Building a Better Future STEM Faculty

How Teaching Development Programs Can Improve Undergraduate Education

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Executive Summary

The Longitudinal Study of Future STEM Scholars answered a question with implications for national efforts to improve undergraduate education: What are the short- and long-term effects of teaching development (TD) programs on doctoral students’ teaching-related skills, knowledge, attitudes, and career choices?

Using surveys and interviews, we followed a cohort of STEM dissertators (initial N = 3,060) from three research universities as they completed their degrees from 2009 to 2013. We examined students’ teaching experiences and TD participation during the doctoral program, their career pathways as long as five years after receiving their doctorates, and the short- and long-term effects of their participation in doctoral TD on their teaching knowledge, skills, and attitudes.

Here are ten key findings from our study.

1. Nearly all doctoral students (94.9%) taught undergraduates during their doctoral programs. Doctoral students spent the greatest amount of time as research mentors (median = 3 semesters), followed by their time in teaching/lab assistant positions (median = 2 semesters). Of all the graduate teaching roles we asked about, they spent the fewest semesters as instructors of record (median = 1.3 semesters).

2. TD programs at the three institutions we studied were diverse and offered by many campus units. We found 77 different TD programs and courses. Based on a literature review and these programs, we created a framework of 12 core features of TD programs.

3. Participation in TD was commonplace, as most (84.6%) doctoral students engaged in at least one formal activity during their degree program. Most respondents attended shorter activities like brief workshops and presentations. The four greatest barriers to participation were students’ lack of time, the perception that TD was a low priority, lack of awareness of TD offerings, and scheduling conflicts. Women participated at higher rates than men during doctoral training, a trend that continued into their postdoctoral appointments and early-career positions.

4. TD during the doctoral program had positive, significant effects for all participants, including those who do not take positions in academia after graduating. Engaging in a moderate amount of TD—one formal course, for example—or more had a significant impact on the short- and long-term outcomes we measured. TD engagement increased STEM doctoral students’ estimates of their teaching competence, bolstered their beliefs about their ability to perform as a college instructor, and increased their sense of community with their peers. Compared with their male counterparts, women benefitted more from their TD participation.

5. Participating in TD programs during the doctoral program had no effect on students’ time to degree completion, which was six years on average. However, actual teaching experiences did increase doctoral time to degree. This finding challenges a common belief held by many faculty that TD participation delays students’ timely progress to the doctorate.
6. **STEM doctoral students’ interest in teaching undergraduates increased during their training, especially among those interested in faculty careers.** More doctoral students (56.2%) were interested in teaching undergraduates at the end of their programs than at the beginning (43.9%).

7. **STEM Ph.D.s followed career pathways to a variety of positions in and outside of academia.** Five years after earning a doctorate, more than half (56.1%) of all STEM Ph.D.s in our study were working in postsecondary institutions. Most Ph.D.s moved immediately into postdoctoral scholar positions after completing their degrees (62.8% at the first year and 56.6% at the second year after receiving a doctorate); a smaller proportion remained in this type of position after five years (18.2%). Within one year of earning their doctorates, 9.3% of students had secured tenure-track positions; by the fifth year after completing their degrees, 23.0% of students were in tenure-track lines.

8. **Higher levels of TD engagement during the doctoral program were associated with getting a tenure-track or non-tenure-track faculty position.** After controlling for other factors, high TD engagement (more than 55 hours) significantly increased the likelihood of moving into a faculty position within five years after completing the Ph.D., regardless of whether the participant completed a postdoc appointment. Higher levels of teaching experience during the doctoral program were also positively associated with getting a faculty position within five years of receiving a doctorate.

9. **Nearly half of STEM Ph.D.s (45.5%) were in positions with undergraduate teaching responsibilities within five years of receiving their degrees.** Of this group, about half (46.6%) taught as instructors of record, one third (36.0%) served as research mentors, and one quarter (24.2%) were guest lecturers.

10. **For STEM Ph.D.s who taught undergraduates, higher levels of TD engagement during the doctoral program had positive effects on their self-efficacy beliefs and teaching practices after completing their degrees.** Although TD type (specifically, formal courses) had a long-term positive impact on Ph.D.s’ self-efficacy beliefs and teaching practices, its impact was mostly mediated by the higher levels of TD engagement. This finding is one of the first to identify long-term impacts for TD participation during the doctoral program.

**Recommendations**

Our findings have shown that TD engagement during the doctoral program is an effective way to prepare skilled STEM instructors. Because STEM Ph.D.s will teach undergraduates at more than 4,000 colleges and universities across the nation, investing time and resources in TD programming has great potential to transform undergraduate STEM education.

Getting people who are involved in doctoral education to take teaching development seriously remains a major hurdle, however. Overcoming faculty resistance and making teaching development a higher priority will require systemic change across national, institutional, departmental, and individual levels. To help stakeholders at all levels lower barriers to participating in doctoral TD, we offer recommendations for action based on our findings and previous research.

**National Stakeholders**

At a national level, research universities face external pressures from many sources: regulatory agencies, public and private funders, accreditors, peer institutions, employers, legislators, and the general public. Because external pressures can move universities to act, these stakeholder groups can influence whether and how universities provide more and better TD opportunities for future STEM faculty. We offer national stakeholders these change strategies:
• Fund initiatives and projects that create high-quality TD programs, reduce barriers to TD participation, and creatively address faculty resistance.

• Require federal research grant awards (namely, those from the National Science Foundation and the National Institutes for Health) that employ graduate students and postdoctoral scholars to include TD in their mentoring and professional development plans.

• Advocate for national policy that elevates the importance of high-quality undergraduate instruction in STEM courses.

• Facilitate discussion among stakeholder groups about the importance of TD to faculty careers and improved undergraduate education.

• Advance lines of research on TD programs and participants that expand our understanding of how future faculty develop as effective teachers.

**College and University Administrators**

Presidents, provosts, deans, and other administrators shape the vision and mission of the institution, establish institutional policy, and distribute funding. This stakeholder group should acknowledge, support, and advocate for doctoral TD programs and initiatives. To this end, we recommend the following actions:

• Provide sufficient funding and support for doctoral TD programs and initiatives on campus.

• Facilitate campus-wide discussions about the importance of doctoral TD for graduate student professional development and undergraduate education.

• Collect and publish data from doctoral students about career interests, experiences, and eventual placements.

• Seek changes across the institution related to faculty reward structures and the adoption of effective teaching strategies.

• Create a map of campus-wide TD programs, organized by key features such as duration, intended audience, and expected learning outcomes.

**Teaching Development Providers**

Multiple campus units (e.g., graduate school, teaching and learning center, departments) provide TD programming to doctoral students and thus play a crucial role in the development of future STEM faculty. Given TD’s positive effects on doctoral students, it should be a priority to lower barriers to students’ participation. Based upon our findings, we offer the following recommendations:

• Increase awareness of TD opportunities through advertising and outreach.

• Offer multiple modalities of TD.

• Gather more and better data about participant experiences and outcomes—and use it for improvement.

• Coordinate TD offerings for stronger and broader impact on doctoral students.

**Department Chairs and Faculty**

Academic departments—where disciplinary and institutional cultures intersect—arguably have the greatest influence on doctoral students’ participation in TD. Our study found that the research-focused culture of departments may prevent doctoral students from engaging in enough TD activities to gain significant, positive, and lasting gains. Negative attitudes about teaching—especially its importance
relative to research—can be a barrier to students’ participation in TD. To foster department cultures that truly value the formation of future STEM instructors, faculty members and chairs must assess and change their practices, processes, and values. We recommend the following actions:

**Department chairs can...**

- Encourage discussions of teaching development during doctoral student orientations and in students’ individual program planning.
- Consider adding a required teaching seminar to the formal doctoral curriculum, perhaps in collaboration with a TD program.
- Provide opportunities to discuss teaching and learning from a disciplinary perspective.
- Reward and recognize effective teaching.
- Encourage faculty and advanced doctoral students to open their classrooms for students to observe effective teaching.
- Include periodic reporting on doctoral teaching development and experience in faculty meetings.
- Provide students with ample career planning information and opportunities.

**Faculty advisors can...**

- Communicate with students about teaching and its place in various types of faculty careers.
- Allow students to have time to participate in TD without fear of shame or reprisals.
- Help students integrate their research and teaching in mutually supportive ways to avoid TD being seen as only preparing graduate students for positions at non-research universities.
- Support students who are seeking community among others who have an interest in teaching.
- Help students gain access to authentic teaching experiences, especially as an instructor of record.
- Set a good example by supporting teaching and learning.

**Doctoral Students**

As our study showed, doctoral students greatly benefit from TD participation; they apply knowledge, skills, and attitudes gained from TD to undergraduate STEM courses. Their reasons for participating in TD are both intrinsic and instrumental. Yet, too few doctoral students participate in enough TD activities to enjoy their significant benefits. Here are some suggestions to increase doctoral students’ TD engagement and outcomes:

- Communicate with faculty members, especially your advisor, about the role of teaching and TD in your career development.
- Participate in TD programs and teaching activities that allow you to learn about, practice, and reflect on undergraduate instruction.
- Find or create a community of like-minded peers and faculty members who work toward improving teaching.
Preparing current and future faculty more effectively as undergraduate instructors is a crucial catalyst for improving undergraduate STEM education at the national level.
Overview:
The Longitudinal Study of Future STEM Scholars

“Teaching is not a lost art, but the regard for it is a lost tradition.”
-Jacques Barzun (1907-2012), American scholar, historian, critic, and teacher

Improving undergraduate education in science, technology, engineering, and mathematics (STEM) fields is a national imperative. STEM degree recipients hired into both STEM and non-STEM jobs help maintain the health, safety, and economic well-being of the nation. Preparing well-qualified graduates to fulfill these roles is therefore essential. Equally important is developing a competent, scientifically literate citizenry that can apply analytical reasoning, communicate effectively, demonstrate cultural competence, and engage in life-long learning. These essential skills are enhanced by high-quality STEM education, especially at the introductory course level.1

To retain and graduate more students who are ready to enter the STEM workforce, we must improve undergraduate teaching in STEM fields. Poor teaching is one of the biggest reasons why students leave STEM degree programs, and even some who complete STEM degrees may not gain deep understanding of fundamental concepts, inquiry skills, attitudes toward learning, and critical thinking skills needed to succeed in their programs and fields.2 Not surprisingly, when the President’s Council of Advisors on Science and Technology called for one million additional STEM Ph.D.s, one of its top policy recommendations was to train college instructors in the use of proven teaching methods for lack of time, training, support, and incentives.3

The preparation of many STEM college teachers starts during their doctoral training. Introducing doctoral students to sound teaching practices early in their career is key to their making teaching a professional priority. Even though one of every three STEM Ph.D.s will be teaching undergraduates within six years of completing their doctorates,4 doctoral students are often expected—especially at the most elite research universities—to focus intensively on their research and ignore other aspects of academic career preparation.5 As a result, it can be difficult for doctoral students with faculty aspirations to learn about the science of effective college teaching.

Over the past two decades, U.S. research universities have started programs to provide professional development in college teaching—what we call teaching development (TD). TD programs help doctoral students develop the knowledge, skills, and attitudes needed to teach undergraduates effectively. In addition, national initiatives to improve undergraduate STEM education—such as the Association of American Universities Undergraduate STEM Initiative, the Association of American Colleges and Universities’ Coalition for the Reform of Undergraduate STEM Education, and the Center for the Integration of Research, Teaching and Learning Network—have
made teaching development a central strategy for achieving systemic change.8

TD programs are growing in number and in importance. Yet there is limited research on how TD programs affect doctoral students’ preparation as college instructors. University administrators, funders, future faculty, and their graduate advisors have lacked evidence that these programs enhance traditional doctoral training, improve participants’ career options, or enhance their performance as early-career academics. The absence of evidence for TD programs’ impact may affect not only doctoral students’ interest in these programs but whether the programs are sustainable. For TD programs to play a major role in national STEM reform, we need to understand their effects on STEM doctoral students, and ultimately to determine whether future faculty gain the kind of teaching skills that will improve undergraduate STEM education.

The Longitudinal Study of Future STEM Scholars

The Longitudinal Study of Future STEM Scholars (LSFSS) was the first national project to explore the short- and long-term impacts of teaching development on key outcomes related to doctoral education and the formation of future faculty. With generous support from the National Science Foundation’s Division of Undergraduate Education, our seven-year study (2008-2015) examined an important but understudied intersection of undergraduate and graduate education: the preparation of future STEM faculty during doctoral training for their pivotal role as teachers and mentors of undergraduates.

Study Methods

Using mixed methods, we followed a group of early-career academics (initial N = 3,060) who in 2009 were late-stage doctoral students in STEM departments at three U.S. research-intensive universities: Arizona State University, the University of Washington–Seattle, and the University of Wisconsin–Madison. These institutions award a significant number of doctoral degrees each year, maintain a high level of research activity, have large doctoral student populations, and support a variety of future faculty professional development programs. Nationally, 108 universities with the Carnegie classification of very high research activity—including the three in the study—produce 74% of the Ph.D.s who eventually serve as the STEM faculty at all undergraduate institutions, dispersing among more than 4,000 research universities, comprehensive universities, liberal arts colleges, and community colleges.9

At four points during five years, we used surveys and interviews to collect information from our participants (see Figure 1). Appendix A describes the study’s methods and participant characteristics.

Organization of the Report

This report describes the experiences of doctoral students who reached the dissertation stage, completed their degrees, and moved into careers. Using our survey data and select quotations from interviews, we present doctoral students’ interest and readiness to teach undergraduates, and the influence of TD participation on their teaching knowledge, skills, and attitudes. In this report, we first examine the career goals of STEM doctoral students when they entered their degree programs and when they reached dissertator status. Although STEM Ph.D.s can assume various professional roles, we focus on study participants with academic aspirations and an interest in teaching undergraduates.
Second, we discuss the teaching experiences of STEM doctoral students during their degree programs. We report how much they taught and the type of instructional roles they took.

Third, we describe the kinds of TD programs available to STEM doctoral students in our study. We present an exploratory classification scheme for organizing and analyzing TD programs, developed by this study to define critical elements of TD programs that contribute to doctoral students’ formation as instructors.

Fourth, we assess STEM doctoral students’ participation and engagement in TD programs. We examine the amount of participation during the doctoral program and in which types of TD activities. We also explain the factors that encouraged and discouraged doctoral students’ participation in TD.

Fifth, we describe the short-term outcomes of TD participation during the doctoral program for all STEM doctoral students. We analyze the impact of different levels of TD engagement on students’ teaching, research, and general professional competencies, and on their beliefs in their ability to teach college students.

Sixth, we describe the early-career pathways of STEM doctorate recipients and assess the extent to which TD influenced the types of jobs they took. We also identify the proportion of STEM Ph.D.s who teach undergraduates, their institutional types, and their teaching roles.

Seventh, we describe the long-term effects of TD participation during the doctoral program on those who received their degrees early in the study (2009 and 2010) and many of whom, in 2013, were working in positions with undergraduate teaching responsibilities.

Finally, we summarize the study’s core findings and offer specific recommendations for stakeholders at national, institutional, departmental, and individual levels.
STEM doctoral students’ interest in teaching undergraduates increased during their training, especially among those pursuing faculty careers.
STEM Doctoral Students’ Career Goals and Interest in Teaching

A person’s interests—that is, one’s likes, dislikes, or indifferences—are important factors in career decision-making. People develop stronger interests in certain kinds of work, like teaching, when they are confident in their ability to do that work and believe their efforts will produce positive professional and personal outcomes. As people become more interested in a particular kind of work, they aspire to careers that will let them engage in that kind of work; for example, people interested in college teaching often consider faculty careers. As people develop career goals around their interests, they usually take steps toward the kind of job they want, such as pursuing professional development activities or practicing their teaching. Interests, therefore, are a significant influence on career-related choices and behaviors.

Our study examined doctoral students’ interest in teaching undergraduates and in academic careers. We hypothesized that students’ interest in teaching undergraduates would influence three things: (1) the kinds of positions they pursued after graduation, such as faculty jobs; (2) the actions they would take to pursue these positions, such as participation in TD; and (3) the amount of TD they engaged in during the doctoral program. Here are our findings.

Many, but not all, STEM doctoral students aspire to faculty careers.

The 2001 foundational study At Cross Purposes found most doctoral students wanted faculty careers. Our data suggest that this interest is still strong. When we asked students to name their primary career goal at the beginning of their doctoral program, about half (53.3%) planned on a faculty career at a college or university, while a quarter (26.4%) planned on a research career in industry or government. While there were no significant differences in academic career aspirations by gender or race/ethnicity, there were differences by discipline. Beginning doctoral students from psychology and the social sciences were more likely to aspire to a faculty career than nearly every other disciplinary group. Beginning engineering students were significantly less likely to want faculty careers than life science or physical science students; given the wider array of opportunities in industry and government for engineering Ph.D.s, these results are not surprising.

As students neared the end of their doctoral programs, the majority still planned to pursue faculty jobs (55.4%), and a substantial proportion (25.0%) were unsure. Although there were still disciplinary differences in faculty careers at this stage, new gender differences appeared (see Figure 2). Female dissertators were less likely to pursue faculty positions than male dissertators, which is consistent with other studies of graduate students’ career goals.

These differences in career goals reflect the continued challenge of achieving gender equity in the professoriate. While we cannot point to a clear cause for the change in career goals for female doctoral students in our study, prior research shows that women’s career goals and professional
persistence are negatively affected by a lack of female role models or mentors, insufficient support, unwritten rules, and a lack of work-life balance.¹⁴ Later, this report will show that women experience their doctoral programs, teaching roles, and TD participation differently than men—differences that may influence women’s early-career choices and pathways.

**Doctoral students were interested in faculty careers in order to do research and teach.**

Interview participants said they decided to pursue a doctorate and eventually a faculty career for various reasons, including the opportunity to conduct research. Most participants said an interest in teaching was a secondary reason for pursuing a doctorate and considering a faculty career, with research being the main driver of their career choices. Others said that teaching was the primary kind of work they wanted in their careers. For example, some had powerful learning experiences at liberal arts colleges and thus wanted to teach at similar institutions. Other interviewees who felt a strong interest in teaching undergraduates were encouraged by their faculty advisors to attend graduate school to follow that interest. One participant explained he hoped to contribute to society through his teaching.

I was approached by faculty who let me know that I was doing OK, and there were opportunities for me. They encouraged me to think about being a faculty member that can in turn help other people. If I cannot provide psychological or counseling services to many people, at least I can bring some impact to society by training quality counselors. *(Asian male in psychology tenure-track faculty position)*
Another interview participant expressed a strong interest in being an exceptionally good undergraduate teacher.

I think when I started grad school I was excited about teaching, and so I was excited about learning how to be a good teacher. I think a lot of people go to grad school and are really only interested in the research and don’t care about teaching at all, and therefore don’t actually try to be good teachers, but I really wanted to learn how to be a good teacher. I think I wanted to take advantage of all the opportunities that I had in order to do that. *(White female in physical sciences research position)*

**More STEM doctoral students became interested in undergraduate teaching as they moved through their programs, especially those who aspired to faculty careers.**

About one third (34.9%) of survey respondents were very or extremely interested in teaching undergraduates at the beginning of their doctoral programs. More students became interested in teaching undergraduates as they advanced through their doctoral programs (40.6%). Among students with faculty aspirations, more of them grew interested in undergraduate teaching as they advanced through their doctoral program (43.9% at the beginning of their programs; 56.2% by the time they were dissertators or very recent graduates).

**Summary**

These findings show that as STEM doctoral students moved through their programs, interest in teaching undergraduates and in faculty positions developed alongside one another.
Almost all STEM doctoral students taught undergraduates. Teaching experience helped doctoral students identify their strengths as instructors.
Teaching Experience during the Doctoral Program

Even though our study focused primarily on the effects of TD, we also explored participants’ teaching experiences for two reasons. First, learning about teaching and authentic teaching experiences are both important to the teaching improvement process. Second, early work experiences have significant and long-lasting effects on career pathways.\textsuperscript{15} Many faculty members first teach undergraduates while working as a teaching assistant (TA). Thus, we included our participants’ teaching experience as we examined TD effects and career choices. Specifically, we asked our survey respondents about the type and amount of undergraduate teaching they performed during their doctoral programs, and about the outcomes they achieved from those experiences.

We also explored interview participants’ teaching during the doctoral program in two ways. First, we asked those who were new Ph.D.s how ready they felt to move into jobs that included teaching responsibilities, and what supported that readiness: teaching experience, TD participation, or both. Second, we asked participants whether they had intended at the start of their doctoral programs to include teaching as a major part of their professional life, and whether their career goals and interest in teaching had changed over time. Our findings about doctoral students’ teaching experiences follow.

Almost all STEM doctoral students taught undergraduates.

At some time during doctoral training, nearly all (94.9\%) STEM doctoral students taught undergraduates, and about half (45.5\%) of doctoral students also taught graduate students. Doctoral students taught undergraduates by serving in a variety of instructional roles—not only as teaching assistants, but also as research mentors, guest lecturers, lab assistants, and instructors of record (see Figure 3). Most participants in our study therefore had an opportunity to gain teaching knowledge and skills from an authentic teaching experience.

Instructional roles varied by gender, race, and citizenship.

Female doctoral students served as undergraduates’ research mentors more often than did male doctoral students (59.7\% women vs. 52.3\% men). In contrast, women were less likely than men to serve as guest lecturers in courses for graduate students (33.7\% vs. 41.9\%) and as instructors of record for courses enrolling both undergraduate and graduate students (13.6\% vs. 25.7\%). There were also differences by race and by citizenship status: temporary visa holders were significantly less likely than White doctoral students from the United States to serve as instructors of record (20.1\% vs. 31.9\%), research mentors (27.2\% vs. 51.4\%), or guest lecturers (27.6 vs. 48.9\%).

These graduate teaching roles require different levels of responsibility, which may have implications for job searching and career pathways. Students who serve as instructor of record can better demonstrate their teaching experience in job application packages than students in roles with less responsibility. Because some groups (e.g., women) are more likely to hold teaching assignments with less responsibility, they may be at a disadvantage in academic hiring.\textsuperscript{16}
STEM doctoral students spent considerable time in teaching roles.

We hypothesized that the time doctoral students spend teaching would influence their career choices, confidence in teaching, and teaching performance. The graduate teaching jobs that doctoral students take require different levels of time, knowledge, and skills. For example, instructors of record, who are responsible for an entire course, would invest more in their teaching role in a single semester than would a student who served as a grader with little or no interaction with undergraduate students. To construct a measure of time spent teaching, we therefore used a weighting scheme to assign more time and responsibility to some roles than others: teaching assistant = 2; lab assistant = 2; instructor of record = 4; research mentor = 0.5; other teaching role = 1.5. The weighted semester for guest lecturers was calculated by using the number of times a doctoral student served in this role rather than the number of semesters.

During their degree programs, STEM doctoral students taught an average of 13.5 cumulative weighted semesters. This average is comparable to serving 2 semesters as a teaching assistant, 1 semester as a lab assistant, 1 semester as an instructor of record, 4 semesters as a research mentor, and one semester in another teaching role, all across an average of six years of study. Note that doctoral students could have taught in more than one role in a given semester (for example, serving as an instructor of record and as a research mentor), which was frequently the case in our study. Figure 4 shows the distribution of doctoral students’ weighted semesters of teaching undergraduates during their programs.

Figure 5 shows the actual (unweighted) number of semesters that doctoral students taught in each teaching position. Doctoral students reported spending the greatest amount of time as research mentors to undergraduates (median = 3 semesters), followed by their time in teaching assistant and lab assistant positions (median = 2 semesters in each role). Of all the graduate teaching roles we asked about, they spent the fewest semesters as instructors of record (median = 1.3 semesters). Students served as guest lecturers an average of 3.9 times (median = 3 times) during their doctoral programs.

As the next section explains, these teaching experiences yielded different results for students, depending on their success in the classroom and their career goals.
Figure 4: Cumulative Weighted Semesters Teaching Undergraduates during the Doctoral Program

1-5 Semesters: 27.3%
6-10 Semesters: 10.5%
11-15 Semesters: 15.5%
16-20 Semesters: 25.0%
21-25 Semesters: 7.6%
26+ Semesters: 14.1%

Figure 5: Mean and Median Number of Semesters in Various Teaching Roles during the Doctoral Program

- Teaching Assistant: Mean 3.5, Median 3.5
- Lab Assistant: Mean 3.0, Median 3.0
- Instructor of Record: Mean 2.0, Median 2.0
- Research Mentor: Mean 4.0, Median 4.0
- Other Teaching Role: Mean 2.5, Median 2.5

Mean Semesters: Blue
Median Semesters: Orange
Teaching experience gave doctoral students an opportunity to identify their strengths as instructors.

One study participant observed that, ultimately, there was no better preparation for teaching in their future roles than actual teaching experience. Or, as she said,

There’s really no substitute for just shoving you in a classroom. (White female in a physical sciences postdoctoral scholar position)

Another interview participant who taught during his doctoral program said he gained a sense of satisfaction working with struggling students.

I really enjoyed teaching, and I discovered that as an undergraduate being a TA in a physical geography lab. I found a lot of enjoyment out of that and so it was one aspect of academia, besides getting the degree, that I actually really looked forward to. I felt I had previous experiences as an undergraduate, feeling very successful in taking students from whatever level they were coming in at and really moving them significantly to a different level. I was very successful at working with students—particularly those that were underperforming or giving a very mediocre performance—and teaching in a different way or spending additional interpersonal time with them, helping them advance. I got a lot of satisfaction from doing that—not just teaching, but actually working with students, particularly those who needed to improve in their performance. (White male in social science non-tenure-track position)

Similarly, another interviewee explained that he enjoyed his teaching experience during the doctoral program and its positive social outcomes.

At first I was really nervous to do it, but once you get going it turns out to be pretty fun and pretty rewarding. You know, if you feel like you can get people excited about something, that’s pretty fun. I really enjoyed it [even though] I thought that I wouldn’t want to devote time to it. But then, maybe there’s something about the fact that you’re doing something maybe for the greater good. (White male in physical sciences postdoctoral scholar position)

However, not all STEM doctoral students felt prepared when they began teaching. On entering the classroom, one interview participant found that she was not prepared to teach, and felt that the initial approaches she used were not successful for her students.

The first quarter that I taught went fairly poorly. I ended up being fairly scattered and just coming into class and saying, “Okay, I studied the material, do you guys have questions?” And it was unstructured and it didn’t really work very well. (White female in a physical sciences postdoctoral scholar position)

These findings suggest that authentic teaching experiences allowed doctoral students to make initial judgments about their teaching capability. In the next section, we explore how different teaching roles prepared students for their future teaching responsibilities.

Doctoral students gained more confidence and skills from teaching roles with greater responsibility.

Several interview participants said that entry-level teaching, such as in a TA position, did not always help them gain skills or experience needed to teach as a faculty member. For example, one participant felt that her TA position was focused on preparing instructional materials and did not offer any challenging teaching experiences. She contrasted her work as a TA with later positions that did offer practice in teaching.

What really helped was actually having a job beyond a TA position, because the TA position is a little bit different. Where a lot of times you’re doing the grunt work, like doing
the research or doing the research reviews for whatever the class is, or preparing the slides. I mean, those are helpful, but a lot of times it’s not mentored in a formal way. It’s more like, “I need a TA. I’m going to advertise for it. You’re going to accept, and you’re going do 20 hours a week. And here’s what I want you to do.” It wasn’t like, “Oh, here’s how to do a literature review for a course. Here’s how to develop a syllabus.” You know, it’s not like that in the TA world. (Multiracial female in mathematics non-tenure-track position)

Another interview participant agreed, explaining that TA positions alone did not offer enough hands-on experience teaching in a classroom.

My friend and I, in graduate school, we decided we really wanted a teaching opportunity. And we didn’t want to just TA. Especially in psychology there’s actually, at least when I left, and certainly mid-way through my graduate career, there was no way that a psychology graduate student could get experience teaching psychology. So, you could be a TA in a psychology course. But then you would just be essentially a grader and hold office hours. And maybe if you were lucky you could give a guest lecture or two. But any class that you TAed that you had section for they were statistics and research methods. And so you never actually got the opportunity to teach psychological content. (Asian female in social sciences researcher position)

Another interviewee explained that the teaching experience gained from running a lab was not sufficient to gain the skills needed to lead a class independently.

To be honest, there’s this gap between graduate teaching experiences and what you’re expected to do as a young faculty member. Which is to actually run the course, build a syllabus, you know? Come up with lectures. And there’s very little training for that in your graduate teaching experience. Often times you’re just running laboratory sessions where a lot of the stuff is handed to you. It’s a bit daunting I think. I think it’s a shortcoming of the doctoral system that it’s largely research in a vacuum with kind of little in the way of teaching training. (White male in biological sciences tenure-track position)

Finally, another interview participant explained that having less teaching experience as a result of being a TA or lab assistant made it harder to compete for some jobs.

I definitely think that’s a big thing that [the school] needs to look at. To be competitive [faculty] have to give their students the opportunity to have that solo instructor [status]. (White male in mathematical sciences tenure-track position)

These findings are similar to research that found that doctoral students’ teaching experiences varied significantly in building teaching skills and in preparing doctoral students’ as faculty members. Students who taught only in TA or lab assistant positions discovered that those roles did not adequately prepare them for teaching on their own.

Teaching experiences strengthened some STEM doctoral students’ pursuit of faculty positions with teaching responsibilities.

We found that teaching experience during the doctoral program had different effects on study participants’ interest in pursuing a faculty position after graduation: it (1) lowered their bias against faculty teaching jobs, (2) confirmed their interest in faculty teaching jobs, or (3) discouraged their pursuit of faculty teaching jobs.

For some participants who had initially entered a doctoral program to pursue a research career, teaching experience prompted them to take teaching seriously and to include it in their academic careers. One interview participant said he became more receptive to teaching responsibilities.
For the most part, I've focused on academic or research jobs, and the kind of the balance of what I was looking for. That was affected a little bit and, as I said, I [became] more open towards the teaching parts. *(White male in physical sciences postdoctoral scholar position)*

Another interviewee shared that she was no longer interested in positions that would include only research responsibilities and exclude teaching opportunities.

I used to think about that. But after mentoring graduate students in the lab and teaching undergraduate students in the class, I think to have a position responsible for both teaching and research is not bad. *(Asian female in health fields tenure-track faculty position)*

Finally, one interview participant shared that while he had entered graduate school to earn a doctoral degree and pursue a research career, he enjoyed his teaching experiences so much that he incorporated teaching in his career plans.

Teaching wasn't what I went into the program to do, but I certainly grew to enjoy it as I experienced it in the program. I really enjoyed working with the students and so that became part of what I wanted to be able to continue to be able to do. I say it definitely having not done a lot of teaching before coming to graduate school, it made me really want to teach. *(White male in engineering tenure-track faculty position)*

For some of those who entered graduate school with previous experience or interest in faculty positions with undergraduate teaching opportunities, experiences during the doctoral program strengthened their interest and confidence in pursuing such a career path. In just one of many examples, an interview participant shared that academic positions with teaching responsibilities were personally and professionally gratifying, feelings that were confirmed when teaching during the doctoral program.

Teaching was a key component in my satisfaction in graduate school and, to be honest, it's been one of the reasons I've been eager to move past the post-doctoral phase. I find ‘research only’ careers or positions set me personally adrift a bit. I find that teaching and community outreach really ground my sense of the importance of what I'm doing and also give me a sense of being involved in something bigger or something relevant to the community that I'm in. And I guess it's probably my personal history and my upbringing that really make me expect that from my surroundings and my career. But I grow quickly tired of being a solo researcher, you know? Working alone at a lab bench with the distant hope of some kind of international applause when I discover something fascinating and new. I mean, I'm certainly motivated to do that. But for me it lacks context without these types of involvement. *(White male in biological sciences tenure-track faculty position)*

Not all STEM doctoral students increased their interest in faculty positions after they taught, however. Some lost interest after seeing how much effort that teaching well required. This feeling was exemplified by one interview participant who described not just the difficulty of balancing teaching and research responsibilities as a doctoral student, but also the realities of a heavy workload for teaching-focused faculty positions.

Actually, in the course of taking a class on preparing my teaching portfolio, my project, and my interviews, I had a couple of people who were professors at teaching colleges. The project was that I wanted to see what it was more about, what it was like in those jobs. Their responses were that they didn't really have more free time than professors at research institutions. They just spent more of their time teaching lessons than attempting research but it was still a pretty overwhelming kind of career. They were happy doing it, but I decided that that wasn't really what I wanted to do either. It definitely had a big impression on
The more I thought about my teaching philosophy and the practicalities of having a very teaching heavy job, I sort of realized that that’s not actually what I want to do. (White female in physical sciences researcher position)

These findings show that as STEM doctoral students engaged in authentic undergraduate teaching, they assessed their interest in pursuing faculty positions which they based not only on their confidence in their ability to perform as instructors, but also on what they expected to gain from that work.

**Summary**

As these findings show, most doctoral students taught undergraduate students—most often while serving as a teaching assistant, but also in other instructional roles such as research mentor, guest lecturer, and instructor of record. These teaching experiences gave doctoral students the opportunity to identify strengths, build skills, gain confidence, and re-evaluate their interest in academic positions that focus on undergraduate education.

In the sections that follow, we describe the TD programs that were available to doctoral students to address these needs. We will then present doctoral students’ participation in these programs and identify factors that both supported and constrained their participation. Several of the themes identified in this section—study participants’ recognition of a gap in their teaching capabilities and a lack of readiness for faculty positions—will reemerge as prominent influences on their choice to participate.
After identifying 77 TD programs from three participating institutions, we created a framework describing the core features of TD programs.
Teaching Development Programs for STEM Doctoral Students

The empirical research on doctoral TD is fairly meager. Previous attempts to categorize doctoral TD activities are usually studies of TA training. We lack solid evidence of the relationship (if any) between type of TD programs and what doctoral students gain from participation. In other words, are different types of TD associated with different outcomes? The Longitudinal Study of Future STEM Scholars was designed to address this gap.

Early in our study, we realized that to examine the effects of TD participation on STEM doctoral students, we had to first identify the TD programs at each of the three participating universities. In early 2009, we collected program information in three ways. We started with a tentative list of TD programs created for a related project. After verifying which of those programs were still active, we conducted a systematic search for additional TD programs on the web sites of possible campus sponsors, such as STEM departments. Finally, we conducted face-to-face interviews with program heads and institutional administrators, who provided web pages, handbooks, study summaries, and literature on other TD programs. Using a database to organize our information, we identified 77 active or recently active TD programs at participating institutions.

TD programs were diverse and offered independently by many campus units. Although one-day, compulsory workshops for teaching assistants were common, we found that TD programs for doctoral students included far more than TA workshops. Some programs took the form of short workshops, webinars, or podcasts, whereas others were quite intensive. For example, each institution offered for-credit courses in teaching for doctoral students; some courses were arranged in a sequence intended to create a sustained professional development experience. Two of the three institutions also offered summer institutes lasting at least one week. Some programs gave students the opportunity to practice and refine their teaching skills.

In this early stage of our study, we learned that there was no single type or source of TD program for doctoral students; TD programs not only came in many shapes and sizes, but they were often sponsored by different university units, such as the graduate school, provost’s office, departments, colleges, and teaching and learning centers. A few programs were unknown to the graduate school—for example, a small Preparing Future Faculty (PFF) program that a department’s faculty quietly sustained even after the national PFF initiative that spawned it had ended. Since no institutions’ TD programs were centrally coordinated, just locating them was an unexpected challenge.

Studying TD programs required a new classification scheme. As the study proceeded, we discovered that comparing TD programs was difficult because there was no existing way to classify or organize them—for example, according to program features...
that might contribute to doctoral students’ teaching development. Without a common framework to discuss the major TD program components, it was difficult to make meaningful cross-program comparisons, both within and between institutions.

To address these concerns and to advance efforts to classify, design and evaluate TD programs, we developed a framework of 12 important TD program features. This framework was based on an analysis of the 77 programs we identified and on a literature review that included research on K-12 teacher professional development programs.21

As Table 1 shows, we divided the 12 core features into three types: organizational context, program features, and program pedagogical practices.

**Summary**

The framework of TD programs’ core features provides a comprehensive approach to analyzing diverse TD programs. In the sections that follow, we explore how type of TD, amount of TD, and doctoral students’ reasons for attending influenced their participation in TD.

<table>
<thead>
<tr>
<th>Core Features</th>
<th>Item Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organizational Context</strong></td>
<td></td>
</tr>
<tr>
<td>1 Scope</td>
<td>The organizational units and institutions involved in a program.</td>
</tr>
<tr>
<td>2 Funding</td>
<td>Sources of resources that establish or sustain the program.</td>
</tr>
<tr>
<td>3 Longevity</td>
<td>How the long the program has existed, whether it is currently active, and its historical background.</td>
</tr>
<tr>
<td>4 Coherence</td>
<td>Extent to which a TD program fits with other TD initiatives/programs and doctoral training.</td>
</tr>
<tr>
<td><strong>Program Features</strong></td>
<td></td>
</tr>
<tr>
<td>5 Audience</td>
<td>Group(s) to whom the activity is targeted or intended and associated characteristics.</td>
</tr>
<tr>
<td>6 Selectivity</td>
<td>Extent to which participation is open or restricted.</td>
</tr>
<tr>
<td>7 Format</td>
<td>The way(s) programs are presented or delivered to participants.</td>
</tr>
<tr>
<td>8 Duration</td>
<td>The length of a program.</td>
</tr>
<tr>
<td>9 Engagement</td>
<td>The number of hours a participant spends engaged in learning activities.</td>
</tr>
<tr>
<td>10 Content focus</td>
<td>The professional skills, knowledge, or attitudes to be advanced by the program.</td>
</tr>
<tr>
<td><strong>Program Pedagogical Practices</strong></td>
<td></td>
</tr>
<tr>
<td>11 Active learning</td>
<td>Extent to which participants are actively engaged in their own learning.</td>
</tr>
<tr>
<td>12 Collective participation</td>
<td>Extent to which participants work together and produce collective products.</td>
</tr>
</tbody>
</table>
STEM doctoral students participated in TD to enhance their teaching knowledge and skills and to prepare more fully for the range of work required of faculty members.
Teaching Development Participation and Engagement during the Doctoral Program

TD is rarely a formal component of doctoral training, especially in research-intensive institutions. STEM doctoral students working as teaching assistants (TAs) are usually required to attend training for their TA duties, but these activities tend to be relatively brief and focus more on policies and procedures than pedagogy. As such, TA training often does not sufficiently prepare future academics for the full range of instructional responsibilities they will face as faculty members.

Feeling underprepared for faculty work, many doctoral students seek out additional opportunities to develop teaching expertise. However, despite growing interest in the preparation of future faculty as effective teachers, there is relatively little research that investigates which doctoral students participate in TD, what types of TD they pursue, why they do or do not participate, and the extent of TD engagement.

To address these questions about the effects of TD on STEM doctoral students, we studied TD participation—that is, whether they participated in TD programs during their doctoral programs, in which types of TD programs, how many times they completed each activity, and what encouraged or discouraged their participation. We also measured TD engagement as the number of times in which students participated in each program type, cumulatively, during the doctoral program.

Most STEM doctoral students participated in TD programs during their training, with most students participating in more than one TD type.

Participation in TD was extremely common among students. As Table 2 shows, the majority (84.6%) participated in at least one type of formal TD activity during their doctoral programs. Some student groups participated at higher rates than others. Women participated significantly more often than men. Within disciplinary groups, physical science outpaced psychology and the social sciences, life sciences, engineering, and other disciplines.

Among doctoral students who participated in TD, most attended brief workshops or presentations, and about half participated in an in-depth workshop or conference. Fewer than half of all doctoral students said they participated in a formal TD course during their degree program (see Figure 6). On average, respondents not only participated in more than one type of TD, but they participated in each type more than once.

In addition to participating at a greater rate overall, women were more likely than men to attend in-depth workshops or conferences as doctoral students (63.0% vs. 55.5%), and on average, women participated in more brief talks or presentations (3.8 talks vs. 3.2 talks).
Table 2: Participation in TD during the Doctoral Program by Demographic Characteristic and Discipline

<table>
<thead>
<tr>
<th>Group</th>
<th>Participation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>87.1%</td>
</tr>
<tr>
<td>Men</td>
<td>82.9%</td>
</tr>
<tr>
<td>Race and Ethnicity</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>84.3%</td>
</tr>
<tr>
<td>Asian</td>
<td>89.1%</td>
</tr>
<tr>
<td>URM</td>
<td>85.5%</td>
</tr>
<tr>
<td>Temporary Visa Holder</td>
<td>85.7%</td>
</tr>
<tr>
<td>Discipline</td>
<td></td>
</tr>
<tr>
<td>Life Sciences</td>
<td>82.2%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>92.6%</td>
</tr>
<tr>
<td>Psychology/Social Science</td>
<td>89.6%</td>
</tr>
<tr>
<td>Engineering</td>
<td>71.7%</td>
</tr>
<tr>
<td>Other Fields</td>
<td>69.6%</td>
</tr>
</tbody>
</table>

Note: Women participated significantly more than men ($p < 0.05$). Within disciplinary groups, physical science significantly outpaced life sciences, engineering, and other disciplines ($p < 0.05$).

Figure 6: Participation in Types of TD Programs during the Doctoral Program
Students engaged in a moderate amount of TD.

Using the program information we gathered in the first stage of the study, we assigned an estimated number of contact hours to each type of TD program. Based on these engagement hours, we created five levels of participation representing the amount of time students spent in TD activities. The levels were:

- none (no participation in any TD activities);
- low engagement (1-10 hours of participation);
- low-moderate engagement (11-25 hours of participation);
- high-moderate engagement (26-55 hours of participation);
- high engagement (more than 55 hours of participation).

Students spent an average of 33 hours in TD activities during their doctoral programs, and two of every five students (42.7%) had high-moderate or high levels of TD engagement (see Figure 7).

As we found when comparing groups on their type of TD activities, the only significant differences were between men and women. During doctoral training, women were more likely to engage in more than 55 total hours of TD than men were (22.8% vs. 15.1%).

TD participation shaped STEM doctoral students’ expectations, relationships with faculty and peers, and career opportunities.

We learned from interviews that many students attended graduate school with hopes of becoming faculty members who would engage in research and, to some extent, teaching activities. Upon entering their doctoral programs, however, they became aware of what Golde and Dore described as a three-way mismatch between (1) their expectations of faculty work, (2) what they actually observed and experienced, and (3) a lack of preparation for the variety of faculty positions (e.g., non-tenure-track as well as tenure-track) at diverse types of postsecondary institutions (e.g., regional comprehensive universities as well as research universities). This discrepancy was particularly noticeable for graduate students who had hoped to develop the knowledge and skills necessary to become effective STEM teachers but instead faced departmental attitudes that devalued teaching. For example:

They [faculty members] didn’t say it directly, but it was sort of an attitude that [teaching] was less worthy or less, I don’t know, less important than research and didn’t really require any preparation. (Multiracial female in earth, ocean, and atmospheric science postdoctoral scholar position)

Figure 7: Levels of TD Engagement during the Doctoral Program

Note: 189 participants were excluded due to missing TD engagement data.
Doctoral students participated in TD activities because it was required and because they genuinely wanted to improve their teaching ability.

Most (71.5%) doctoral students participated in TD programs because it was required of them. This is no surprise given that most (78.3%) of these same respondents served as teaching assistants (TAs), positions that often require training sessions to orient them to campus policies, resources, technology, and very basic teaching skills. Likewise, interviewees reported that TD was often a component of their mandatory TA training, although it typically focused more on policies and procedures than on pedagogy.

Students also participated in TD because they wanted to learn more about teaching and learning (57.0%) and to improve their teaching skills (53.2%). Some interview participants explained that they simply wanted to learn more about teaching and learning as a field in order to be a good college teacher.

I wanted to learn how to teach because in the back of my mind I was thinking of at least supplementing whatever I was going do with my life with teaching. Because I do really want to pay it forward. (White female in health fields non-tenure-track faculty position)

Other students participated to gain knowledge or skills because they perceived a gap between their current abilities and how well they wanted to be able to teach. For example, one participant noted that he was not gaining all that he needed from his doctoral program to perform the full range of faculty responsibilities.

The experiences and training I had in grad school were incomplete. I knew I wasn't doing the things the instructional faculty had to do. I realized that there were deficiencies in my training that I needed more experience to address. (White male in biological sciences postdoctoral scholar position)

Another interview participant shared that she had gained some content knowledge in early TA training activities, but after getting some hands-on teaching experience, she knew she needed more support to teach effectively.

I felt that first semester I was just not prepared to teach. I hated going to class to teach that first semester. I don't know what really I could've been doing differently . . . maybe more time during TA training or maybe practice lectures. Even though everything was organized and although I learned a lot, once I was in the classroom that was just very new to me. (Hispanic female in mathematical sciences non-tenure-track faculty position)

Some interview participants said they participated in TD not necessarily to be a great teacher but simply to avoid being a poor teacher.

At that point, I'd TAed a couple of times and realized I really liked it and wanted to actually learn how to do it on my own. I was like, “There are so many bad professors out there; I really don't want to be one of them.” I think I decided I wanted to be a good teacher because I knew I was going to have to teach, and I was interested in teaching, and I didn't want to be one of those TAs who obviously doesn't care. If I'm going to do something, I want to do it well. I was interested in learning a little bit more about how to be a good teacher. (White female in a psychology postdoctoral scholar position)

Many students participated in TD to prepare for a career as a faculty member (39.0%) and to be more competitive in the job market (25.0%). Some students were quite strategic in selecting their TD offerings, looking for topics or activities that, as one participant explained, would have “direct applicability to my preparations for my career, or my ability to write successful applications for jobs (White male in social sciences non-tenure-track faculty position).” These students believed TD activities would expose them to skills not provided
by their doctoral programs, such as designing a syllabus, engaging students, assessing student learning, and learning “tricks of the trade.” They also expected to connect with peers and faculty from other disciplines who were also interested in teaching and learning.

**Doctoral students’ participation in TD varied by gender and discipline.**

Men participated in TD more often because it was required, whereas women considered professional learning and professional pathways when they chose to participate in TD. In fact, they were more likely to participate in TD programs to learn more about teaching and learning, improve their teaching skills, gain practical teaching experience, prepare for a career as a faculty member, and be more competitive in the job market (See Figure 8).

Doctoral students in life science and health fields were more likely than students in engineering and physical science to participate in TD to learn about teaching and learning. The same is true for improving one’s teaching knowledge and skills and preparing for a faculty career (see Figure 9). These differences may be partially explained by the fact that the life science and health fields groups in our study had higher representations of women, whereas men were overrepresented in the physical science and engineering groups.

![Figure 8: Reasons for Participating in TD Programs during the Doctoral Program, by Gender](image)

*Note: 1 = TD participation was required; 2 = learn more about teaching and learning; 3 = improve knowledge and skills regarding teaching and learning; 4 = gain practical teaching experience; 5 = prepare for career as faculty member; 6 = be more competitive on job market.*

*After accounting for other covariates, regression analysis still indicated significant differences between males and females, p < 0.05.*
Many factors discouraged participation in TD, but chief among them were lack of time and seeing TD as a lower priority among doctoral students’ many responsibilities.

Lack of time was the most significant barrier to participation for most (71.0%) respondents, followed by the perception that TD was not a high priority (45.9%), participants’ lack of awareness of TD programs (39.1%), and scheduling conflicts (27.0%). Many respondents (78.0%) said two or more factors reduced their participation in TD.

More women than men reported that TD programs conflicted with their schedules (30.7% vs. 23.9%) and that advisors discouraged their participation (12.4% vs. 5.7%), whereas more men believed that TD was not a high priority (52.4% vs. 38.4%).

Survey respondents in biological science and health fields assigned TD a higher priority than engineering and physical science students (51.3%, 53.6% vs. 42.9%, 41.0%). Biology and health students were also more likely to report that TD conflicted with their schedules (29.3%, 31.4% vs. 23%, 22.6%). Biology students were also more likely to indicate they were discouraged to participate than engineering and physical science students (14.1% vs. 6.6%, 6.2%).

Taking time away from research to teach or participate in TD was strongly discouraged.

Students were dissuaded from participating in TD because it purportedly meant they would spend less time in the lab or field, which in turn could reduce their research productivity. They felt that they were being narrowly trained for positions like their advisors’ (i.e., tenure-track faculty at research-intensive universities) and not for careers where teaching would play a significant, if not dominant, role. Many students were not given enough support to teach effectively and instead were encouraged to do only the bare minimum so teaching would not affect their work in the lab.

You can [be a] TA…[but] you just watch how someone else teaches…go along with what they do, but [you never learn] how to build a syllabus or how to manage a classroom, or how to develop a series of lectures or develop tests that actually accurately measure student performance. (White female in a psychology postdoctoral scholar position)
The support of faculty advisors was particularly important to students determining whether they should participate in TD. We found that, among our interview participants, advisors' attitudes toward TD participation fell into one of three stances: (1) openly supporting TD activities despite departmental resistance, (2) remaining neutral and uninvolved, or (3) expressing their disdain for TD involvement explicitly or implicitly. The third stance created stressful and even painful interactions, which led to the advisor investing less time in doctoral students who did not “take science seriously.”

*My first advisor was very against any time that my teaching took up. That advisor just continually reminded me, “That is just a requirement. You get your focus where it belongs, and it belongs on your research. You get into that class, do what you have to do, and get out and do not do any more than you have to do.” That professor—it was very explicit, it was not just implicit. It wasn’t just guessed. In fact, there was one semester that I was looking forward to teaching a new class; it would be second semester calculus. And that professor said, “You know something? I don’t like the amount of time that you take for teaching your classes. The time you spend with students and all this... you are not going to be teaching that new class.”* (White male in mathematical sciences non-tenure-track faculty position)

The messaging that students often received from their faculty advisors and from their departments was that teaching was subordinate to research, no matter what one’s career goals might be.

Adding TD participation on top of other responsibilities also increased doctoral students’ stress and workload. Nonetheless, they thought the benefits of TD participation far outweighed potential negatives because they said TD was crucial to their career development and improved their job applications by showcasing additional teaching knowledge and skills.

**Summary**

Our findings help explain why doctoral students participated in TD programs and which factors that influenced their participation. In the next section, we explore what doctoral students gained from their TD participation.
Engaging in TD at higher levels improves students’ teaching knowledge and skills, increases their confidence, and creates a sense of community with their peers.
Short-term Effects of Teaching Development Participation during the Doctoral Program

For STEM doctoral students who become faculty, the period between the start of a doctoral program and attaining a tenure-track faculty position can be lengthy. For example, it takes a person who begins a biomedical doctorate more than 10 years on average to begin her or his first faculty position. For some people, there may be years between being a teaching assistant, participating in TD, and teaching one's first class as the instructor of record.

Thus, a longitudinal perspective is key to understanding the various effects of doctoral TD on aspiring academics over time. Short-term effects of TD during doctoral training can include gaining teaching-related knowledge, skills, and beliefs. Long-term effects of TD can include the type of jobs one pursues and how one teaches undergraduates as a new faculty member.

Here we discuss the short-term effects of doctoral TD. Because the purpose of our study was to understand the impact of TD on doctoral students’ ability to teach undergraduates, we focused on the effects of TD participation on two important outcomes for students: their formation of faculty competencies and their college teaching self-efficacy beliefs. We studied how much these two outcomes were affected by three things: (a) participation in TD activity of any kind, (b) level of TD engagement, and (c) specific types of TD activity. Because the women in our study already reported different experiences than those of men, we also looked for differences in the effects of TD based on students’ gender and race or ethnicity.

Using our interview data, we also examined whether TD participation influenced peer support systems as students moved through their doctoral programs. Because students can receive negative messaging about teaching and TD participation from their faculty advisors and others in their departments, peers’ support and encouragement may help doctoral students persist in teaching and TD. Our findings about these and other short-term effects of TD follow. We also asked interview participants whether their TD participation helped them prepare for their jobs (for those who had completed their degrees by Years 2 and 3 of the study), especially with regard to teaching responsibilities.

Higher TD engagement levels increased doctoral students’ teaching-related competencies.

Professional competencies are the essential skills, knowledge, attitudes, or behaviors one needs to perform real-world tasks. When doctoral students with academic aspirations develop competence in teaching and areas other than research, they can get off to a faster start as early-career faculty. Since traditional doctoral training builds only some of these competencies, we studied what influence teaching experience and TD may have on faculty competencies.

We asked study participants how much they had gained as Ph.D. students in four general faculty competency areas: Instruction, Research, Career Preparation and Decision-making, and General Professional Skills. We also asked study participants
whether they had made any gains as Ph.D. students in six specific knowledge and skill areas in pedagogy: Course Design, Classroom Instruction, Assessment, Diversity in Learning, Teacher-student Relationships, and Teaching in General. Our analysis focused on whether the amount and type of TD program influenced students’ ability to perform these responsibilities.

First, we found that participation in TD was consistently associated with self-reports of significant gains in Instruction competence. As TD engagement increased, the greater the gains in Instruction. Even participation at a low level (fewer than 11 hours) had a significantly positive impact on Instruction. However, we found no relationship between TD engagement and the items that constituted Research, Career Preparation, or Professional Skills. The lack of a significant relationship between TD and these three general faculty competencies is noteworthy. Finding that TD does not appear to impede acquisition of research-related competencies is especially noteworthy since many faculty discourage advisees’ participation in TD out of concern that it may harm their research training.

We found that students with high TD engagement levels had significant increases in all six specific pedagogical knowledge and skill areas, even after we controlled for other potential influences. This suggests that higher levels of TD engagement improve college teaching in its broadest sense.

Intensive programs and courses increased STEM doctoral students’ teaching-related competencies.

We found that type of TD program—whether non-intensive, intensive, or a formal course—had no influence on students’ general faculty competencies, once we controlled for other potential factors. However, students who took formal courses significantly improved in Instruction competence, and in each of the six specific pedagogical knowledge and skill areas. Compared with participants in non-intensive TD activities, doctoral students enrolled in formal courses or intensive TD programs had significantly higher scores in each of these skill types.

Additionally, doctoral students who participated in formal courses benefitted even more significantly in Course Design and Teaching in General than did participants in non-intensive activities.

For women, high TD engagement improved their pedagogical knowledge and skills, but some had negative effects.

After finding that TD engagement and TD type had significant effects on all respondents, we explored whether these effects might be different for women, given the different experiences women had in teaching during their doctoral programs and in their TD engagement. Women students with high TD engagement especially improved their knowledge and skills around Course Design and Teaching in General.

Although women doctoral students gained much from TD participation, there were some worrisome effects. Women who engaged in a high amount of TD reported fewer gains in their Research and Career Planning competencies than women who did not participate in TD at all. Because we do not know why participation has these effects for women, they require further study.

Doctoral students were eager to apply what they learned from TD programs in their classrooms.

From interviews, we learned that doctoral students applied what they had learned from TD programs to teaching undergraduates. The preparation they received from TD programs helped them feel more prepared for more independent teaching roles (e.g., instructor of record) and encouraged them to use different teaching techniques. For example, one interview participant described how she applied what she learned about assessment.

Yeah, definitely [I felt more prepared]. I used clickers in my statistics class. It was through some of the symposium stuff that I learned about clickers. Learned like became aware of them and, you know, sort of decided to try that out. I had lots of just general ideas about how to structure a classroom, and I do think it
helped prepare me for that as well, definitely. *(Asian female in social sciences researcher position)*

When the same participant was asked whether she gained other skills from a formal TD course that were helpful in her current position, she added that she also learned about course design.

I mean, I’ve gained so much. It taught me how to design an entire course, like a holistic course, how to think about the way you write and plan assessments. It was incredibly helpful and enlightening.

Other interview participants discussed the impact of TD engagement from the small to large scale, discussing both individual instructional practices while also considering the effect of their teaching choices within the larger framework of undergraduate STEM education. One interviewee said she felt a need to support her students’ future success by teaching them effectively.

When I think about structuring time for a class, not specifically just a day but rather how to structure a course, it came from nowhere but those [TD] meetings. Learning to look at a curriculum and understand, okay, this is my role in the larger curricular picture for this undergraduate. This is the role that I must fulfill so they can be successful in their next class. That’s really where I felt like I got that, was from that experience and really nowhere else. *(White female in biological sciences tenure-track faculty position)*

Another interview participant said his TD participation prompted him to reflect on his teaching, both in the present and in his career—which in turn led him to attend more TD activities.

[The TD program] started me thinking about how teaching should be and it definitely, I think it helped in the sense that I had to be prepared for my sessions and how should I prepare those sessions, what is it that would help me help these students who would be attending my tutorial sessions. So it made me think about these things and it started a chain where I started inquiring or wondering about how, what the new techniques in teaching or learning are. *(Asian male in engineering postdoctoral scholar position)*

These findings suggest that TD engagement gave doctoral students an increased sense of competence for fulfilling some of their responsibilities as future faculty members. TD engagement also provided doctoral students with appreciable strategies, knowledge, and attitudes toward teaching that were applied in their instructional practice.

**Higher TD engagement increased college teaching self-efficacy beliefs.**

Also central to the development of future faculty is gaining confidence in one’s abilities to perform essential duties of a STEM college instructor—also called their college teaching self-efficacy beliefs. Measuring doctoral students’ teaching self-efficacy beliefs is essential to understanding TD impact because, as more than 30 years of research has shown, self-efficacy beliefs are one of the most reliable predictors of a person’s performance. Doctoral students’ teaching self-efficacy beliefs are influenced, in part, by five elements:

1. their previous teaching experiences (positive and negative);
2. the messages they receive about their teaching abilities from people whose opinions matter to them (faculty advisors, other department faculty, and peers);
3. what they observe when watching others like them teach in college settings;
4. feelings of anxiety about teaching; and
5. active participation in educational experiences like TD programs.32

In our Year 3 survey, we asked students to rate their confidence in their ability to perform tasks representing six components of college teaching: Course Planning, Teaching Methods, Creating
Learning Environments, Assessment of Student Learning, Interaction with Students, and Mastery of Subject Knowledge. Our analyses found that students in the high-moderate and high engagement groups were more confident than students in lower engagement groups. For example, students who had high-moderate engagement were more confident in their Course Planning and Teaching Methods than students who had no TD. Students in the high engagement group were more confident in Course Planning, Classroom Instruction, and Assessing Student Learning than students with no TD.

Students who completed formal TD courses experienced a greater impact on their self-efficacy beliefs in Course Planning, Teaching Methods, and Assessment of Student Learning. Students in intensive TD activities also had increased self-efficacy beliefs about their Teaching Methods. Even after accounting for the levels of TD engagement, we found that participation in formal courses and intensive TD activities contributed to their increased self-efficacy beliefs about teaching.

These quantitative, survey-based results are supported by comments from interview participants. For example, one interviewee said her TD experience gave her confidence to improve her teaching.

It gave me the confidence that I was aware of everything that I could use, getting ideas for how to develop courses differently, but also I did learn how to kind of change my current teaching. (White female in computer sciences non-tenure-track faculty position)

Another participant in a tenure-track position agreed that TD participation improved his teaching, by aligning content knowledge with authentic teaching experiences.

Yes, I think to the extent that I didn't have a huge amount of teaching experience while I was in graduate school, I think the fact that I did the activity and was able to do fairly well as part of the [TD] activity gave me additional confidence. Maybe it was more of a chain in the sense that doing that [TD] activity helped me feel more confident preparing for my teaching assistant activities, which in turn gave me the confidence that I could be a good teacher as a faculty member. (White male in mathematical sciences tenure-track faculty position)

Women who participated in any amount of TD had greater confidence in their college teaching abilities than women non-participants.

Because TD experience differs depending on gender and race, we also tested whether there were any interaction effects of TD experience with gender and race on self-efficacy. Although there was no significant effect for race and ethnicity on self-efficacy, which is similar to our results in other areas, we found that women initially were less confident than men in five of the six components. When we looked for interactions, we found that any amount of TD participation increased the teaching self-efficacy beliefs of women. Likewise, women who had participated in non-intensive TD activities had positive gains in teaching self-efficacy beliefs. These findings suggest that TD participation nearly cancels out women participants’ initial, comparatively lower college-teaching self-efficacy beliefs.

TD participation created a sense of community and a network of like-minded peers.

Doctoral students we interviewed shared that participation in TD programs gave them the opportunity to work with peers who also may have been teaching without much prior preparation.

I definitely had a corps of friends, which is very important for going through graduate school—to have a network of support. And beyond that, a network of people—you know, other teaching assistants—you could go to, to bounce things off of. And also the person who ran the teaching assistant orientation. He was obviously a great resource, and you know he really made himself available to anyone who had been through the training. So I used him as a resource throughout my teaching, even when I was a lecturer. (White female in physical sciences researcher position)
I think the kind of collaboration that was promoted was in the sense of, “Let’s share our successes and failures.” (White male in engineering tenure-track faculty position)

Several students said participation in a required departmental TD program provided an opportunity to connect with peers that otherwise was difficult to arrange.

It’s a very good thing to go through with your classmates again and forge new relationships with people in the same boat. (White male in physical sciences non-tenure-track faculty position)

Other students said that the connections they made in TD programs led to research collaborations, in addition to conversations about teaching experiences.

There were several people, you know, from those TA trainings that I actually did work with later on. It started conversations just because I could feel comfortable saying, “Hey. How’s your research? What are you doing right now?” And then in several instances I could actually say, “Oh you’re doing that? I’ve done something similar. Here’s an experience. Here’s some compounds that I’ve done. Why don’t you try these?” In certain cases, those conversations led to successful results for other researchers. So I definitely think it helped, you know, STEM collaborations later. (White male in physical sciences postdoctoral scholar position)

Still other students explained that they connected with faculty members other than their advisors, which was valuable when entering the academic job market. When asked whether participation in a TD program had helped him develop a community or social network, one student said that TD participation allowed him to talk with faculty members who supported his career goals, especially positions that included teaching responsibilities. Such conversations were not possible with all faculty members, especially those who expected students to pursue research-intensive careers.

Well, they are people I particularly stay in touch with, I’ll admit. There were people I felt like I could talk to about careers, like the one that I described as my goal. Whereas, other professors in the department, it was awkward to talk about career goals that did not involve being a research professor. And, feeling comfortable with the instructional faculty gave me someone I could talk to about other kinds of career goals and they were comfortable talking about that. (White male in biological sciences postdoctoral scholar position)

Finally, some students said participation in TD programs allowed them to build professional relationships with students and faculty from other campus units with whom they did not otherwise interact.

I met a few people there that were in different departments. Actually, I talked to a few professors that I knew from my department and actually from a campus group that I belonged to. I had no idea that they were that interested in education, too. So, you know, I talked to them, made a networking connection, like, “We’re both interested in this, too.” (White female in biological sciences postdoctoral scholar position)

Well, I think it gave me a community of people to talk to about teaching. You know, in addition to the fact that we were organizing a symposium, all those people cared about teaching. I met a professor in the biology department who was tenured. She was in a safe position—you know, she had her job—and she had a lot of candid conversations with me about teaching and priorities. It was very helpful to talk with her about what type of things I thought I wanted to do and what I enjoyed, and using that to figure out what I wanted to do. (Asian female in social sciences researcher position)

They were all people who had taken it upon themselves to come and get some teaching experience. It was very valuable because we were all in that same position of “Well, we
really don’t know what this is all about," but you know, we thought it was interesting. So from that perspective, we were all in the same boat. What was really nice was that we all came from very different departments and backgrounds. *(White male in agricultural sciences tenure-track faculty position)*

**Participation in TD programs did not increase students’ time to degree completion, but teaching experience did.**

When doctoral students discussed their experiences as new teachers and their participation in TD programs, the most prominent theme was that of balancing demands on their time. Specifically, students explained that faculty advisors said participating in TD programs and other activities that constituted spending “too much time” on teaching would delay the completion of their degree. Most students disagreed with this belief, stating that participation in teaching-related activities did not interfere with completing their doctorate.

I remember one of my supervisors saying that I would never finish or I’d be like a nine-year Ph.D. or something. But that might’ve been in regard to me having a kid while a grad student as opposed to teaching. Both of them were probably activities that he didn’t really think were all that worthwhile. *(Multiracial female in earth, ocean, and atmospheric sciences postdoctoral position)*

One participant shared a story of how a group of students in a particular department wanted more teaching opportunities, and how their efforts to design ways for more active participation and practice in teaching classes were met with firm resistance.

The chair of our department basically said this will just slow you down, it will take you longer to get out of here, and what you need to do is do more research anyway. So, you know, you’re never going to do this. I certainly—other professors in the department, you know, openly questioned why was I trying to teach a class on my own, [saying] this really was going to slow me down. *(White male in earth, ocean,

and atmospheric sciences non-tenure-track faculty position)*

Because doctoral students’ priorities seemed to have a significant influence on their experiences around teaching, we examined this issue using our survey data. We found that although participating in TD programs did not, after other factors have been controlled, lengthen time to doctoral degree, teaching experience did. See Table B1 in Appendix B for the different effects of TD engagement levels and teaching experience on time to degree.

**Summary**

These findings show that TD engagement during the doctoral program supported positive outcomes that aligned with two of students’ most influential reasons for participation: wanting to learn more about teaching, and wanting to improve their teaching knowledge and skills. Doctoral students achieved these gains in both self-reported faculty competencies and stronger self-efficacy beliefs, and those who engaged in TD at higher levels reaped greater benefits in most cases. TD participation also helped doctoral students create a sense of community among peers and faculty members who were interested in teaching, both inside and outside of their departments. Finally, although doctoral students were sometimes told that their degree progress would be harmed by TD participation, it did not lengthen time to degree. In the next section, we will explore the effects of TD engagement on their overall preparation for a faculty career and their entry into the academic job market.
STEM Ph.D.s followed career pathways within and outside of academia. Higher levels of engagement in doctoral TD were associated with getting a faculty position after graduation.
Early-career Pathways and Employment of STEM Doctorates

In the last decade, the global economic recession shrunk university endowments, hobbled public investment in colleges and universities, and reduced funding opportunities— all of which have led to a drastic reduction in the number of available tenure-track faculty positions and other academic positions in postsecondary institutions. As STEM Ph.D.s move into an uncertain employment landscape, it is more important than ever to understand their early-career experiences and pathways. Yet most universities collect too little data about their doctoral students’ career pathways and outcomes. As a result, campus leaders, faculty and current students do not know where doctorate recipients end up, whether they are satisfied with their jobs, and how well their doctoral program prepared them for the kinds of positions they pursued. In addition, it is unclear whether TD participation influences doctoral students’ career decisions or employment outcomes.

In this section, we take further advantage of the five-year timeframe for our data collection to describe the career pathways of STEM doctorates in the five years after receiving their degrees. We asked survey respondents about the number and type of positions they held, whether they had teaching responsibilities, and the type of organization in which they worked. We asked interview participants whether they felt participation in TD programs had any effect, positive or negative, on their job searches. With these questions, we explored whether and how TD participation influenced STEM doctoral students’ career decision-making and early pathways. Here is what we learned.

STEM Ph.D.s have complex career pathways in the first five years after completing their degrees.

We analyzed the likelihood of a STEM Ph.D. taking a certain type of employment each year after completing her/his degree. Types of employment included (a) postdoctoral scholar; (b) tenure-track faculty; (c) non-tenure-track faculty; (d) other academic professional; (e) other professional outside of academia; and (f) unemployed (see Table B2 in Appendix B). Within one year of earning their doctorates, 9.3% of study participants had secured a tenure-track position; by the fifth year after completing their degrees, 23.0% of survey respondents were in tenure-track lines, slightly higher than the national average. Contrary to the national narrative about the boom in contingent positions, a small proportion (7.4%) of participants held non-tenure-track positions five years after earning their doctorate.

The majority of STEM Ph.D.s moved into postdoctoral scholar positions within two years of completing their degrees (62.8% at the first year and 56.6% at the second year after receiving a doctorate), although a smaller proportion remained in this type of position after five years (18.2%). Also after five years, a little more than one third (37.5%) of STEM Ph.D.s had taken positions outside of postsecondary institutions. The percentage of unemployed doctorates was relatively low five years after receiving their degrees (4.0% average overall).
About half of STEM Ph.D.s work in postsecondary institutions and have undergraduate teaching responsibilities. Within five years of receiving their degrees, just more than half (56.1%) of all STEM Ph.D.s were working in postsecondary institutions, and nearly half (45.5%) were in positions with undergraduate teaching responsibilities (see Tables B3-B5). Among study participants with teaching responsibilities in 2013, STEM Ph.D.s who graduated earlier in the study (in 2009 and 2010) were most likely to teach undergraduates as the instructors of record for a course (50.5% for 2009 graduates and 47.7% for 2010 graduates) and to serve as a research mentors (47.3% for 2009 graduates and 33.7% for 2010 graduates). See Table B6 for the complete results by cohort.

Higher levels of TD engagement during the doctoral program were associated with getting a faculty position. According to doctoral students we interviewed, there was a perception among department faculty, their advisors, and some peers that participating in TD would not only harm their ability to carry out rigorous research, but also that it would harm their chances of landing a desirable faculty position (especially on the tenure track). However, higher levels of TD engagement during the doctoral program increased the likelihood of getting a faculty position (see Table B7). After we controlled for all other factors, high TD engagement (more than 55 hours) significantly increased the likelihood of moving into a faculty position. In the final model, this effect was tempered for students who planned to apply for faculty position, which suggests that such plans may have increased TD participation during the doctoral program.

STEM Ph.D.s’ TD experience and interest in teaching influenced their job searches. Although some interview participants said TD participation was commonly assumed to harm STEM doctoral students’ career prospects, others said TD participation had a positive impact on their job searches. For some in the latter group, TD influenced the kinds of positions and institutions to which they applied.

Did that experience in particular have effects on what kind of jobs I pursued? Yeah. I would say that it definitely did, just in the fact that it supported my belief that teaching was important and also allowed me to go, “Well, teaching is also a viable career choice and something I should pursue. And to see if it will work for me.” My experiences in the symposium definitely influenced me to actually pursue teaching positions. I don’t know that I would have if I hadn’t had that experience. (Asian female in social sciences researcher position)

Other interviewees said TD programs informed their personal reflection as they searched for jobs. For example, one interview participant explained that participating in an intensive TD program sharpened his expectations of the academic job market, and of faculty careers themselves.

That program was a two-year experience for me, which was very influential in shaping my understanding of the kind of the job market and the kinds of expectations and the kind of professional life of different career options available to me as well as issues surrounding balancing family life with work and these kinds of things. So that gave me a really good, broad overview of what a career in academia could look like. It helped me to really identify the pros and cons and where I was really focused and what I would need to do to get there, in terms of my kind of career selection. (White male in biological sciences tenure-track faculty position)

Another interview participant said that a TD workshop on preparing for an academic job search, which included preparing statements of teaching philosophy, prompted him to ask whether working in academia aligned with the kind of work he hoped to do.
They’re trying to make you figure out, what is it that you want out of your career? How do you find the school that’s going to be a good fit for you? How do you figure out what kind of job you even want to apply for? I went to this workshop with a few other friends from my university, and a couple of them after that said, “You know what? I sort of realized I don’t even want to stay in academia.” You know, and that’s part of that too. It’s making you think, you know, what is a life going to be like in academia and all these different sort of levels. It’s also making you think, what is it that you would like to do? How do you figure that out? It’s nice that way, that there’s a lot of reflection to make you write paragraphs. How would you describe yourself? Where do you see yourself in ten years? And all these things. So, it’s definitely sort of a career workshop that way. (White male in earth, ocean, and atmospheric sciences non-tenure-track faculty position)

This same student said a TD workshop encouraged him to examine the role that he wanted teaching to play in his professional life, if any at all.

Yeah, it did [influence my job search], in terms of a lot of the teaching experience or teaching, just ideas that I got, that certainly helped. It definitely did make me think about what I want. You know, what kind of job do I want to apply for? It definitely helped me find this job that way. So yeah, I found the workshop to be fantastic.

Finally, another interview participant explained that interest in teaching undergraduates in a classroom setting was a deciding factor in his job search.

I’ve tended to apply more, I find, toward schools that have a greater teaching emphasis, less on the tier one research institution, ones where I am going to be able to be in the classroom and interacting with students, particularly undergraduate. I really value that, and I’m also applying to mixed graduate and undergraduate programs, but I have a preference for ones where I know that I’m actually going to be able to have the opportunity to actually be an instructor in class. I also want to be able to have the opportunity to teach graduate students, if that lends itself, I’m applying to ones that don’t have graduate programs as well. But, I would eliminate one from my list if I knew that my interactions with undergraduates would be limited to just some graduate classes and occasional undergraduate, I wouldn’t be likely to apply for that type of position. (White male in social sciences non-tenure-track faculty position)

These findings suggest that TD programs, along with teaching experience, helped STEM doctoral students examine their interest in teaching and its place in their professional lives. In turn, these reflections helped doctoral students pursue positions that aligned with their knowledge, skills, and values.

STEM Ph.D.s’ with TD and teaching experience compiled competitive job applications.

The second major influence on STEM doctoral students’ job searches resulting from doctoral TD came in the competitive advantage it represented in their application packages. For those who felt their TD influenced their job search, this positive outcome was mentioned most often. For example, just two of many interview participants noted that their TD participation made them more attractive candidates.

I mean, I would say that the line on the vitae [describing participation in TD program] really did help, that I think it did. I think when I was looking for teaching positions it was another credential that helped, you know, helped me get job offers. (Asian female in social sciences researcher position)
Especially with more teaching-focused colleges, it [TD participation] was something that I would highlight. It changed the way that I presented myself in my applications. I assume that it would have led me to be, you know, taken more seriously as someone who was serious about teaching.  (White male in mathematical sciences postdoctoral scholar position)

Other interview participants noted that as a result of their TD participation and, in some cases, teaching experiences, they could provide specific examples of their teaching materials, which strengthened their overall applications. Several interviewees described how TD participation influenced how they prepared their teaching philosophies.

Yes, it influenced the job search that I just went through, because I found that the kinds of ideas that I gained from the course and the teaching experience lent themselves to, well, what I felt was a strong and convincing teaching statement. I think I came off as strong in the teaching category which may not have been anywhere near the case had I not gone through that teaching program.  (Multiracial female in earth, atmosphere, and oceanic sciences postdoctoral scholar position)

The biggest thing that I took away that was most fruitful was really putting together the teaching philosophy statements. It contributed a lot to my job search and I think to my actual performing the job of teaching right now—although I think that it also contributed to my teaching while I was a doctoral student.  (Asian male in social sciences tenure-track faculty position)

Yes, there were positive effects from the class I took on my job search. I was able to talk about the things that I learned in the course. . . . We started a teaching and learning philosophy in that class, too. Going back, I did actually think about teaching and learning with starting to write that, and then modified it a lot later. I sent it with some of my application materials, and it helped in the job search in those ways, I guess. Starting to put together a teaching and learning statement and being able to think about teaching and learning and being able to talk about it [was helpful].  (White female in physical sciences tenure-track faculty position)

Other interview participants gave different examples of teaching materials they created in TD activities during the doctoral program and later included in their job applications. One student referenced classroom assessments on which other TD program participants gave feedback.

Oh yes, [that program] gave me a much better idea of how to present myself as a better candidate in a job search. Not only did our instructor or facilitators go into detail, but you were asked to bring five copies of activities and résumés to class and you were asked to give them out. It had a very good impact on my job search.  (Asian male in computer sciences tenure-track faculty position)

Other interview participants said doctoral TD engagement helped them present themselves as skilled instructors. For one interview participant, this translated into presenting herself as someone who could perform the full range of faculty work.

I think it [TD participation] definitely changed the way how I was perceived as a candidate. Because it just made me look like I was pretty well-rounded. I think like a lot of employers look to see like well, not only are you doing your job, but are you doing extra-curricular activities to help support whatever future career you want to hold. I think most people think that grad students are going to become professors somewhere, so they want to see the teaching, they want to see the mentoring. I think it helps a lot.  (Asian female in biological sciences postdoctoral scholar position)
Another interviewee said that the evidence of his teaching skill, gained from both TD participation and teaching experience, landed him a job he enjoyed.

This [position] is a teaching-focused one, so the teaching was of prime importance. My level of experience was stand out, it was communicated to me in securing this position and the strong student evaluations and the strong recommendations that I received from faculty were the reason that I was successful in gaining this position. So teaching is the reason that I have a job right now. (White male in social sciences non-tenure-track faculty position)

Finally, one participant said she obtained a faculty position not only by using materials she prepared in a formal TD course, but also from how she presented herself and the role teaching would have in her work. To do this, she presented three things during her interview: a peer-reviewed journal article based on a paper from a TD course, her teaching and research statements, and her general approach to teaching.

It did come up, that [teaching-focused] paper. The fact that it was published and on my CV, I think, did bring it to people’s attention, and we did talk about that. I also think that in the class, we had to do a teaching statement and a research statement. I took these courses—that course in my second year of graduate school—so of course four years later a lot had changed when I was preparing my application. But I think it gave me the foundation for how to prepare this and what it means, and I kind of get the sense when I was being interviewed by the department chair, he had my teaching statement in front of him. And I got the sense that I’d kind of sort of ticked all the right boxes for him, that I was saying things that resonated with his view of teaching, and so I think that that course certainly helped me articulate what I believed about teaching even though I’d had relatively no teaching experience. (White female in engineering tenure-track faculty position)

TD participants said they were more competitive in the job search because they could demonstrate their abilities and interest in teaching to potential employers. By helping STEM Ph.D.s develop the knowledge, skills, and attitudes for a wide range of academic careers, TD expanded doctoral students’ job prospects.

Summary

Our findings show that TD and teaching experience influence doctoral students’ decisions to pursue faculty careers and improved the job search for those seeking positions with undergraduate teaching responsibilities. Together, with the short-term outcomes discussed in the previous section, these results show that many STEM doctoral students largely received what they sought from participation in TD: learning about teaching, gaining teaching knowledge and skills, and preparing for faculty careers.

In the next section, we share findings about the long-term effects of TD participation during the doctoral program, focusing on doctorate recipients who worked in academia and who taught undergraduates. We discuss the influence that TD engagement had not only on their long-term self-efficacy beliefs, but also on their teaching practices in the classroom.
TD engagement and teaching experience had a long-term effect on STEM Ph.D.s’ confidence in their ability to teach undergraduates and use evidence-based instructional practices in their early academic careers.
Long-term Effects of Teaching Development Participation during the Doctoral Program

Policymakers and scholars have suggested that doctoral TD programs might improve undergraduate STEM education. Yet it has not been clear whether doctoral students’ participation in TD programs has influenced their subsequent use of evidence-based instructional practices. Without this information, it is not possible to know whether TD can be a lever for change in a national strategy to improve undergraduate teaching and learning.

To address this lack of knowledge, we examined the long-term effects of TD participation for STEM doctoral students who, by the Year 5 (2013) survey, had graduated and moved into their careers. Because teaching experience may have improved study participants’ confidence in their abilities, we looked at the impact of both TD and teaching experience during the doctoral program.

We investigated the impact of TD and teaching experience during the doctoral program on early-career STEM Ph.D.s’ college teaching self-efficacy beliefs and their self-reported teaching behaviors in Year 5. We included the same six components of college teaching as we did when investigating their self-efficacy beliefs in Year 3; the six components were Course Planning, Teaching Methods, Creating the Classroom Environment, Assessment of Student Learning, Interactions with Students, and Mastery of Subject Knowledge. For this survey, however, we not only asked participants to rate their confidence in their abilities to carry out each teaching task we listed, but we also asked them to indicate how often they performed each task when teaching.

TD engagement during the doctoral program had a long-term effect on college teaching self-efficacy beliefs as study participants moved into their early careers.

Participants’ level of TD engagement during the doctoral program had positive, significant effects on their Year 5 self-efficacy beliefs (see Figure 10). Low-moderate, high-moderate, and high levels of TD engagement each had different effects on participants’ self-efficacy, but low engagement had no long-term effect. Low-moderate engagement had a significant effect on participants’ beliefs about their ability to use different Teaching Methods and Mastery of Subject Matter, while high-moderate engagement had significant effects on their Course Planning and Teaching Methods beliefs. High TD engagement during the doctoral program had positive effects on the self-efficacy beliefs regarding most teaching components, including Course Planning, Teaching Methods, Creating the Classroom Environment, and Assessment of Student Learning.

In examining the long-term outcomes of TD program type during the doctoral program (see Figure 11), we found that formal courses had the most enduring impact on self-efficacy beliefs. We found positive effects of formal TD courses on early-career study participants’ self-efficacy beliefs around Course Planning, Teaching Methods, and Assessment of Student Learning.
Note: Filled bars within this graph indicate that the given TD engagement level during the doctoral program had a significant effect on doctorates’ self-efficacy beliefs in a given teaching component (reference group: non-participants). For example, low-moderate TD engagement had a positive, significant effect on Year 5 self-efficacy beliefs in mastering subject knowledge, compared with non-participants.

Figure 10: Effect of TD Engagement Level during the Doctoral Program on Year 5 Self-Efficacy

Figure 11: Effect of TD Type during the Doctoral Program on Year 5 Self-Efficacy

Note: Filled bars within this graph indicate that the given TD program type during the doctoral program had a significant effect on participants’ self-efficacy beliefs in a given teaching component (reference group: non-participants). For example, intensive and other program types had a positive, significant effect on Year 5 self-efficacy beliefs in mastering subject knowledge, compared with non-participants.
As we have noted in other analyses, levels of TD engagement and TD type are correlated because the level of engagement is based upon the type of TD program in which a student participates. For example, participants in formal courses or intensive TD activities are likely to spend more time in TD programs than participants in non-intensive TD activities, because these TD programs simply require longer time commitments. To parcel out these effects, we estimated the effect of TD engagement level and TD type simultaneously. After accounting for the type of TD activities, only two significant effects remained: high engagement during the doctoral program improved participants’ self-efficacy beliefs around teaching methods and assessment of student learning.

We also found that the amount of teaching experience during the doctoral program had a consistent, positive effect on doctorates’ long-term self-efficacy beliefs across all six college teaching components. This significant relationship remained even in the final model when we accounted for the effects of TD engagement level and TD type independently. These results are not surprising because research has long shown that a person’s mastery experiences—that is, their opportunities to practice the tasks in a given content area—are the strongest influence on their self-efficacy beliefs.45

TD engagement and teaching experience during the doctoral program influenced teaching behaviors among early-career academics.

We also investigated teaching behaviors of study participants who had become early-career academics to understand whether TD participation during the doctoral program, especially at higher levels of engagement, had any influence in actual teaching practices. As with participants’ self-efficacy beliefs in Year 5, simply having participated in a TD activity during the doctoral program had no effect on the frequency of teaching behaviors. And again, as it did with Year 5 self-efficacy beliefs, the amount of teaching experience during the doctoral program had a positive, significant effect for teaching behaviors in each of the six teaching components. The level of engagement during the doctoral program, however, had varying, positive effects on participants’ teaching practices. Generally, as the level of TD engagement increased during the doctoral program, so too did the frequency with which study participants used certain practices in their early-teaching careers.

As Figure 12 shows, high-moderate and high engagement levels in TD during the doctoral program had the most positive effects on how frequently early-career doctorates used certain teaching strategies; each of these engagement levels had a significant, positive effect on teaching behaviors in all six college teaching components. Low-moderate TD engagement also had effects on multiple teaching components, and even low TD engagement had a positive effect on how frequently early-career doctorates used different techniques to assess student learning.

Just as we did with Year 5 self-efficacy beliefs, to parcel out the correlative effects of TD engagement level and TD type, we estimated the effects for each simultaneously. Unlike with self-efficacy beliefs, however, significant effects on teaching behavior remained. Even after accounting for the type of TD activity, high-moderate and high engagement during the doctoral program improved study participants’ teaching practices in course design, teaching methods, creation of their classroom environments, and assessment of student learning; the effect of TD type (especially formal courses) was almost explained by TD engagement. And, just as with Year 5 self-efficacy beliefs, we found the amount of teaching experience during the doctoral program had a consistent, positive effect on study participants’ teaching behaviors, across all six of the college teaching components we assessed.

Figure 13 shows the effects of TD type on teaching behaviors. We found that formal courses were the only format to have an effect on early-career academics’ teaching practices. This finding is consistent with those in the rest of the study, which generally found that participation in intensive TD programs or formal courses yielded the most positive effects.
Figure 12: Effect of TD Engagement Level during Doctoral Program on Teaching Behaviors

Note: Filled bars within this graph indicate the given TD engagement level during the doctoral program had a significant effect on doctorates’ behaviors in a given teaching component (reference group: non-participants). For example, high-moderate and high engagement levels had a positive, significant effect on how frequently study participants who completed their doctorates used the strategies we identified in course planning at the time of the Year 5 survey, compared with non-participants.

Figure 13: Effect of TD Type during the Doctoral Program on Teaching Behaviors

Note: Filled bars within this graph indicate the given TD type during the doctoral program had a significant effect on doctorates’ behaviors in a given teaching component (reference group: non-participants). For example, formal courses had a positive, significant effect on how frequently study participants who completed their doctorates used the strategies we identified in course planning, and teaching methods at the time of the Year 5 survey, compared with non-participants.
Summary

These results show that TD participation during the doctoral program has the potential to create long-term changes in future STEM instructors by (a) raising their confidence in their ability to teach undergraduates and (b) increasing their use of evidence-based instructional practices. These outcomes suggest that doctoral TD may play a vital role in reforming undergraduate STEM education.

This interpretation of our findings has a caveat, however. Although we explored the long-term effects of TD activities, we have not yet addressed how past TD activities affect current teaching self-efficacy and teaching behavior. Because there are many mediating and confounding factors between past TD activities and current self-efficacy and teaching behavior, sophisticated structural models are necessary to understand this long-term process. Thus, our analyses here are preliminary and exploratory. We need further investigation of the long-term and iterative relationship among TD activities, self-efficacy beliefs, and teaching behavior.
Conclusions

Providing potent, high-quality TD opportunities to doctoral students is a strategy with the potential to reform undergraduate STEM education on a national scale. Although doctoral students who participate in TD are presumed to obtain crucial knowledge, skills, and attitudes that help them become effective undergraduate instructors, there has been limited empirical evidence for the impact of TD programs. To address this gap, we designed a longitudinal study to examine the short- and long-term impact of STEM doctoral students’ participating in TD.

Overall, we found that TD offers numerous short- and long-term benefits for doctoral students related to their journeys to becoming effective STEM instructors. TD participation had these principal outcomes for our study participants:

- A moderate amount of TD engagement and type of TD (formal TD courses and intensive TD activities) had a positive impact on:
  - short-term teaching competency, knowledge, and skills;
  - short- and long-term college teaching self-efficacy beliefs; and
  - long-term self-reported teaching behaviors.
- TD had a greater impact on women than men overall; women who participated in TD were more confident in their teaching abilities than women non-participants.
- The more an individual participates in TD programs, the greater the impact on their college teaching self-efficacy beliefs.
- TD participation created a sense of community and network of likeminded peers.

In addition to the effects of TD, we found that actual teaching experience also had a long-term positive impact on teaching self-efficacy beliefs and behaviors.

In summary, our study found that TD engagement during the doctoral program can be an effective way to prepare skilled STEM instructors who foster greater undergraduate learning.

Recommendations

Because STEM Ph.D.s will teach undergraduates at more than 4,000 colleges and universities across the nation, investing time and resources in TD programming has great potential to transform undergraduate STEM education.

Getting people who are involved in doctoral education to take teaching development seriously remains a major hurdle, however. Overcoming faculty resistance and making teaching development a higher priority will require systemic change across national, institutional, departmental, and individual levels. Our model for changing the preparation of STEM doctoral students to teach (Figure 14) shows how these levels of action and influence are nested. Reducing political, financial, structural, and cultural barriers to student engagement in doctoral TD must occur across all levels. To help stakeholders lower these barriers, we offer recommendations for action based on our findings and previous research.16
At a national level, research universities face external pressures from many sources: regulatory agencies, public and private funders, accreditors, peer institutions, employers, legislators, and the general public. Because external pressures can move universities to act, these stakeholder groups can influence whether and how universities provide more and better TD opportunities for future STEM faculty. We offer national stakeholders these change strategies:

- Fund initiatives and projects that create high-quality TD programs, reduce barriers to TD participation, and creatively address faculty resistance.

- Require federal research grant awards (namely, those from the National Science Foundation and the National Institutes for Health) that employ graduate students and postdoctoral scholars to include TD in their mentoring and professional development plans.

- Advocate for national policy that elevates the importance of undergraduate teaching.

- Facilitate discussion among stakeholder groups about the importance of TD to faculty careers and improved undergraduate education.

- Advance lines of research on TD programs and participants that expand our understanding of how future faculty develop as effective teachers.
College and University Administrators

Presidents, provosts, deans, and other administrators shape the vision and mission of the institution, establish institutional policy, and distribute funding. This stakeholder group should acknowledge, support, and advocate for doctoral TD programs and initiatives. To this end, we recommend the following actions:

- Provide sufficient funding and support for doctoral TD programs and initiatives on campus.
- Facilitate campus-wide discussions about the importance of doctoral TD for graduate student professional development and undergraduate education.
- Collect and publish data from doctoral students about career interests, experiences, and eventual placements.
- Seek change across the institution related to faculty reward structures and the adoption of effective teaching strategies.
- Create a map of campus-wide TD programs, organized by key features such as duration, intended audience, and expected learning outcomes.

Teaching Development Providers

Multiple campus units (e.g., graduate school, teaching and learning center, departments) provide TD programming to doctoral students and thus play a crucial role in the development of future STEM faculty. Given TD’s positive effects on doctoral students, it should be a priority to lower barriers to students’ participation. Based upon our findings, we offer the following recommendations:

- Increase awareness of TD opportunities through advertising and outreach.
- Offer multiple modalities of TD.
  - Provide not only in-person activities but also technology-hosted resources.
  - Hold events at times that fit doctoral students’ schedules.
- Gather more and better data—and use it.
  - Assess doctoral students’ needs and design TD programs that meet their needs.
  - Rigorously measure TD program participants’ learning outcomes, such as their knowledge of evidence-based instructional approaches, observed teaching behaviors, and their confidence in their teaching abilities.
  - Use outcomes data to evaluate and improve TD programs.
  - Provide doctoral students, their advisors, and other key stakeholders with convincing evidence of the value of TD.
- Coordinate TD offerings for stronger and broader impact on doctoral students.
  - Work with other TD providers to address gaps in TD offerings and to reduce redundant programming.
  - Help students save time by providing a map of opportunities and outcomes.
Department Chairs and Faculty

Academic departments—where disciplinary and institutional cultures intersect—arguably have the greatest influence on doctoral students’ participation in TD. Our study found that the research-focused culture of departments may prevent doctoral students from engaging in enough TD activities to gain significant, positive, and lasting gains. Negative attitudes about teaching—especially its importance relative to research—can be a barrier to students’ participation in TD. To foster department cultures that truly value the formation of future STEM instructors, faculty members and chairs must assess and change their practices, processes, and values. We recommend the following actions:

**Department chairs can...**

- Encourage discussions of teaching development during doctoral student orientations and in students’ individual program planning.
- Consider adding a required teaching seminar to the formal doctoral curriculum, perhaps in collaboration with a TD program.
- Provide opportunities to discuss teaching and learning from a disciplinary perspective.
- Reward and recognize effective teaching.
- Encourage faculty and advanced doctoral students to open their classrooms for students to observe effective teaching.
- Include periodic reporting on doctoral teaching development and experience in faculty meetings.
- Provide students with ample information about career planning and opportunities.
- Provide current information to prospective and current students about a broad range of Ph.D. career pathways, including non-tenure-track academic positions and positions outside of academia.
  - Encourage doctoral students to begin career planning early in their programs using tools such as individual development plans and other self-assessments.
  - Track the career pathways of alumni in order to give doctoral students accurate information about their post-Ph.D. prospects.

**Faculty advisors can...**

- Communicate with students about teaching and its place in various types of faculty careers.
  - Clarify your and your advisee’s expectations with respect to the amount of time spent in TD and teaching.
  - Discuss students’ timely progress and work to ensure that they have the experiences they need to prepare them for the careers they want.
  - Ask students about their career interests and support their interest in college teaching.
  - Provide information about teaching opportunities, TD activities, and career options.
- Allow students to have time to participate in TD without fear of shame or reprisals.
- Help students integrate their research and teaching in mutually supportive ways to avoid TD being seen as only preparing graduate students for positions at non-research universities.
- Support students who are seeking community among others who have an interest in teaching.
• Help doctoral students gain access to authentic teaching experiences, especially as an instructor of record.
• Set a good example around teaching and learning.
  - Show students that you take teaching seriously by investing time in faculty professional development or self-directed learning.
  - Periodically include a presentation and discussion on teaching in regular research group meetings.
  - Communicate the value of teaching to peers inside the department and beyond.
  - Engage in cross-campus, cross-disciplinary conversations and projects aimed at improving teaching and learning at the institution.

**Doctoral Students**

As our study showed, doctoral students greatly benefit from TD participation; they apply knowledge, skills, and attitudes gained from TD to undergraduate STEM courses. Their reasons for participating in TD are both intrinsic and instrumental. Yet too few doctoral students participate in enough TD activities to enjoy their significant benefits. Here are some suggestions to increase doctoral students' TD engagement and outcomes.

• Communicate with faculty members, especially your advisor, about the role of teaching and TD in your career development.
  - Discuss your and your advisor's expectations about your doctoral program; if appropriate, discuss your interest in teaching or teaching careers.
  - Recognize the value of having faculty support and buy-in for your involvement in TD programs and authentic teaching experiences, preferably before you begin.
  - Ensure teaching is part of any individual development plan.
  - Regularly reflect on the role you want teaching to play in your professional life.
  - Call for more information from your department and the institution about career choices for Ph.D's and alumni pathways.
• Participate in TD programs and teaching activities that allow you to learn about, practice, and reflect on undergraduate instruction.
  - Opt, when possible, for TD programs that require greater engagement and feedback, such as formal courses.
  - Pursue authentic teaching opportunities—preferably those that are mentored—that intentionally prepare you to be an undergraduate instructor.
  - Observe others' teaching.
  - Solicit feedback on your teaching from trusted mentors, peers, and your own students to identify areas of strength and opportunities for improvement.
• Find or create a community of like-minded peers and faculty members who work toward improving teaching.
  - Provide feedback and suggestions to trusted faculty or administrators about how to improve teaching preparation in your department.
  - Connect with others who take teaching seriously, both inside and outside of your department.
  - Support those who are trying to increase the visibility and importance of teaching on campus, or those for whom TD participation is risky.
Appendix A

Research Methods

Sampling Criteria for Institutions and Students

Using an established methodology,49 we selected the institutions using the following criteria: (a) each awarded at least 100 doctoral degrees per year and maintained a very high level of research activity;50 (b) each had a relatively large STEM doctoral student population;51 and (c) each actively supported a variety of future faculty professional development programs.52 To be included in the study, students needed to be enrolled in a doctoral program in a STEM department and have achieved dissertator status.

Surveys

Sample. The sampling frame for the study consisted of all 3,060 late-stage doctoral students in STEM departments at Arizona State University, University of Washington–Seattle, and University of Wisconsin–Madison as of March 2009. Thus, study participants included both doctoral students who participated in TD and those who never participated in TD. Contact information for enrolled STEM doctoral students was obtained directly from the graduate schools of the three institutions following approval from their respective institutional review boards.

Administration. The University of Wisconsin Survey Center administered the Longitudinal Study of Future STEM Scholars’ three major surveys. One of the nation’s preeminent research centers, the UWSC provided human subjects consultation, designed questionnaires, handled incentive monies, and delivered email and telephone reminders. Critically, the center also tracked participants over the life of the study, enabling the success of its longitudinal design.

Year 1 (2009). The Year 1 (2009) survey examined the extent to which respondents participated in TD activities during their doctoral programs, especially the activities we identified in our study of each participating campus. We also explored the reasons respondents participated (or did not participate) in TD activities, and perceived gains in critical areas such as teaching, research, and career skills following TD participation. Among all 3,060 late-stage doctoral students in three institutions, 2,163 doctoral students responded to the Year 1 survey (70.7%).

Year 3 (2011). The Year 3 (2011) survey examined the early-career pathways of the study participants who had completed their degrees. It continued measuring respondents’ participation in TD programs, along with the perceived gains achieved through such participation. The survey gauged participants’ interest in teaching at the college level and assessed their college teaching self-efficacy beliefs. The Year 3 (2011) survey followed 2,146 Year 1 participants and collected data from 1,445 participants (67.3%).

Year 5 (2013). The Year 5 survey (2013) asked about respondents’ current employment, again measured respondents’ self-efficacy beliefs, and measured their self-assessed use of evidence-based teaching practices. We asked respondents to report participation in TD programs, teaching experience, self-efficacy beliefs, teaching behaviors, and career pathway information. The Year 5 (2013) survey followed 2,146 Year 1 participants and collected data from 1,414 participants (65.9%).

Interviews

Sampling. We purposively selected 75 interviewees from among the respondents of the Year 1 (2009) survey. Interviewees needed to (1) have completed their doctoral programs, (2) have participated in one or more TD programs from 2007 through 2009, and (3) taken new positions working in postsecondary institutions.

Purpose and Protocol. The Year 2 and 3 interviews addressed several questions:
1. Which TD program characteristics are associated with positive and negative participant outcomes?
2. What encourages and discourages participation in TD programs?
3. What do doctoral students gain from TD programs that help them prepare for diverse academic careers?
4. What influence does participation in TD programs have on the kinds of careers that STEM Ph.D.s choose?
5. What impact, if any, does participation in TD have on indicators of early-career performance?
6. What degree of investment in TD must a doctoral student make, and for what length of time, to receive modest but significant benefits?

To address these questions, we used a semi-structured interview protocol that asked about participants’ career aspirations and reasons for pursuing a doctorate, their participation in TD programs, factors that influenced their participation, their satisfaction with the programs, their perceived gains from participating, their application of the skills and knowledge in their new positions, and the perceived outcomes of their teaching for their students. We also asked about the perceived effects of their departmental context, including advisors’ and peers’ attitudes about TD participation and teaching.

**Administration and Analysis.** Four researchers conducted the interviews during Year 2 and Year 3 of the study. We conducted the interviews by telephone and digitally recorded the conversation with participant permission. We then transcribed the interviews word-for-word, and coded the transcripts using NVivo 10 software.

**Participant Demographic Characteristics**

Table A1 shows how our survey respondents varied by gender, race/ethnicity, citizenship, and doctorate-granting institution. Compared to women, men made up a slightly higher proportion of the response group at each survey, although the proportion of women who responded to each wave increased. The proportion of temporary visa holder respondents declined at each survey, which we suspect may be tied to career pathways.

**Table A1. Survey Respondents’ Demographic Characteristics by Gender, Race, and Doctorate-Granting Institution**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,136 (54.41%)</td>
<td>758 (53.42%)</td>
<td>729 (52.33%)</td>
</tr>
<tr>
<td>Female</td>
<td>952 (45.59%)</td>
<td>661 (46.58%)</td>
<td>664 (47.67%)</td>
</tr>
<tr>
<td>Race and Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1,307 (63.1%)</td>
<td>974 (69.3%)</td>
<td>973 (70.5%)</td>
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<tr>
<td>Asian</td>
<td>104 (5.0%)</td>
<td>68 (4.8%)</td>
<td>65 (4.7%)</td>
</tr>
<tr>
<td>Underrepresented Racial Minority</td>
<td>115 (5.6%)</td>
<td>71 (5.1%)</td>
<td>69 (5.0%)</td>
</tr>
<tr>
<td>Temporary Visa Holder</td>
<td>545 (26.3%)</td>
<td>293 (20.8%)</td>
<td>273 (19.8%)</td>
</tr>
<tr>
<td>Ph.D.-granting Institution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arizona State University (Tempe)</td>
<td>314 (14.5%)</td>
<td>188 (13.0%)</td>
<td>178 (12.6%)</td>
</tr>
<tr>
<td>University of Washington–Seattle</td>
<td>997 (46.1%)</td>
<td>705 (48.8%)</td>
<td>661 (46.8%)</td>
</tr>
<tr>
<td>University of Wisconsin–Madison</td>
<td>852 (39.4%)</td>
<td>553 (38.2%)</td>
<td>575 (40.7%)</td>
</tr>
</tbody>
</table>
after completing their degrees; many international doctorate recipients return to their home countries or work outside the United States.53

We were careful to look for differences between gender and racial groups during our analyses. Although we found some important patterns in gendered experiences during the doctoral program, we rarely observed significant differences among students by race. This lack of significance is likely due to the small sample sizes of Asian and underrepresented racial/ethnic minority students in the study. Race/ethnicity and citizenship status were collected from separate questionnaire items. Therefore, racial categories such as “Asians” include both U.S. citizens and non-citizens.

**Defining STEM Fields in the Longitudinal Study of Future STEM Scholars**

We represented the disciplinary representation of our survey respondents in two ways: using the broad National Science Foundation (NSF) categories to describe the STEM disciplines, and the specific disciplinary fields provided as response choices on the Year 1 questionnaire. For most analyses in the study, we grouped the detailed disciplinary categories within those broader NSF categories.

Doctoral students and doctorate recipients from the life sciences, particularly the biological sciences, made up the largest proportion of respondents for each survey, followed closely by the physical sciences. Life sciences and physical sciences made up roughly two-thirds of the response groups for each survey administration. Respondents from psychology and the social sciences, engineering, and other disciplines represented the other third of respondents. The representation of the different disciplinary groups was stable over time, with only a small decline in the proportion of engineering respondents.

**Table A2. Survey Respondents’ Ph.D. Disciplines**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NSF Disciplinary Categories</td>
<td>Life Sciences</td>
<td>750 (35.5%)</td>
<td>503 (35.3%)</td>
</tr>
<tr>
<td>Detailed Disciplinary Categories</td>
<td>Agricultural Sciences</td>
<td>37 (1.8%)</td>
<td>18 (1.3%)</td>
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<tr>
<td></td>
<td>Biological Sciences</td>
<td>604 (28.6%)</td>
<td>416 (29.2%)</td>
</tr>
<tr>
<td></td>
<td>Health Fields</td>
<td>109 (5.2%)</td>
<td>69 (4.8%)</td>
</tr>
<tr>
<td>NSF Disciplinary Categories</td>
<td>Physical Sciences</td>
<td>615 (29.1%)</td>
<td>430 (30.2%)</td>
</tr>
<tr>
<td>Detailed Disciplinary Categories</td>
<td>Earth, Atmospheric, and Oceanic Sciences</td>
<td>82 (3.9%)</td>
<td>62 (4.4%)</td>
</tr>
<tr>
<td></td>
<td>Mathematical Sciences</td>
<td>118 (5.6%)</td>
<td>77 (5.4%)</td>
</tr>
<tr>
<td></td>
<td>Physical Sciences</td>
<td>339 (16.0%)</td>
<td>240 (16.8%)</td>
</tr>
<tr>
<td></td>
<td>Computer Science</td>
<td>76 (3.6%)</td>
<td>51 (3.6%)</td>
</tr>
<tr>
<td>NSF Disciplinary Category, Detailed Disciplinary Category</td>
<td>Engineering</td>
<td>312 (14.8%)</td>
<td>185 (13.0%)</td>
</tr>
<tr>
<td>NSF Disciplinary Categories</td>
<td>Psychology and Social Sciences</td>
<td>351 (16.6%)</td>
<td>247 (17.3%)</td>
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<td>Detailed Disciplinary Categories</td>
<td>Psychology</td>
<td>80 (3.8%)</td>
<td>58 (4.1%)</td>
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<tr>
<td></td>
<td>Social Sciences</td>
<td>271 (12.8%)</td>
<td>189 (13.3%)</td>
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<tr>
<td>Other Fields</td>
<td>87 (4.1%)</td>
<td>61 (4.3%)</td>
<td>56 (4.0%)</td>
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## Appendix B

### Career Pathways of STEM Ph.D.s

**Table B1: Effect of TD Engagement and Teaching Experience during the Doctoral Program on Time to Degree Completion**

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD Participation</td>
<td>0.043 (0.104)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TD Engagement (ref. Non-Participants)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (10 hours or fewer)</td>
<td>0.028 (0.159)</td>
<td>-0.033 (0.157)</td>
<td></td>
</tr>
<tr>
<td>Low-Moderate (11-25 hours)</td>
<td>0.091 (0.152)</td>
<td>0.022 (0.151)</td>
<td></td>
</tr>
<tr>
<td>High-Moderate (26-55 hours)</td>
<td>0.174 (0.159)</td>
<td>0.037 (0.158)</td>
<td></td>
</tr>
<tr>
<td>High (55 hours or more)</td>
<td>0.365* (0.178)</td>
<td>0.234 (0.177)</td>
<td></td>
</tr>
<tr>
<td>TD Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formal Course</td>
<td>0.135 (0.113)</td>
<td>0.156 (0.112)</td>
<td></td>
</tr>
<tr>
<td>Intensive</td>
<td>0.087 (0.092)</td>
<td>0.009 (0.092)</td>
<td></td>
</tr>
<tr>
<td>Teaching experience</td>
<td></td>
<td>0.113**</td>
<td></td>
</tr>
<tr>
<td>Covariates</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: * p < 0.05; ** p < 0.01. Model 1 and Model 2 control for Ph.D. cohorts. In addition to Model 2, Model 3 accounts for teaching experience during doctoral program, demographic information, institutions, disciplines, career goal, and whether or not TD was required. n = 1,301.*
Table B2. Doctoral Students’ Career Pathways Since Earning Their Ph.D.

<table>
<thead>
<tr>
<th></th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
<th>Total</th>
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<tbody>
<tr>
<td>Unemployed</td>
<td>5.7%</td>
<td>4.0%</td>
<td>2.9%</td>
<td>2.8%</td>
<td>5.8%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Unemployed N</td>
<td>54</td>
<td>49</td>
<td>36</td>
<td>24</td>
<td>29</td>
<td>192</td>
</tr>
<tr>
<td>Postdoctoral Scholar</td>
<td>62.8%</td>
<td>56.6%</td>
<td>43.1%</td>
<td>28.1%</td>
<td>18.2%</td>
<td>45.2%</td>
</tr>
<tr>
<td>Postdoctoral Scholar N</td>
<td>600</td>
<td>702</td>
<td>538</td>
<td>243</td>
<td>91</td>
<td>2174</td>
</tr>
<tr>
<td>Tenure-Track Faculty</td>
<td>9.3%</td>
<td>10.2%</td>
<td>14.8%</td>
<td>21.4%</td>
<td>23.0%</td>
<td>14.6%</td>
</tr>
<tr>
<td>Tenure-Track Faculty N</td>
<td>89</td>
<td>127</td>
<td>185</td>
<td>185</td>
<td>115</td>
<td>701</td>
</tr>
<tr>
<td>Non-Tenure Track Faculty</td>
<td>2.5%</td>
<td>5.0%</td>
<td>5.5%</td>
<td>5.4%</td>
<td>7.4%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Non-Tenure Track Faculty N</td>
<td>24</td>
<td>62</td>
<td>69</td>
<td>47</td>
<td>37</td>
<td>239</td>
</tr>
<tr>
<td>Others in Academia</td>
<td>2.9%</td>
<td>3.7%</td>
<td>5.6%</td>
<td>7.1%</td>
<td>8.2%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Others in Academia N</td>
<td>28</td>
<td>46</td>
<td>70</td>
<td>61</td>
<td>41</td>
<td>246</td>
</tr>
<tr>
<td>Others outside Academia</td>
<td>16.8%</td>
<td>20.6%</td>
<td>28.1%</td>
<td>35.2%</td>
<td>37.5%</td>
<td>26.2%</td>
</tr>
<tr>
<td>Others outside Academia N</td>
<td>161</td>
<td>255</td>
<td>351</td>
<td>304</td>
<td>188</td>
<td>1259</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total N</td>
<td>956</td>
<td>1241</td>
<td>1249</td>
<td>864</td>
<td>501</td>
<td>4811</td>
</tr>
</tbody>
</table>

Note: * may not add to 100% due to rounding.

Table B3. Respondents’ Employment Sector (Postsecondary Institution) Since Earning Their Ph.D.

<table>
<thead>
<tr>
<th></th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Postsecondary Institutions</td>
<td>33.1%</td>
<td>33.5%</td>
<td>37.8%</td>
<td>41.6%</td>
<td>43.9%</td>
<td>37.2%</td>
</tr>
<tr>
<td>Outside Postsecondary Institutions N</td>
<td>273</td>
<td>377</td>
<td>449</td>
<td>348</td>
<td>207</td>
<td>1654</td>
</tr>
<tr>
<td>Postsecondary Institutions</td>
<td>67.0%</td>
<td>66.5%</td>
<td>62.2%</td>
<td>58.4%</td>
<td>56.1%</td>
<td>62.8%</td>
</tr>
<tr>
<td>Postsecondary Institutions N</td>
<td>553</td>
<td>747</td>
<td>740</td>
<td>488</td>
<td>265</td>
<td>2793</td>
</tr>
<tr>
<td>Doctorate-granting University</td>
<td>64.38%</td>
<td>63.09%</td>
<td>62.33%</td>
<td>55.65%</td>
<td>52.65%</td>
<td>60.85%</td>
</tr>
<tr>
<td>Doctorate-granting University N</td>
<td>356</td>
<td>470</td>
<td>460</td>
<td>271</td>
<td>139</td>
<td>1696</td>
</tr>
<tr>
<td>Associate's, Bachelor's, Master's Colleges</td>
<td>16.09%</td>
<td>16.38%</td>
<td>18.7%</td>
<td>23.61%</td>
<td>23.11%</td>
<td>18.84%</td>
</tr>
<tr>
<td>Associate's, Bachelor's, Master's Colleges N</td>
<td>89</td>
<td>122</td>
<td>138</td>
<td>115</td>
<td>61</td>
<td>525</td>
</tr>
<tr>
<td>Medical School</td>
<td>9.4%</td>
<td>9.93%</td>
<td>10.3%</td>
<td>11.5%</td>
<td>14.39%</td>
<td>10.62%</td>
</tr>
<tr>
<td>Medical School N</td>
<td>52</td>
<td>74</td>
<td>76</td>
<td>56</td>
<td>38</td>
<td>296</td>
</tr>
<tr>
<td>University Research Institute</td>
<td>10.13%</td>
<td>10.6%</td>
<td>8.67%</td>
<td>9.24%</td>
<td>9.85%</td>
<td>9.69%</td>
</tr>
<tr>
<td>University Research Institute N</td>
<td>56</td>
<td>79</td>
<td>64</td>
<td>45</td>
<td>26</td>
<td>270</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total N</td>
<td>826</td>
<td>1124</td>
<td>1189</td>
<td>836</td>
<td>472</td>
<td>4447</td>
</tr>
</tbody>
</table>

Note: We combined the results for respondents working in Associate’s, Bachelor’s, and Master’s institutions due to small cell sizes.
### Table B4. Respondents’ Positions with Undergraduate Teaching Responsibilities Since Earning Their Ph.D.s

<table>
<thead>
<tr>
<th></th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Teaching Positions N</td>
<td>52.5% 259</td>
<td>52.5% 391</td>
<td>53.1% 465</td>
<td>53.5% 432</td>
<td>56.0% 280</td>
<td>53.4% 1827</td>
</tr>
<tr>
<td>Positions with Teaching Responsibility N</td>
<td>47.5% 234</td>
<td>47.5% 354</td>
<td>46.9% 411</td>
<td>46.5% 376</td>
<td>44% 220</td>
<td>46.6% 1595</td>
</tr>
<tr>
<td>Total</td>
<td>100.0% 493</td>
<td>100.0% 745</td>
<td>100.0% 876</td>
<td>100.0% 808</td>
<td>100.0% 500</td>
<td>100.0% 3422</td>
</tr>
</tbody>
</table>

### Table B5. Respondents’ Positions with Undergraduate Teaching Responsibilities Since Earning Their Ph.D.s, by Graduation Cohort

<table>
<thead>
<tr>
<th>Positions at 2013 yr</th>
<th>2009 Cohort</th>
<th>2010 Cohort</th>
<th>2011 Cohort</th>
<th>2012 Cohort</th>
<th>2013 Cohort</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Teaching Positions N</td>
<td>53.7% 255</td>
<td>51.6% 206</td>
<td>53.5% 147</td>
<td>63.1% 70</td>
<td>72.9% 35</td>
<td>54.5% 713</td>
</tr>
<tr>
<td>Positions with Teaching Responsibility N</td>
<td>46.3% 220</td>
<td>48.4% 193</td>
<td>46.6% 128</td>
<td>36.9% 41</td>
<td>27.1% 13</td>
<td>45.5% 595</td>
</tr>
<tr>
<td>Total</td>
<td>100.0% 475</td>
<td>100.0% 399</td>
<td>100.0% 275</td>
<td>100.0% 111</td>
<td>100.0% 48</td>
<td>100.0% 1308</td>
</tr>
</tbody>
</table>

### Table B6. STEM Ph.D.s Teaching Role for Undergraduates

<table>
<thead>
<tr>
<th>Positions at 2013 yr</th>
<th>2009 Cohort</th>
<th>2010 Cohort</th>
<th>2011 Cohort</th>
<th>2012 Cohort</th>
<th>2013 Cohort</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor of Record N</td>
<td>50.5% 111</td>
<td>47.7% 92</td>
<td>42.2% 54</td>
<td>36.6% 15</td>
<td>38.5% 5</td>
<td>46.6% 277</td>
</tr>
<tr>
<td>Research Mentor      N</td>
<td>47.3% 104</td>
<td>33.7% 65</td>
<td>28.9% 37</td>
<td>12.2% 5</td>
<td>23.1% 3</td>
<td>36.0% 214</td>
</tr>
<tr>
<td>Guest Lecturer       N</td>
<td>32.3% 71</td>
<td>18.1% 35</td>
<td>22.7% 29</td>
<td>17.1% 7</td>
<td>15.4% 2</td>
<td>24.2% 144</td>
</tr>
<tr>
<td>Others               N</td>
<td>6.8% 15</td>
<td>5.2% 10</td>
<td>4.7% 6</td>
<td>0.0% 0</td>
<td>0.0% 0</td>
<td>5.2% 31</td>
</tr>
<tr>
<td>Total</td>
<td>220</td>
<td>193</td>
<td>128</td>
<td>41</td>
<td>13</td>
<td>595</td>
</tr>
</tbody>
</table>

*Note: Multiple choices were allowed in teaching roles, so that N did not necessarily represent the sum of the column.*
Table B7: Probability of Getting a Tenure-Track or Non-Tenure Track Faculty Position

<table>
<thead>
<tr>
<th>TD Engagement</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Participants</td>
<td>0.047</td>
<td>0.046</td>
<td>0.042</td>
</tr>
<tr>
<td>Low (10 hours or less)</td>
<td>0.082*</td>
<td>0.067</td>
<td>0.055</td>
</tr>
<tr>
<td>Low-Moderate (11-25 hours)</td>
<td>0.094*</td>
<td>0.08*</td>
<td>0.068</td>
</tr>
<tr>
<td>High-Moderate (26-55 hours)</td>
<td>0.118*</td>
<td>0.088*</td>
<td>0.066</td>
</tr>
<tr>
<td>High (55 hours)</td>
<td>0.139*</td>
<td>0.105*</td>
<td>0.077*</td>
</tr>
</tbody>
</table>

* * p < 0.05. Model 1 only accounts for time. Model 2 controls for time, demographic background, institutions, disciplines, level of teaching experience, and time-to-degree. In addition to Model 2, Model 3 controls for respondents’ initial plan to apply for faculty jobs. The type of TD program that STEM Ph.D.s participated in during the doctoral program had no effect on their likelihood of moving into a faculty position.
Notes


12. We observed no significant differences by race and ethnicity among U.S. citizens for any of these items, though this lack of difference may be attributable to small samples sizes.


23. We used the following weights for TD program contact hours: formal courses = 30 hours; in-depth workshops of conferences lasting more than a day = 12 hours; brief workshops or conference = 6 hours; and talks, presentations, or other types of TD = 1 hour.


27. Recall that for this study, we have established five levels of TD engagement based on the estimated number of contact hours in each activity type: none, low (1–10 TD contact hours), low–moderate (11–25 hours), high–moderate (26–55 hours), and high (> 55 hours).

29. We created these groups of items based on the many competencies identified by Austin and McDaniels (2006), who also included awareness of ethical issues, collaborating with others, appreciation of diversity in teaching and learning. Another group of items asked participants how much they had learned as a Ph.D. student about instruction—specifically, about Course Design, Classroom Teaching, Assessment, Diversity in Learning, Teacher-student Relationships, and Teaching in General. The items for this analysis are found in our Year 1 survey, available on the LSFSS website, and were also reported in the appendix of our 2014 paper (Connolly & Lee, 2014). Descriptions of the analytic approach and full results are also reported in that paper. See also: Austin, A. E., & McDaniels, M. (2006); Connolly, M. R., & Lee, Y.-G. (2015). The effects of doctoral teaching development on early-career STEM scholars’ college teaching self-efficacy (WCER Working Paper No. 2015-1). Retrieved from the University of Wisconsin-Madison, Wisconsin Center for Education Research website: http://www.wcer.wisc.edu/publications/workingPapers/papers.php

30. Other factors that we controlled for in our analyses included demographic characteristics, level of teaching experience, first year of doctoral studies, institution, discipline, interest in a faculty career, whether TD participation was required, and candidate status.

31. We found no significant interactions with race and faculty work competency or pedagogical knowledge and skill, although we included this demographic characteristic in each model.


33. We selected teaching tasks related to these six components based on research literature that attempted to identify the various components of college teaching and a synthesis of research on college teaching in science and math (National Research Council, 2003). Students indicate how confident they were on a five-point scale, with responses ranging from “not at all confident” to “extremely confident.” See also: National Research Council. (2003). Evaluating and improving undergraduate teaching in science, technology, engineering, and mathematics. Washington, D.C.: National Academies Press.


37. We constructed position type variables based on the job titles reported in the Year Five (2013) survey. Survey respondents who indicated that they were a postdoctoral scholar, fellow, or associates were coded as postdoctoral scholars. Tenure-track faculty was comprised of respondents who said they were an assistant professor, associate professor, full professor, research professor, clinical professor or teaching professor, or instructor, lecturer, adjunct professor or visiting faculty and they were eligible to earn or receive tenure. Non-tenure-track faculty was comprised of these same job titles but was restricted to respondents who were not eligible to earn or receive tenure.
Other academic professional included staff researchers or scientists (who were not postdoctoral scholars), engineers, administrators or managers, or other job titles specified by the respondent who were working in a postsecondary institution. Finally, other professionals working outside of academia included all of these job titles but was restricted to respondents who were not working in a postsecondary institution.


40. We coded survey respondents as working in postsecondary institutions if they said their primary employment organization or institution was in the postsecondary sector and they selected an associate’s college (community college or technical institute), baccalaureate college (liberal arts college or university), Master’s college or university (few or no doctoral programs), doctorate-granting university (research college or university), medical school (including university-affiliated hospitals and medical centers), university-affiliated research institute, or other type that they identified. We categorized respondents as working outside of postsecondary institutions if they said their primary employment organization or institution was outside the postsecondary sector or they selected a preschool, elementary, or secondary school; government (other than educational institutions); not-for-profit institution (such as a foundation); for-profit industry or business; self-employed, or other as they identified.


43. For this section, we focus only on those respondents who graduated in the earlier years of the study (2009 or 2010) and who would have had sufficient time to complete a postdoctoral appointment before moving into a more permanent job.

44. Doctorates could indicate how often they were using a practice along a five-point scale. Responses ranged from “never” to “very often.”


Additional Resources and Information

To learn more about the Longitudinal Study of Future STEM Scholars, please visit our website: http://lsfss.wceruw.org. This site is the study’s primary means of communication for the study, and contains the many results of our work, including:

**Academic products**

- Research briefs
- Working papers, conference papers, and abstracts
- Posters
- Presentations

**Tools for research and practice**

- Survey instruments for each administration (Years 1, 3, and 5)
- Early-Career Academics Interview Protocol (Years 2 and 3)
- STEM College Teaching Proficiency Self-Assessment Tool

You may also contact us directly:

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Email: mark.connolly@wisc.edu