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A Longitudinal Study of Career Choices after a non-Academic Undergraduate Research Experience

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A Longitudinal Study of Career Choices after a Non-Academic Undergraduate Research Experience

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Abstract
There is a national need for an adequately prepared STEM (science, technology, engineering, and math) workforce, and the need is growing. Developing talented students at the undergraduate level is a major part of satisfying the workforce demands. Here, we examine the graduate enrollment and career choices of alumni from our undergraduate research internship program, specifically beyond graduate school. In plasma physics and fusion, unlike other subfields, the PhD production is only about half of what is required to keep the total workforce constant, based upon the expected retirement rate. A key question to ask is whether or not plasma physics PhDs are finding jobs within plasma physics or within another STEM discipline. When compared to other programs, our undergraduate interns have a much higher percentage that go to graduate school after the program. For the period 2001-2005, our rate is 95% enrolling in graduate school and they are entering the STEM workforce at a rate of 82%.

Introduction

It is clear that there is a national need for an adequately prepared STEM (science, technology, engineering, and math) workforce for international economic competitiveness.[1] STEM is one of the fastest growing sectors for employment. According to the U.S. Bureau of Labor Statistics, during this decade employment in STEM occupations will grow by 18.7%, compared to 14.3% for all occupations.[2] This growth in demand for qualified STEM workers is accelerated, in part, by the aging of our workforce. According to the National Science Foundation's 2014 *Science and Engineering Indicators* report, the proportion of scientists and engineers in the U.S. workforce over age 50 is increasing (20% in 1993 to 33% in 2010) and so is the number between the ages of 60 and 69 (54% in 1993 to 63% in 2010). As these workers leave the workforce, they take with them their knowledge and expertise.[3]

However, overall job growth and an aging workforce does not necessarily mean that we need to produce more PhDs. Unemployment or underemployment in a variety of scientific subfields has led to calls for decreases in the number of PhD students. For example, in a recent report the US Bureau of Labor Statistics addressed the question of whether we are experiencing a STEM worker glut or dearth. Its answer was "yes and yes," depending on the field and sector considered. In academia and the biomedical private sector, the report found that there is a surplus. This is in contrast to shortages seen in government and industry in certain fields such as energy and computer/software engineering.[4]

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The situation within academia is particularly stark. Julie Gould, in her recent Nature article, *How to build a better PhD*, quoted labor economist Paula Stephan who pleads with graduate departments to "partake in (PhD) birth control,"[5] Gould noted that many of those who are actively seeking permanent academic positions wind up in lengthy postdoctoral positions while they wait for a faculty position to come along. In addition, a 2015 Nature study found that only about a quarter of PhD students find tenure-track academic jobs although nearly 80% planned to pursue an academic career after completing the PhD.[6]

That is not a particularly surprising result, given the stereotypical hierarchy that has a tenured professor at the top of the intellectual "food chain" and that there are limited opportunities for prospective graduate students to experience a non-academic research environment. The perception of hierarchy and a faculty position as the end goal often imprints on students' minds at the undergraduate level in the classroom and in undergraduate research experiences. Any opportunity for non-academic research in this critical period would open new pathways for undergraduates. It is rare to do research outside academia as an undergraduate, and the path from science major to graduate school to professor is so often seen as the preferred path when no alternatives are presented. Non-academic research internships for undergraduates provide exposure to careers outside academia and even to the idea of entering the workforce before, or instead of, graduate school.

Adequately preparing undergraduates for graduate school and careers is a major part of satisfying the workforce demands. Reports from the National Research Council (NRC) recommend summer internships for engineering and physics undergraduates, especially to help address the lack of diversity. The NRC also notes that many professional societies have issued statements in support of the value of undergraduate research experiences.[7,8]

Research internships are common among undergraduate STEM majors, though mostly in the labs of professors at academic institutions. The impact of those internships on students' academic and professional careers remains unclear, but there are strong suggestions in the literature that it does lead to more students enrolling in graduate school and persisting in a particular field.[9-12] The American Institute of Physics found that those who did participate in research chose physics or astronomy for graduate study at a rate of 48%. This is 3 times higher than those who did not participate in any kind of undergraduate research.[13]

Lopatto evaluated enrollment into graduate school after an undergraduate research experience on a large general sample (1135 students) in all STEM fields. He found that 48.3% pursued PhDs overall, 23.9% in the physical sciences.[14] Other studies have shown that students who participate in summer and academic year STEM research internships, when compared to those who do not, are more likely to pursue graduate school in a STEM field and have plans to pursue careers in STEM.[12,15] In a review of NSF research experiences for undergraduate programs (REUs) conducted by SRI, International, 70% planned to go to graduate school after the program (life sciences: 81%, physics: 74%, and engineering: 67%).[16]

Data from these studies show that students who participate in undergraduate research experiences tend to pursue graduate school, and students feel they are more adequately prepared. While it is common to report the number that went on to graduate school, it is less common to follow the students through the completion of the degree and beyond. While some studies show that, at the conclusion of the internship, the students have *plans* to pursue careers in,[10,11,14-16] we found no published studies that reported on the number of former interns who had gone on to careers in STEM after graduate school. Though some, such as Villarejo, do survey alumni after graduate school about whether the research experience influenced their career paths, the percentage of alumni who complete their advanced degrees and entered STEM professions is not a reported figure.[17]

Our goal in this work is to examine the long-term career paths of alumni from our undergraduate research internship program, specifically beyond graduate school. At our institution, the Princeton Plasma Physics Laboratory (PPPL), we focus on plasma physics and fusion energy research. While PPPL is managed by Princeton University, it is a Department of Energy National Laboratory. There are graduate students working under research scientists, but there are very few tenured professors that work at the lab. Like other fields, the plasma physics workforce is rapidly aging. According to a US Department of Energy (DOE) Fusion Energy Sciences Advisory Committee (FESAC) report published more than 10 years ago, the average age in the fusion energy workforce in 2004 was 50 years old with 1/3 over the age of 55. If we look at only those in faculty positions, 1/3 were over the age of 60. At PPPL currently, 32.9% of the research and engineering staff is over the age of 60.[18]

However, unlike other subfields, the PhD production is only about half of what is required to keep the total workforce constant, based upon the expected retirement rate.[19] A key question to ask is whether or not plasma physics PhDs are finding jobs within plasma physics or within another STEM discipline. Does a non-academic research internship have any influence over the participants' pursuit of non-academic careers?

Undergraduate Internships at PPPL

PPPL offers research internships to undergraduate students during both the school year and the summer. Applicants are selected based on their relevant experience and coursework, but also their curiosity, creativity, and tenacity that often is evident in their essays and letters of recommendation. Most students participate in the summer program which is ten weeks long, with the first week devoted to an intensive course in theoretical and experimental plasma physics since that is rarely taught in an undergraduate curriculum. At the end of the internship, students present their work at a poster session and write up their results in a paper.

Participants are given pre- and post- participation surveys to assess gains in research skills, quality of program design, and students' career plans. Career choices of participants are tracked for up to ten years to ensure that sufficient time is given to complete a graduate degree and enter the workforce.

Pre- and Post Survey Methods

Here, we present the survey data from 2010 through 2013. 116 out of 165 (70.3%) undergraduate interns completed an online pre-survey before the start of the internship with questions about their expectations for the internship, career plans, and perceived skill set. One hundred nine (66.1%) completed a post-survey distributed during the final week of the internship with nearly identical questions. Questions in the survey were designed to assess changes in career plans and skills occurring between the start and end of the internship. Participants were asked about their graduate plans, preferred employment sector, fields of research, and type of career (professor, teacher, scientist/engineer, or other). Participants were also asked to self-assess their strengths and weaknesses in an assortment of skills identified as valuable in a STEM career such as experimental design and construction, data analysis, and scientific/technical writing.

Pre- and Post-Survey Results

Based on entrance surveys, nearly all students intended to pursue a doctoral level degree (105, 90.5%) and this did not change significantly after the internship (100, 91.7%). When asked about the effect of the internship on their graduate school intentions after the internship was completed, 58.7% said that the internship affirmed their desire to go to graduate school, 22.9% said the internship had no effect and they still want to go to graduate school, 9.2% are now considering graduate school, and 2.8% no longer intend to go to graduate school.

Overall, more participants considered careers as scientists or engineers after the internship. The largest changes were in an increased interest in a career as a scientist or engineer in the military or government (31.0% pre-, 43.1% post-survey) and a decline in interest in faculty positions at research institutions (68.1% pre-, 59.5% post-survey) as shown in Fig. 1. A Pearson's chi-squared test of this data finds that it is not statistically significant (p=0.06 and p=0.186, respectively), not a surprising result given our small sample size. However, an extrapolation of this data set that assumes that these percent increases remain does imply that we will be able to show statistical significance within the next few years.

As for the career fields considered described in Fig. 2, there was a decrease in interest in general physics (35.0% pre-, 27.3% post-) after the internship, but the highest gain was, perhaps not surprisingly, an increase in interest in plasma physics (41.0% pre-, 45.5% post-survey). This may indicate that many students shifted from pure physics to more specifically plasma physics and fusion for their career field after the internship.

Longitudinal Study Survey Methods

For this study, participants from the years 2000 through 2009 were surveyed. During this period, there were 313 interns. Of those, 215 participants responded to surveys and were tracked in the longitudinal study (35 of those tracked were females). Only students that were in the program from 2001-2005 were asked about their career choices to make sure sufficient time had passed so that these participants had completed their PhD. This cohort included 76 students, 10 of which are female, and 60 students (10 female) were tracked. Long-term tracking methods include informal communication with alumni via email and social media, Internet searches, as well as a formal online survey sent via email to addresses on record.

Longitudinal Results

Figure 3 shows the participation period 2001-2005. For this cohort, internship alumni attended graduate school (masters or doctoral) at a rate of 95% (57 of 60 tracked students). 26.3% (15) of those who attended graduate school did so in plasma physics. Of those who went to graduate school in non-plasma STEM fields, 88.1% remain in STEM careers, similar to the results for those that studied plasma physics (86.7%) (Figure 3). Of those employed in STEM, 7 took post-doctoral positions (5 at universities and 2 at National Labs), and 1 became a professor at a university. Counting only the 5 post-docs at universities and the one professor, 6 former PPPL interns or 10% of the total number tracked went into academia. While only ten (16.7%) of this cohort was female, all but one entered graduate school, four in plasma physics. All nine pursued careers in their graduate fields (Figure 4).

Discussion

When compared to other internships in physics and engineering, PPPL's undergraduate interns have a much higher percentage that go to graduate school after the program.[14,17,20,21] For the period 2001-2005, PPPL's rate is 95% enrolling in graduate school; NSF's REU programs have a rate of 70% (for physics and engineering combined).[16] In the SURE study, Lopatto found that 88.4% of 2021 participants in undergraduate research intended to pursue graduate school though advanced degrees in physical science only represented 23.9% of these plans.[14]

PPPL's high rate of interest in graduate school is also shown in the 2010-2013 pre- and post-survey results, indicating that we will likely continue to see the high rates of enrollment in graduate school. Similar to the SRI and SURE studies, our pre-surveys indicate that PPPL interns do indeed enter the program with an already high level of interest in graduate school. As with the other studies, there is some minor fluctuation in our interns' interest in graduate school before and after the program, but most often, a confirmation of interest is the result. These confirmations are supported in the interview data that the program helped "cement" their choice to pursue graduate school, as one alumnus put it, particularly in the area of plasma physics. Other statements from the post-survey's open-ended questions highlight those who did see an increase in their interest: "This experience has increased my desire to continue to do scientific research. I will probably continue to do research in plasma physics when I return to my school."

Nine of the ten women in the 2001-2005 cohort went on to graduate school. These 10 women represent 1/6 of the cohort. While this is less than the national representation of women among physics majors (around 21%, the lowest of the hard sciences) and physics PhDs (19-20%), it is much higher than the representation of women in the American Physical Society's Division of Plasma Physics, a decent proxy for their representation in the plasma and fusion workforce.[7,22,23] Among the 13 students (male and female) from the 2001-2005 cohort who chose plasma physics careers, 4 of them were women – 30%. The sample size prevents us from drawing big conclusions from this information, but this is certainly promising.

While little gains were seen in interest in general graduate studies, some have shifted their field of interest from general physics to specifically plasma physics. The sample size is small, but it stands to reason that an internship in the specific field of plasma physics would lead to increased interest in that field. Based on the pre- and post-surveys, nearly all planned to pursue advanced degrees upon entering the program, and they remained interested in graduate school after the program. We expect our continued research into this program to show a high rate of graduate school enrollment and persistence in the STEM workforce.

In the surveys for 2010-2013, there was a shift away from interest in becoming a professor. The nature of a research internship at a government lab allows for exposure to scientists and engineers who do not teach, who are not professors, but still do fundamental research. These factors contribute to a broadening sense of possibilities for those pursuing STEM careers. Interns are exposed to multiple career options for success in STEM fields. Within this cohort, several interns are in post-doc positions (7 of the 60 tracked students, 11.7%), and one did become a professor, but the large majority (42) found employment in STEM in other roles outside academia. Gould's Nature article also suggests alternatives to traditional PhDs, such as vocational PhDs, masters, or skipping graduate school altogether. Rather than the "PhD birth control" suggested by the economists in Gould's article and in addition to changes that would make a PhD more relevant in the non-academic workforce, PPPL's non-academic research internship model introduces students to options outside faculty positions.

Conclusions

Research internships such as that of PPPL provide valuable experience to undergraduates allowing them to develop their skills as scientists and as professionals. Such experiences also help young scientists make informed choices to pursue further study or enter the workforce. When they do choose to enter the workforce, they are open to career possibilities that are not limited to academia.

In a job market that has limited opportunities in academia, relatively steady government research and ever-increasing opportunities in independent companies, it makes sense for students to seek experience and exposure in varied career paths to increase their competitiveness. PPPL's alumni are completing graduate school and entering the STEM workforce. In future studies of more recent cohorts, we expect to see a continued shift away from academia and post-docs to reflect the job market. STEM students and workers would do well to gather as much knowledge and skills as they can to respond to the opportunities available to them. Research internships, such as PPPL's, are a key element in broadening horizons and providing necessary skills for success in STEM for students and a key element in developing the STEM and fusion workforce.

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Figure 1. Careers considered by interns, Pre- and Post-Survey, 2010-2013, pre- n=116, post- n=109

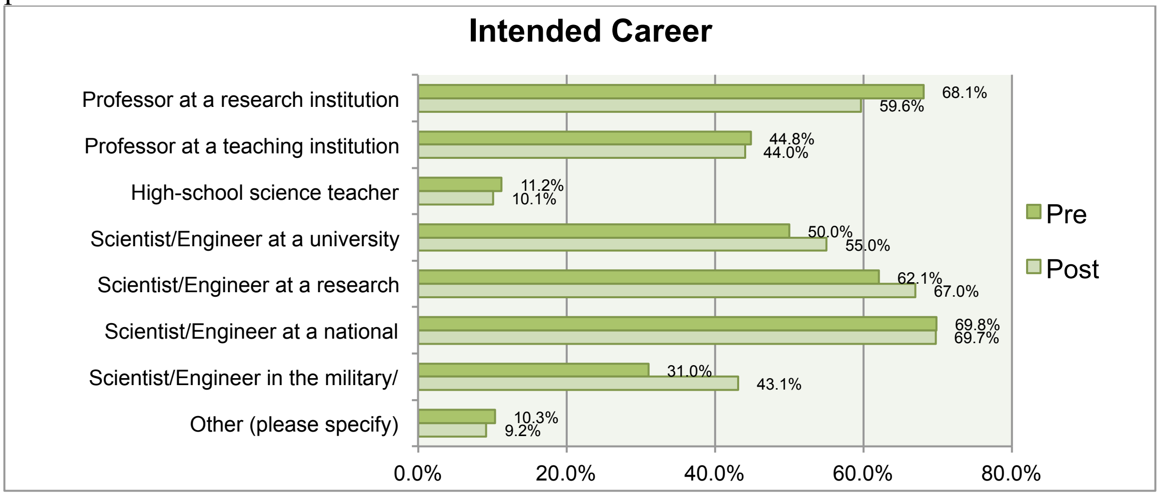


Figure 2. Fields considered by interns, Pre- and Post-Survey, 2010-2013, pre- n=116, post- n=109

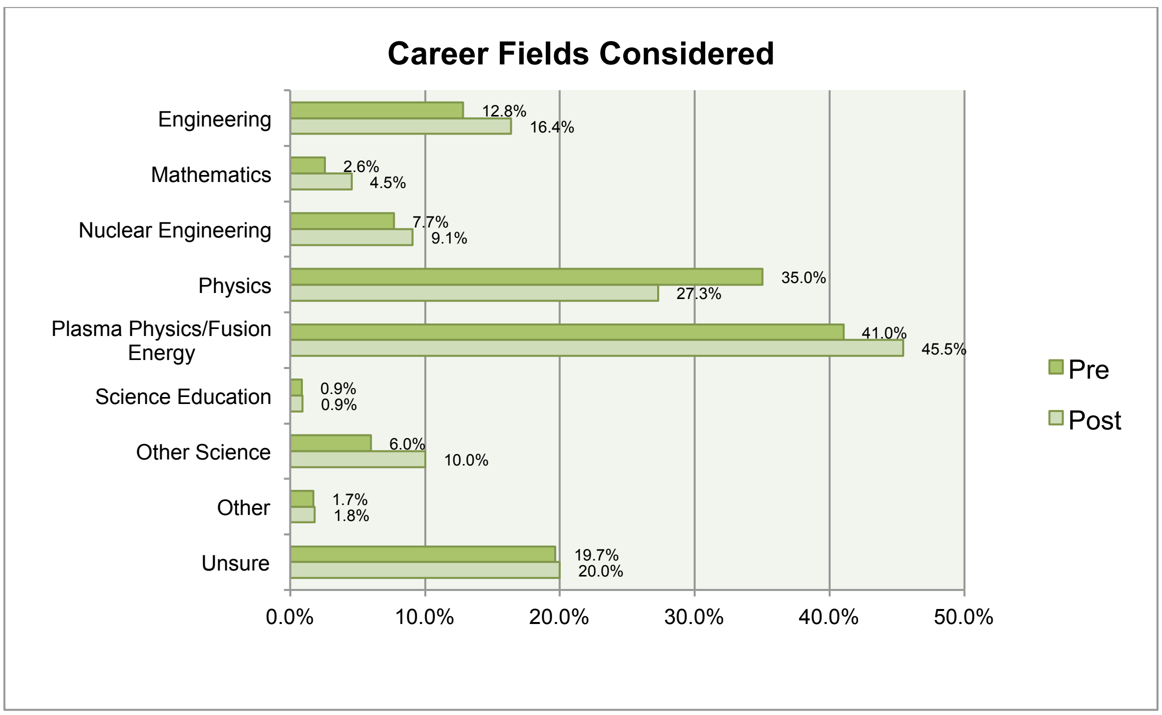


Figure 3. Tracked Students' Paths after Internship, n=60

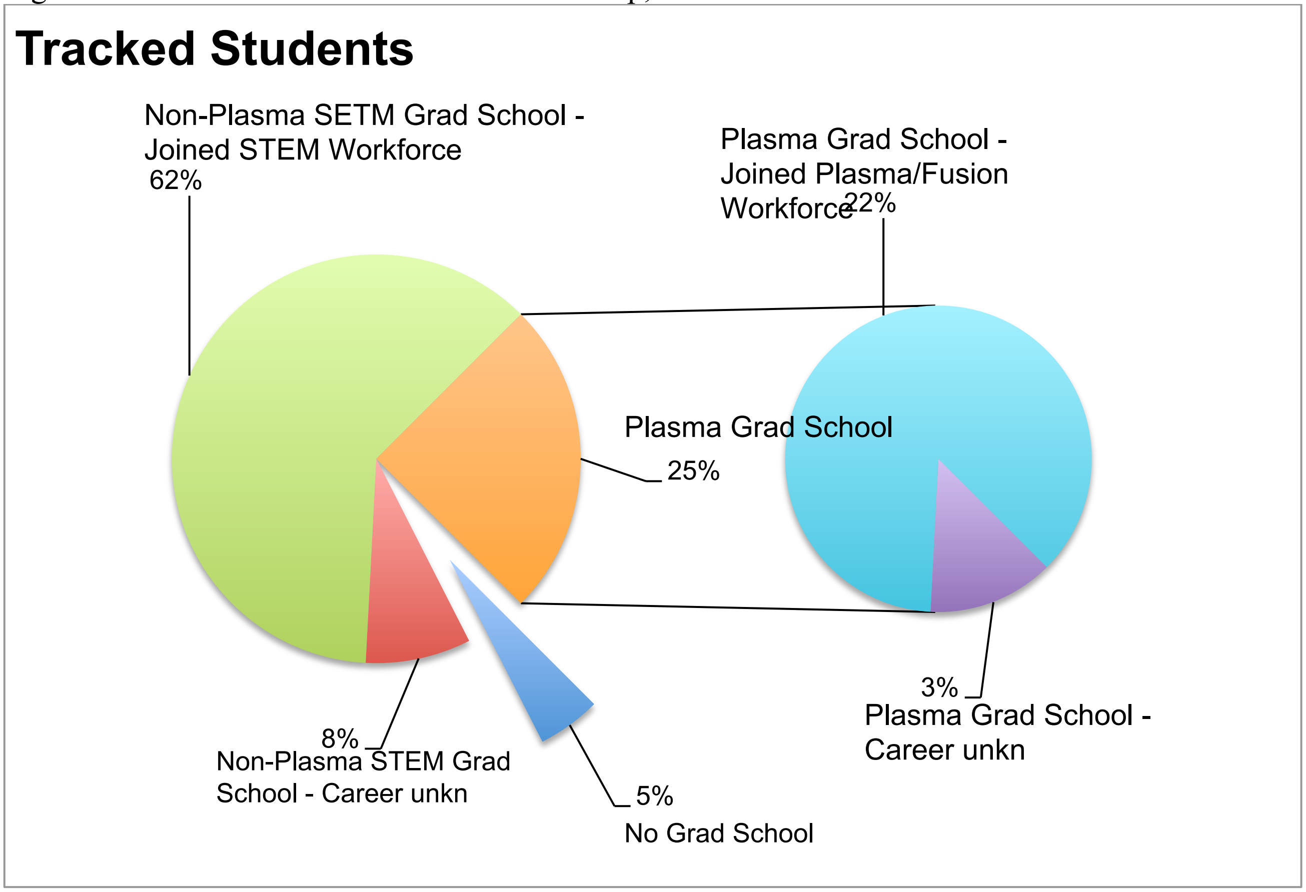
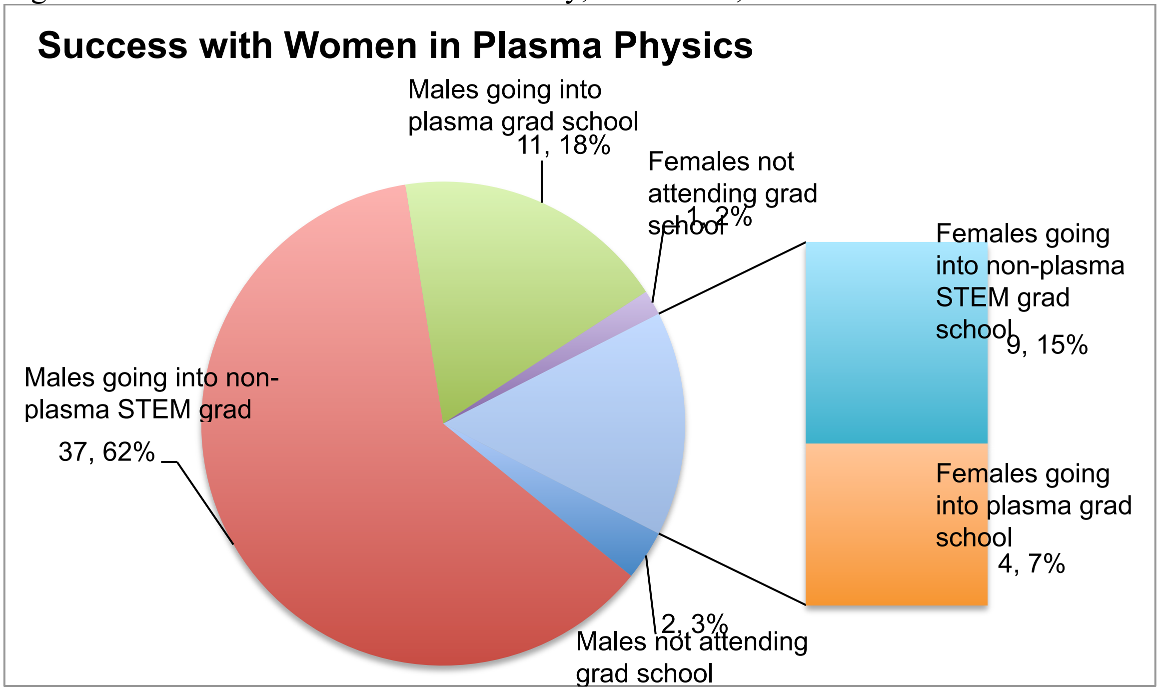


Figure 4. Women's Graduate Fields of Study, 2001-2005, n=60



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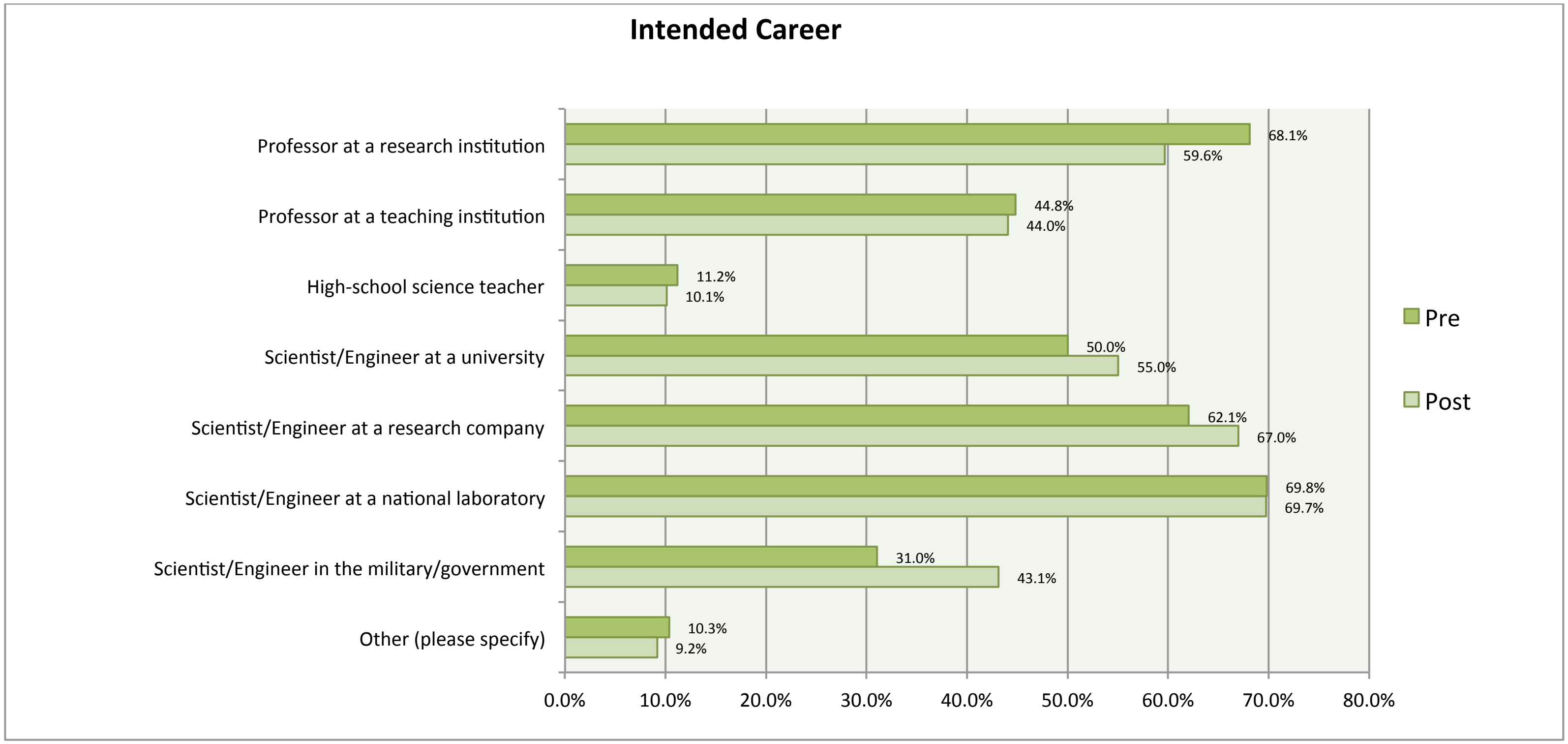

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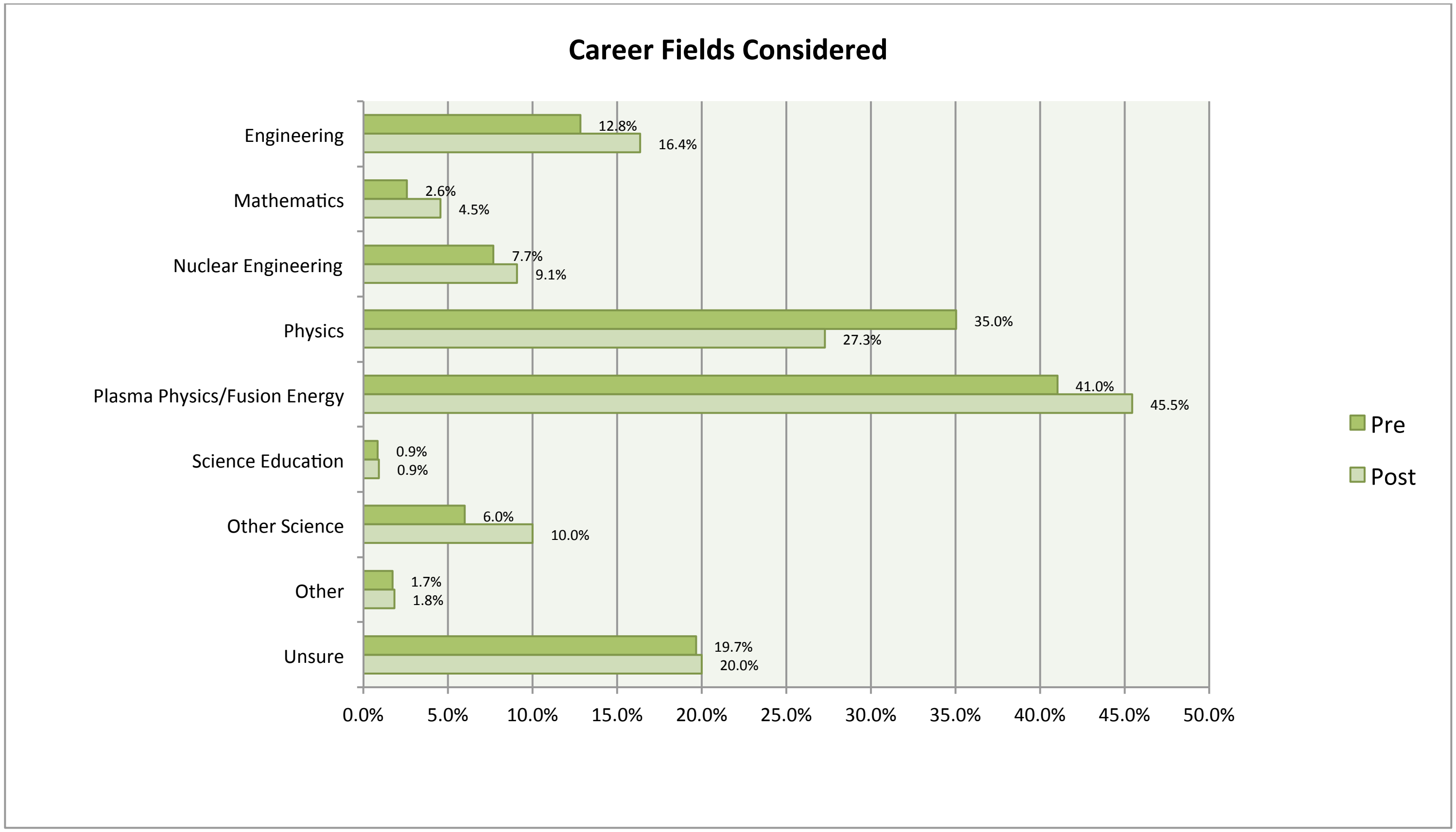

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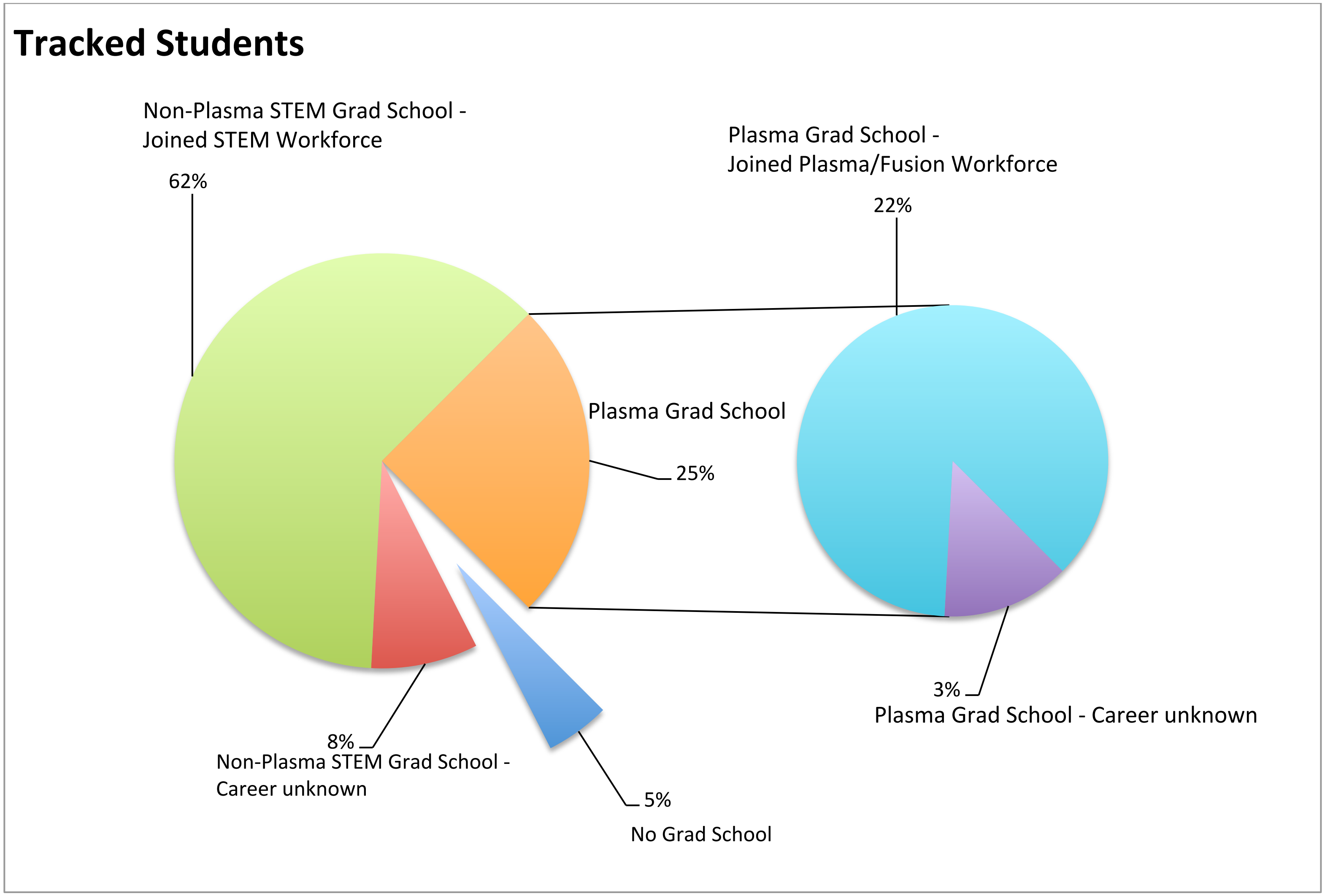

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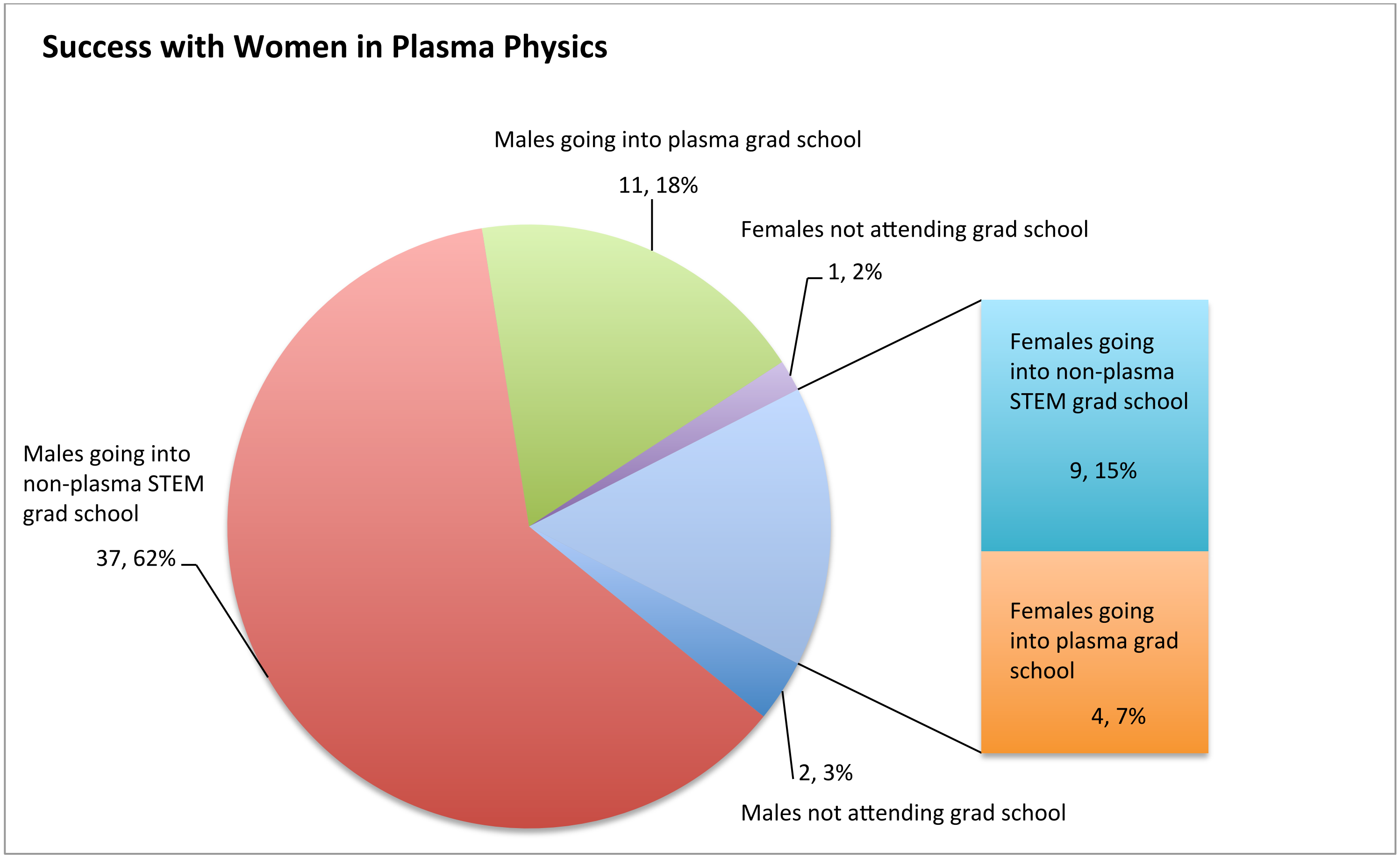

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