to their physics knowledge. Both these suppositions are supported to some extent by the literature^{12,13,14,18,20,22}. Accordingly, two important points for high school physics to focus on would be to narrow any experiential knowledge and confidence gap. In addition, males' extensive reporting of knowledge based on equally accessible out-of-school experiences (e.g. TV) may illustrate an *internal* drive or personal interest towards physics that many females lacked, which is another supposition supported by the literature^{13,22}. Thus, the need to meaningfully engage the interest of females in high school is evident.

Females, on the other hand, reported more *external* influences than males such as home environment support and encouragement. Perhaps this support was the confidence boost they needed to continue to college-level physics. Monhardt et al.'s²³ findings also stress the importance of providing support and encouragement for young women in order to overcome their fears of pursuing science. Since science, especially physics, is a male dominated field, it is conceivable that females might need extra support and encouragement. Hatchell²⁴ found that encouragement was crucial to "the way female students positioned themselves in science classrooms and how they related the importance of studying science to themselves". In their study of SME (Science, Math, and Engineering) undergraduates, Seymour and Hewitt²⁵ found that the active influence of someone significant (e.g. family member) and receiving praise were important motivational factors for women. Additionally,

The factor most frequently cited by women physicists as contributing to their success was the support of their families, including their parents and husbands. Many also mentioned the support of advisors, professors, and teachers, and some cited the support of colleagues.³

Female students also reported at a higher rate than males that their families viewed science as a way to a better career. The importance the family assigns to different careers may also be a key component in influencing females' choice of career path. The Center for the Education of Women found that "women were less confident of their abilities than men and therefore needed encouragement and reinforcement in order to pursue a career in science"²¹. In agreement with this finding, the female students in this study reported much more overall encouragement than the males; this encouragement might be related to their persistence to college-level science.

Conclusion

The results of this study highlight some important areas of concern for physics educators and physics education researchers in terms of gender. Although females are entering college physics with academic records that are competitive with or better than those of males, this study indicates that they may still lag in expertise related to physics learning strategies, experience, confidence, and interest. These findings have two potentially troubling implications. First, we know that there is a disproportionate attrition of females taking physics from high school to college. If the females who make it to college physics have issues with learning strategies, experience, confidence, and interest, one might speculate that the disproportionate numbers of female non-persisters may have had similar, though perhaps more extreme, issues. Second, the college-level differences found are themselves problematic since positive learning strategies, experience, confidence, and interest may be crucial in determining whether a student will pursue a physics-related field and/or become a lifelong physics learner.

Caution must be exercised in interpreting these findings for two reasons: First, it is impossible to ascertain exactly how important some of these factors are in influencing females' persistence to college physics since the sample did not include a comparison group who abandoned physics study after high school and second, there might be some underlying factors that were unaccounted for because they were beyond the scope of this study (e.g. early socialization and schooling experiences). Nonetheless, the following suggestions can be made for physics teachers from the results of this study:

- Assess experiential gaps at the beginning of the course.
- Help females bridge any experiential gap through active-learning and inquiry, contexts relevant to their experience, and topics of interest to them.
- Avoid pedagogy and assessments that require the use of rote learning strategies.
- Include real-life and human appeal contexts and provide “appealing” out-of-school resources (videos, books, etc.).
- Encourage students so that they build confidence in their own abilities.
- Assess whether the steps taken are working through action research (e.g. document changes in interest, confidence levels, resistance, and learning strategies through evaluations, surveys, talking to students, etc.).

As this century progresses, we must keep in mind the many physics education inequities of the past centuries that led to the current state of affairs and begin the reversal so that females become not only active participants in, but also definers of the field of physics.

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