

The Value of a Disciplinary Teaching Certificate Program for Chemistry and Biology Graduate Students

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We explored the value of a teaching certificate program administered by a disciplinary teaching and learning center (TLC) and tailored specifically to the needs of graduate students in biology and chemistry. Using a survey and interviews, we investigated the participants' motivation, the value of each program component, and the effectiveness of the overall program design. We found that the disciplinary nature of the program, especially the two-credit science teaching course, and the flexibility of the program's design were particularly valuable to the program participants. We believe that the disciplinary focus of the certificate program, which relies on the deep involvement of the TLC, serves as a model for professional development that is responsive to the specific needs of STEM graduate students.

Introduction

This study characterizes and investigates the value of a teaching certificate program for science graduate students at a large research university in the mid-Atlantic region of the U.S. At most research universities, graduate students teach undergraduate classes as a requirement of their financial support. In some cases, teaching experience may even be a graduate program requirement. A graduate student's preparation for these teaching responsibilities varies between institutions and even between departments within a given institution. In most research intensive universities, the departmental culture tends to discourage science graduate teaching assistants (GTAs) from devoting time to developing their teaching skills and broadening their knowledge of science education (Addy & Blanchard, 2010). Teaching preparatory programs range from half-day orientations to department-specific, full semester courses (Luft, Kurdziel, Roehrig, & Turner, 2004, Roehrig, Luft,

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Kurdziel, & Turner, 2003). Especially in research intensive universities, GTAs generally receive little guidance or feedback in developing their teaching abilities (Austin, 2002; Austin, Campa, Pfund, Gillian-Daniel, Mathieu, & Stoddart, 2009; Boyer Commission, 2002).

Individuals who apply to science graduate programs at research universities come with the understanding that they are expected to devote themselves to a substantial, independent research project (Austin, 2002; Boyer Commission, 2002; Golde & Dore, 2001; Nyquist et al., 1999). Their advisors, who invest considerable time and resources to train them, encourage this understanding. The advisors usually draw on their own experiences, viewing their own preparation and graduation training as a model for how to prepare their graduate students. However, this traditional model is very limited and does not take in account two main issues (Boyer Commission 2002):

- The diversity of potential careers open to those with advanced science, technology, engineering, and mathematics (STEM) degrees, and
- The ongoing transformations in academia.

The diversity of potential careers. The Boyer Commission report (2002) showed that in 1995, only about 50% of the graduate students in life sciences stated that they were planning to stay in academia. The remainder intended to pursue other career paths, including federal laboratory research, science policy, and industry research and development (Fox & Stephan, 2001). Of those holding positions in academia, only about 26% worked at research universities, while the others worked at institutions with a primary focus on teaching. Since the publication of the Boyer report, the availability of academic positions has steadily decreased (Fuhrmann, Halme, O'Sullivan, & Lindstaedt, 2011). As stressed in the Boyer report, for those STEM graduates not planning to pursue academic positions, there is a substantial discrepancy between their graduate school preparation and the nature and requirements of their future workplaces. The expectation of society, as well as employers, is that doctoral STEM students will have a broad range of skills, including the ability to communicate science to broad audiences, train other employees, communicate policy decisions, and know how to evaluate their work. Development of these essential skills needs to be part of the standard preparation for graduate students.

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The ongoing transformations in academia. Even students who are following in the footsteps of their mentors into tenure-track positions at research intensive institutions need to be better prepared for their responsibilities, since it is no longer sufficient to be simply adequate at teaching. Two decades ago, in response to national calls to improve undergraduate education (NRC, 1996; NSF, 1998), higher education institutions started to push for major changes in how undergraduate courses are taught. These changes included increased emphasis on using student-centered teaching approaches, incorporating new technologies in the classroom, and accommodating students' diverse backgrounds and preparation (Austin, 2002). This transformation in undergraduate science education requires new and enhanced teaching preparation programs for graduate students to enable them to fulfill their potential future roles as educators (Rice, Sorcinelli, & Austin, 2000; Menges, 1999).

One of the biggest hurdles to implementing extended teaching preparation programs for GTAs is the spectrum of responsibilities (e.g., research, teaching, coursework, mentoring, grant writing) that they must take on within the limited time frame of graduate school (Kline, 1977). Despite this time pressure, there is a growing interest among science graduate students to supplement their research training with opportunities to develop effective teaching skills and strengthen their understanding of science education theory. In 2011, we investigated GTA teaching philosophies, level of involvement in professional development activities, perceived challenges, and the extent of institutional/departmental support for their teaching efforts (Marbach-Ad, Schaefer, Orgler, & Thompson, 2013). We found that around 55% of biology and chemistry GTAs (N=97) reported that their primary career goal involved teaching, and 55% indicated an interest in participating in a two-day workshop to develop and articulate their teaching philosophies (Marbach-Ad, unpublished data).

As a testimony to this growing number of GTAs who are interested in more professional development in teaching, in the last decade a growing number of universities across the country have developed optional teaching certificate and other extended programs for graduate students in the sciences. At the University of Wisconsin-Madison, for example, the Delta program was created through the Center for the Integration of Research, Teaching, and Learning (CIRTL). The Delta Program, funded by the National Science Foundation (NSF), provides multifaceted professional development to graduate students through formal courses, intergenerational small-group

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programs, internships, workshops, and regular dinners. Program participants form an interdisciplinary learning community, and participants who complete the program receive a certificate (Bouwma-Gearhart, Millar, Barger, & Connolly, 2007).

Teaching certificate programs augment existing, required teaching preparatory programs and apply to students with a variety of interests and career goals, from those who wish to develop better skills to support their teaching as GTAs to those who are planning careers in academia. They typically include components such as on-line and face-to-face workshops, mentoring relationships, observation of classes, teaching and learning courses, teaching projects, reflective writings, and documentation of accomplishments relating to teaching. Several of these program components (e.g. portfolio development, statements of teaching philosophy) may make the participants more attractive when competing for faculty positions. Growing numbers of universities, including research intensive universities, pay close attention to teaching expertise when hiring new faculty members, asking for statements of teaching interests as well as a sample teaching presentation. Moreover, there is an understanding that the presentation and communication skills emphasized in such programs are generalizable to a variety of science careers, including policy, industry, and research administration (Boyer Commission, 2002; Caserio, et al., 2004; Karagiannis, 2009).

Creating Better Synergy Between Research and Teaching

In this study, we aimed to learn more about the relationship between science research and teaching and to suggest what might be done in support of a closer, more synergistic relationship between these two essential university activities. This synergy can be fostered through the development of teaching certificate programs that have a strong disciplinary focus. Such programs are more applicable to the GTAs' experiences and expertise than programs that are intended to encompass all disciplines (Hammrich, 2001). Disciplinary-based programs are also better able to help STEM GTAs develop pedagogical content knowledge (PCK) (Addy & Blanchard, 2010). PCK, a term coined by Shulman (1986), refers to the teachers' ability to integrate their knowledge of the subject matter with their understanding of how students learn. Studies suggest that teaching approaches taught to GTAs in the context of their discipline enhance their understanding of the nature of effective scientific teaching. This understanding leads them to use more active learning approaches

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in their classrooms and take the role of facilitators of student learning (Luft, et al., 2004; Rushin et al., 1997).

At our University, a university-wide teaching certificate program for graduate students (University Teaching and Learning Program, UTLP) was established in 1994 by the campus Center for Teaching Excellence (CTE). Drawing from the PCK model, and based on the recommendations of the CTE director, several colleges and departments built on this campus-wide model and began offering their own disciplinary teaching certificate programs. One of these satellite programs was launched by the College of Chemical and Life Sciences (CLFS) in 2010 under the auspices of the College's Teaching and Learning Center (TLC, described more fully below) and serves graduate students in the chemical and biological sciences. The CLFS UTLP is a voluntary program that provides professional development in teaching and carries official recognition benefits to the participants (a teaching certificate notation on the diploma).

We present here the results of our research on graduates from our program, followed by a discussion of the value of optional professional development programs for GTAs. We also consider the perspective of university administration (as represented here by two biological sciences faculty members who, at the time of this study, held the positions of CLFS Associate Dean of Graduate Studies and Director of the campus Center for Teaching Excellence). As noted above, institutional and departmental perspectives strongly influence the priorities of graduate training programs and have the power to either create or mitigate tension between time devoted to research and time devoted to teaching experience or teaching preparation. This tension was an undercurrent of this research. Finally, we suggest how disciplinary Teaching and Learning Centers might mitigate this tension.

The College of Chemical and Life Sciences TLC

Within the chemical and biological sciences at our university, there are 165 faculty members, about 2,400 undergraduates pursuing majors in the Biological Sciences and about 400 undergraduates pursuing majors in Biochemistry and Chemistry. Every year there are about 90 graduate teaching assistants (experienced and new) in chemistry and biochemistry, and 90 in the biological sciences. A college-based Teaching and Learning Center (TLC) was established in 2006 to increase the depth, challenge, and relevancy of our curriculum and facilitate the adoption of nationally recommended approaches for teaching and learning in the sciences

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(Handlesman, Miller, & Pfund, 2007; Wieman, 2007; Wieman, Perkins, & Gilbert, 2010). TLC programs, which are open to graduate teaching assistants as well as faculty, include (1) individual assistance on teaching issues, (2) seminars by visiting scholars who have been nationally recognized for their ability to integrate teaching and research, and (3) opportunities to attend workshops and present their research on teaching and learning at national conferences. In addition, the TLC offers some programs specifically tailored for graduate teaching assistants, including (4) mandatory six week teaching preparatory courses for entering graduate students (Marbach-Ad, Shields, Kent, Higgins, & Thompson, 2010, Marbach-Ad, Schaefer, Kumi, Friedman, Thompson, & Doyle 2012) and (5) an optional College of Chemical and Life Sciences, University Teaching and Learning Program (CLFS UTLP) that allows graduate students to earn a teaching certificate and diploma notation.

Three key personnel design and administer TLC programs. The director, a science educator by training, creates a bridge between the disciplines of science and education. She develops programming, teaches graduate courses in pedagogy and instruction, and provides individualized guidance to faculty and graduate students. A second college administrator, a biologist by training, specializes in grant writing and administration, science education data analytics, and graduate student mentoring. Additional support for program development, delivery, and assessment is provided by a graduate assistant. Importantly, the TLC also relies on the engagement of faculty members from across the College, especially lecturers, who are taking major roles in creating systematic mentoring programs for graduate students interested in science education.

CLFS UTLP Requirements

To receive the UTLP certificate, students need to complete six different requirements (Figure 1).

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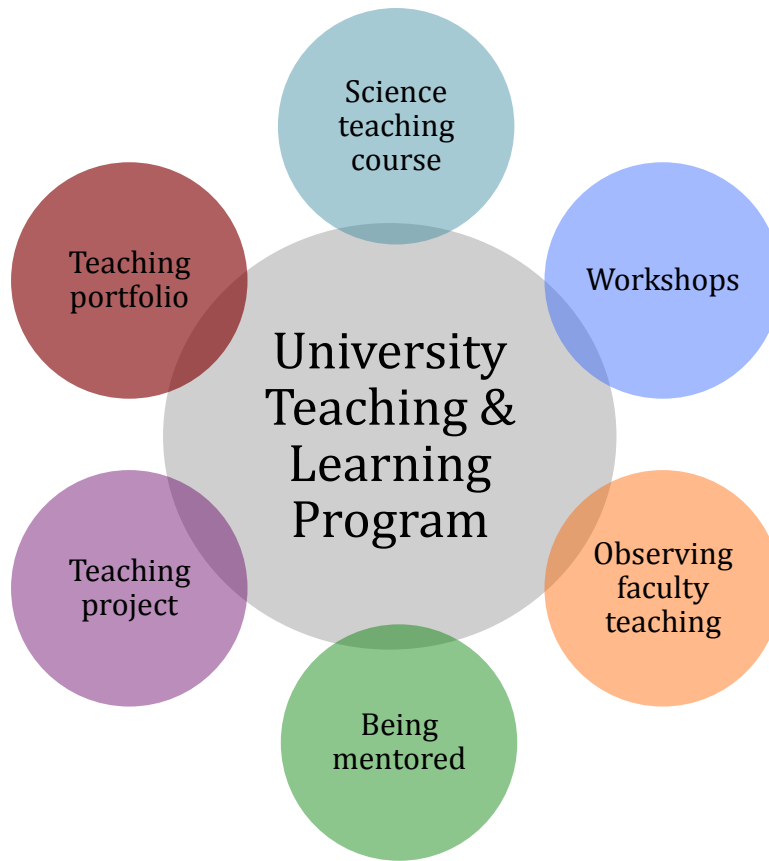


Figure 1: The six components that students are required to complete for the CLFS UTLP certificate.

The program requirements can be completed in any order. Students work through the program at their own pace and time, and there is no penalty if students decide to withdraw from the program at any stage. We encourage students to tailor their selection of certificate activities to what is most relevant to their scientific discipline, so that they can develop their PCK. Below, we elaborate on each of the six components that students are required to complete to earn the CLFS UTLP certificate:

1. **Science teaching course.** We encourage students to enroll in a two-credit course on teaching and learning that is offered by the college. The course is discussion-based, and the director of the TLC designed the course to include specific literature focused on biological and

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chemical education. The course broadens student knowledge of pedagogy and science education theory, especially as it relates to teaching science at the university level. The course uses activities and research to develop pedagogical content knowledge specifically in chemistry and biology (Marbach-Ad, Egan, & Thompson, 2015). If scheduling conflicts do not allow students to take the science teaching course, they can choose to enroll in a similar course offered by the campus CTE and intended for students of all disciplines.

2. **Workshops.** Students attend at least seven 90-minute workshops that focus on teaching and learning, including at least one workshop on teaching with technology. While students can fulfill this requirement with any workshops or seminars offered on our campus, we strongly recommend that they participate in TLC workshops because of their special emphasis on science teaching and learning. The TLC director also hosts each semester a visiting teacher/scholar who has been nationally recognized for his or her ability to integrate teaching and research. These individuals serve as role models for graduate students and faculty members. In addition to giving a seminar on teaching and learning, the guest meets with UTLP participants in a small group to discuss science education initiatives and innovations, grant opportunities, and career preparation.
3. **Observing faculty members teaching.** Students observe three faculty members teaching, preferably in large enrollment classes, and write reflections on what was learned from these observations. Prior to these observations, we provide students with an observation template that helps focus their attention on different facets of teaching (e.g., physical attributes of the classroom, the lesson's learning goals, the instructor's teaching style, student engagement, and assessment of student learning). After students have completed their observations they meet with a TLC or CTE representative to analyze and summarize their observations.
4. **Being Mentored.** Each student chooses a faculty member from his/her department or college to serve as a teaching mentor. The mentor observes the student teaching at least twice. Following each observation, the mentor gives the student verbal and written feedback to help them improve their teaching effectiveness. It is recommended that students meet with their mentors at least three times to discuss their teaching and establish a mentoring relationship where

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future concerns related to teaching can be addressed. The TLC maintains a list of faculty who are respected for their teaching and willing to serve as mentors.

5. **Teaching Project.** Students complete a teaching project that demonstrates understanding of the field of science teaching. Students are encouraged to collaborate with faculty members from their department to design a research project that contributes to departmental, college, or university educational goals. The TLC staff supports these projects by assisting with project selection, recommending appropriate background literature, assisting with data analysis, and collaborating with the student to disseminate project results in conferences and publications.
6. **Teaching Portfolio.** Students develop a teaching portfolio that includes at least the following:
 - a statement of teaching philosophy;
 - a description of teaching responsibilities over the student's tenure at the university;
 - a reflective summary of undergraduate student evaluations of their teaching, covering at least two semesters of classes; and
 - a statement about their efforts to improve their teaching and contribute to broader discussions of teaching and learning.

We encourage the students to participate in a two-day workshop on how to build a teaching portfolio that is offered by the campus Center for Teaching Excellence. The TLC staff reviews the portfolio with each of our CLFS UTLP participants to help them finalize the portfolio.

CLFS UTLP Participant Feedback

Since its creation in 2010, twenty students have formally registered in the CLFS UTLP program. Five graduate students have finished the program, two graduated without finishing the program, and the remainder are still participating. An independent, outside science education evaluator, who had no previous involvement with the UTLP program or the CLFS TLC, conducted interviews with the five students who completed the program and the two who decided to leave the program. In addition, she conducted interviews with two advisors of CLFS UTLP participants who completed the program, the Director of the campus CTE, and the associate dean for graduate

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studies in CLFS. Below we provide demographic background for the interviewees. At the time of the interviews, all the CLFS UTLP interviewees were between the ages of 27-31. (All interviewee names are pseudonyms.)

- **Sharon:** Female; completed MS in biological sciences; currently employed at a non-profit foundation focused on science literacy.
- **Linda:** Female; completed MS in biological sciences; currently employed at a science library.
- **Stephanie:** Female; completed PhD in biological sciences; currently a postdoctoral researcher at a U.S. government agency.
- **Katie:** Female; completed PhD in biological sciences; currently employed as a lecturer in biological sciences.
- **Robert:** Male; completing PhD in chemistry and biochemistry.
- **Jenna:** Female; completing PhD in biological sciences but decided not to complete the UTLP certificate.
- **Tina:** Female; completing PhD in biological sciences but decided not to complete the UTLP certificate.

The five graduates who completed the CLFS UTLP program were asked to complete an online survey constructed by CLFS TLC staff and the independent researcher. The survey respondents were then interviewed to clarify and expand upon the answers they provided in the survey. The two students who left the program were interviewed only and did not complete the online survey. The interviews (which followed a semi-structured protocol) were voice recorded and transcribed. The online survey included two sets of Likert-style questions. One set of questions asked the participants to reflect on the importance of each CLFS UTLP program component in their decision to participate (from 1=very little influence to 5=most influence). The other set of questions asked them to reflect on the value of each program component (from 1=no value to 5=most value). Additional questions probed the students' motivation to participate in the program, their satisfaction from and challenges in the program, and how they thought the program could be improved. Two science education researchers separately analyzed the interviews and survey data to define emergent themes. Then, they negotiated the findings until they could agree upon the themes (Maykut & Morehouse, 1994).

We also examined the students' original CLFS UTLP applications. Upon registration in the program, students completed a short survey, in which they provided background information (e.g., teaching experience, name of

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research advisor, and expected date of graduation), as well as a brief (<500 word) statement on why they wanted to participate in the program.

Questions were sent by email to the research advisors of the CLFS UTLP program graduates for their perspectives on how participation in the program affected the students' degree progress and professional development. Two biology professors with administrative roles were also interviewed to gauge their perspective on the program.

Motivation to Participate in the CLFS UTLP

At the time of application to the program, the GTAs expressed their enjoyment of teaching and the pleasure that they derived from previous teaching experiences. The word "passion" was often used. Katie said, "I have been passionate about teaching for a long time. I worked as a science teaching assistant for summer science programs for children; then in college I minored in education." Linda wrote that she had worked with an after-school program for four years and that she had "a deep passion and dedication towards education."

All applicants also mentioned the importance of educating others and learning how to do this well. Katie claimed, "I plan on continuing teaching throughout my career and would like to be an effective educator and learn more approaches to engage students and increase their knowledge." Sharon explained how the program helped her to be a better teacher, "I believe that it will give me an outlet for discussing and reflecting on my own teaching methods and goals."

Linda referred to how science GTAs generally lack background knowledge of education theories and best practices, which negatively impacted their teaching:

Not having an undergraduate background in education means that many TAs including myself simply do not know much about current theories and practices in education. Too many times we rely just on lectures, when we should be engaging students in active learning, seeking ways to appeal to different learning styles, and designing creative approaches to achieve learning outcomes.

Robert stressed that although he always strived to provide his students "a rich, deep, and meaningful experience of science," this goal was not easy

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to reach, and he believed that by participating in the CLFS UTLP, he would “be able to develop skills necessary to foster this process.”

Another reason for signing up for the program that was mentioned by most of the applicants related to their future plans and career aspirations. Linda mentioned that she believed that her participation in the program “would be a huge step towards achieving my goal of improving education both in our institution and in my future career.” Katie explained how completing the program would make her more prepared for her future career, “participating in this program, and therefore learning valuable educational skills as well as preparing a teaching portfolio will help in the application process in order to become a college educator.”

In the online survey that we sent to our interviewees prior to the interview, we asked them to rate the level of influence that each of the program components had on their decision to participate in the CLFS UTLP (Table 1).

Table 1: Average ratings of the College of Chemical and Life Sciences University Teaching and Learning Program components with respect to the importance of each component in the student’s decision to participate in the program (where 1=very little influence; 5=most influence) and the perceived value of each component at the end of the program (where 1=no value; 5=most value).

Component	Importance in Participation Decision (Average)	Most Valued (Average)
Science teaching course	4.2	4.8
Teaching portfolio	4.0	4.8
Flexibility of the program (with respect to order of components)	4.0	3.8
Self-pacing of the program (timing of participation)	4.0	3.8
Technology workshops	3.8	3.2
Teaching project	3.8	4.8
Publishing and presenting about college-level STEM teaching	3.6	4.0
Workshops	3.6	4.2
Observing faculty members teaching	2.8	3.0
Being mentored	2.4	2.4
Research advisor’s encouragement	2.2	3.2

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The component that received the highest average score in motivating student participation was the two-credit science teaching course. In the interview, one student explained how the course instructor influenced her decision to join the program, and another noted the social aspects of the course:

I knew about the program but I wasn't sure if it was going to be worth the time and effort until I was doing the 2-credit class in higher education. I was interested in the topic...and the instructor sold it well in there. She said, well, you're already in the course, you're already going to these seminars, all you have to do is the project. And also it was nice networking. So I ended up working with someone else from that class on the research project and I think all of us from that class ended up doing the UTLP. (Katie)

[In the course] You could kind of meet and talk about what was going on in your teaching, and we did a lot of reading and little write-ups. It really made me think, and talking to other people, seeing what their experiences were, was really good. It gave me some ideas. (Linda)

Other components that rated as highly influential in motivating the students' decision to participate were the flexibility of the program, the self-paced nature of the program, and the opportunity to create a teaching portfolio. The components that were the least influential were observing faculty members teaching, being mentored in teaching by a faculty member, and their research advisor's encouragement. From the interviews, we learned that only one of the five students who completed the program had the unequivocal support of her research advisor. In this case, the research advisor wanted to learn from her student's experience since the advisor felt she did not have sufficient time to participate in professional development activities for faculty. The student noted, "She was very supportive....She wanted to know everything that I was learning, the cliff notes, because she didn't have the time to attend everything" (Stephanie). Two students said that their advisors did not have strong opinions either way towards their participation in the program, and two students reported that they didn't have the support of their advisors to participate in the program.

Overall, three themes emerged from the interviews regarding student motivation to participate in the program:

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1) The excitement about the value of science that the graduate students wanted to share with students, "I think science explains the world.... Especially using research as a tool for teaching" (Katie). "I love working with students. I love helping them understand and figure things out on their own and watch them become more independent." (Stephanie).

2) Earning a teaching certificate and acquiring skills for specific potential teaching jobs, "I think it diversifies you a bit [when you apply for a new job], it helps you stand out, and it helps prepare more that science education side..." (Katie).

3) A general understanding that learning how to teach science is a good exercise for honing communication skills more generally, "...what you really learn... is how to be careful about knowing that different students or different people in society are different learners....When you want to teach, you have to consider these things" (Robert); "I think that as an aspect of science, not only we need to be good at asking the right questions and finding the answers, but also to be able to communicate it to other people" (Tina).

Perceived Value of Individual Program Components

In the online survey, the CLFS UTLP participants were asked to reflect on the value of each program component (Table 1). The components that received the highest average scores were the science teaching course, the teaching portfolio, and the teaching project. In the interviews, Sharon and Robert explained why they rated the course as highly valued and gave examples of how they planned to use what they learned from the course in their future teaching:

I think just learning about best practices and different types of teaching approaches helped me reflect on the class and my own teaching. Yes, that was certainly useful, for myself, for my own teaching when I was TA-ing, also just knowing more about it [science teaching] so that I would be able to speak more intelligently about it to people who are in education. (Sharon)

I can go over a few of [the activities that we had in the course] like having an active interaction with the students, having an animated teaching style rather than standing still at the podium or looking at the board. Those are very helpful....I

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wasn't conscious about it before that, but I became very conscious and I think it's very helpful. (Robert)

Students also reflected on the usefulness of creating the portfolio and working on the teaching project:

I think the teaching portfolio was really important. I could never have done that on my own. That was a great workshop to attend. (Linda)

The portfolio workshop was fantastic. I give that a stellar 105%. (Stephanie)

I worked with another person from the UTLP program on that [the teaching project], and we got to work with undergrad students. We did an actual controlled test for these different teaching approaches. We ended up presenting that work at a conference, got that paper published, so it's already been submitted and we're just working on the reviews. (Sharon)

Students were required to attend at least seven 90-minute workshops, including at least one that focused on the effective use of technology to enhance teaching. Analysis of students' responses to the survey showed that the workshops on teaching with technology were not as highly valued as the workshops overall (average ratings of 3.2 and 4.2, respectively). When asked in her interview why she gave the workshop on teaching with technology a poor rating (2), Sharon responded,

There was only 1 or 2 workshops that I went to about technology and it was a clickers workshop. At that point, I had been a lecture TA for my advisor and so I had some experience with clickers and I guess what was I expecting was more discussion about how to incorporate technology effectively in the classroom, as opposed to just how to use the hardware, software.

The program component that received the lowest average score was the one that involved being mentored by a faculty member (2.4). Students

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reflected that they did not benefit from this as much as other program components. In the interviews, we probed why this component fell short of their expectations. Students indicated that they had hoped to have developed a better connection with their mentors and to have received more guidance from them. As Linda and Sharon explained,

...I think that they [faculty mentors] observe you 2 or 3 times and you just meet and they talk to you after that. For me, I didn't get that much out of it, like, just you know meeting with someone 2 or 3 times. I didn't establish a link where that was helpful to me. (Linda)

I thought that [the faculty mentor component] was a really nice aspect of it, I think maybe focusing a little bit more on that would really be good. I don't know, I kind-of feel like, is there any way to get the faculty a little bit more involved, because we want to be able to find the teachers who are just really great teachers. You want to be able to find those people and talk to them and figure out what they learned. (Sharon)

Overall we learned from the interviews that students are satisfied and see the value of the UTLP components that are offered by our center and the campus center. Students though pointed out that their advisors are not always supportive of the program, and faculty mentors are not involved enough in the program. We are working to strengthen these aspects. Our college is now involved in systematic redesign of foundational courses within the undergraduate curriculum, an initiative that is actively promoted by the Dean. This has increased faculty awareness of the importance of teaching in higher education.

Factors that Facilitate or Hinder Progress towards Certificate Completion

Three themes emerged from analyzing the participants' responses to this question. The disciplinary nature of the program and the interaction with the CLFS TLC staff were mentioned only as a positive aspect. The flexibility of the program was mentioned by some as facilitating their progress, but by others as hindering their progress in the program. The last theme concerned the level of support provided by the research advisor.

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The disciplinary nature of the program and interaction with TLC staff

In our college, all new GTAs are required to attend a six-week mandatory training course offered through the departments. These courses emphasize practical training in science teaching, such as how to run a recitation discussion, how to communicate with students, how to evaluate students, and how to employ different teaching approaches. The students who choose to participate in the certificate program are provided with broader perspectives of science education. They learn about a range of science education theories (e.g., constructivism, learning progressions, multiple intelligences, and learning styles) and the theoreticians who have influenced the development of science education theories (e.g., Bruner, Piaget, Vygotsky, Dewey, and Bloom). They learn how to build “teachable units” according to the backwards design model (Wiggins & McTighe, 1998), employ evidence-based teaching approaches, and use innovative assessment tools (Handelsman, et al., 2007). The campus UTLP program emphasizes education theories and practices in general while the CLFS UTLP emphasizes the specific ways in which teaching theories are applied to the sciences. The CLFS UTLP also provides detailed advice on how different teaching approaches can be adapted to overcome students’ alternative conceptions or deficiencies in prior knowledge. We emphasize components of PCK in all our activities (e.g., participants observe classes in their discipline, do a project related to their discipline, and practice their teaching skills in their discipline).

In the interviews, students mentioned that the key features that motivated them to apply and held their interest in the program was the disciplinary nature of TLC programming and the opportunity for regular, extensive interactions with TLC staff:

I think that’s [the disciplinary nature of the program] actually what kept me more interested, because some of the earlier things I attended were too broad, because it was all CTE-wide, and a lot of the things that apply to people in the humanities or the social sciences, maybe some basic techniques are there, but it wouldn’t have kept me going if she [the director of TLC] hadn’t been there to bring in all those interesting speakers specific for science. (Stephanie)

... So there is a university-wide program, but I’m very glad that it’s been subdivided so that I can go to seminars that are specifically about how to engage your students in authentic

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scientific research in a classroom. So it's a very focused type of teaching. And there are people that tell me that good teaching is good teaching whatever your subject matter is, but there are certain aspects of teaching science.... So I can go and say, I'm having problems helping my students understand this important aspect of DNA replication and it's not something that you see. It's something that you have to be able to visualize. What things have you done as a teacher teaching this specific thing that I can then incorporate so that they can understand. Whereas if I asked a history professor, you know I'm trying to do this, I would not get the same response.... It's more localized, more personal, and more focused. (Tina)

Linda mentioned the importance of the interaction with the TLC coordinator:

I guess some people might find it [the interaction with the mentor] valuable but to me it didn't...or maybe if we had more meetings, try to establish that relationship, but if I could have just had [the UTLP coordinator] as my mentor it would have been better for me because I interacted with her more.

Sharon explained how the relationships that she developed with the TLC staff helped her secure employment after graduation:

So I talked with [TLC staff members] about what can I do next, and they gave me some contacts, and I spoke with a number of different people, and so when I finally applied for the position that I'm working at right now, I think that probably helped me. I wouldn't have even known about them were it not for the connections that I made with UTLP.

It is noteworthy that all participants presented their teaching project at least once at a teaching and learning conference. The CLFS UTLP teaching projects resulted in two papers in peer-reviewed science education journals, involving three CLFS UTLP participants as co-authors. All participants requested letters of recommendation for future job applications from the CLFS

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TLC director, who was also the instructor of the two-credit science teaching course. In conversation with us, the UTLP participants mentioned how meaningful it was to them that someone knew them well enough to speak about their knowledge of and expertise in teaching and learning.

The flexibility of the program

The flexibility of the program with respect to pacing and the order of the components was seen by most of the students as an advantage, allowing them to progress through the program when they had fewer research or other demands on their time. Sharon explained how she benefited from this flexibility:

... And then I saw, the requirements were all really things that I thought could benefit me, so the fact that they took a little bit of time, that wasn't too much of an issue to me. It might have been if there had been a strict time limit on when you had to complete them, but there was a lot of flexibility in regards to how long you could take to finish all of the requirements. Because of that, it wasn't really an issue because I knew I had as much time as I needed.

Stephanie, however, mentioned that the flexibility allowed her to procrastinate: "...I stretched it out too much so by the time I did the majority of the stuff, I wasn't even teaching anymore." Through these interviews, we learned that it is important to keep track of the students' progression and remind them periodically to revisit the requirements of the program so that they are more likely to finish program requirements that are time sensitive (such as "being mentored," which can be completed only while they are teaching).

The lack of support from the advisor

CLFS UTLP participants repeatedly mentioned a lack of support from their research advisors. While we were aware that advisors had concerns about such programs, primarily relating to time constraints, the personal experiences of our participants helped us realize that this challenge is pervasive and requires careful consideration in professional development planning and implementation.

Robert explained that his advisor did not object to his participation but warned him a little: "Do you really want to do that [he said to me]? It's

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really a time commitment. Just be careful that you don't get trapped." Sharon explained that her advisor didn't see any value in the program and wanted her to focus on her research:

[My advisor was] not supportive...it's just that he wanted me to focus on my research. From his perspective, I was here to do that and only that and the fact that I had to TA was only because I needed tuition remission. He didn't really see much, if any value in that. But I think that's, I don't think, necessarily unique to him. I think that a lot of professors think that.

Jenna, who eventually quit the program, explained that her "advisor thought that it wasn't a priority right now," and did not make funding available for her to take the required science education course. Tina, who also decided to leave the program, referred to a miscommunication with her advisor:

I'm going to start looking for a job, and I think she [my advisor] may be under the impression that I'm going to go one direction and I'm not. So I'm perfectly open to taking a teaching position and maybe research for a while, but ideally I would like to stay in research and teach at the same time, but if that doesn't work there are lots of different options. And I don't think I'm going to stay in academia at a principally research institution. If I go somewhere, I think it will be small, liberal arts, primarily undergraduates, where teaching is the main focus and research is done on the side....

Tina also stressed that she believed it was important for advisors to support and promote the UTLP programs:

I would like to see greater support from faculty to encourage their students to complete it. I think that by not emphasizing it, they're doing their students a disservice in some ways. It isn't something with the program itself, but maybe advocacy or awareness to say this is a really good idea, you should really learn to do this, because at some point we're going to

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teach, whether it's in a formal teaching sense, type of environment where you get up and you're teaching a microbiology class, or whether it's, you're giving a presentation at a scientific meeting. Both of them are teaching, just at different settings. So if there were a bit more emphasis and value placed on good teaching, I think that would encourage students to do this a little bit more. Other than that, I think the requirements are not unattainable, they're something that you can do while pursuing all of the research responsibilities that are placed on you.

Impact of UTLP Participation on Career Development

As noted above, all the UTLP participants who graduated from the program requested and received a letter of recommendation from the TLC director. When asked about this, they reflected that the TLC director had interacted with them in multiple contexts, including as the instructor of the 2-credit course, so she could write a substantial recommendation on their behalf. This highlights the important role of UTLP participation in career advancement. We asked Katie, who had obtained a full-time university teaching position following completion of her PhD, how the certificate program had enhanced her teaching, particularly her understanding of and interest in the scholarship of teaching, her technical skill as a teacher, her awareness of how to address student needs, and her interest in the teaching process. Katie's response provided us with a broad input:

The University Teaching and Learning certificate program provided me with the resources and support to transition from being interested in the scholarship of teaching to becoming actively involved in it. Without participating in the UTLP program, I would not have conducted (and published) original science education research as a graduate student. Without question, the science education research experience I gained through the UTLP was a valuable asset. First, this experience helped me obtain jobs. At both my current and previous position I discussed my involvement and findings of the UTLP science education research during my interview. Further, I have used the findings of this research to guide my own classroom curriculum to promote both student learning and positive options of science. Ultimately,

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this experience fostered my interest in science education research which has led to my continued involvement in science education research. In addition to assisting in the development of a science education research project, the UTLP program allowed me to become part of network of individuals interested in promoting best teaching practices. Years later, I continue to discuss science teaching and research with faculty and students who were involved in the TLC and the University Teaching and Learning Program.

Faculty and Administrator Perspective on the Value of the Certificate Program

In order to better understand the faculty and administrators' perspective on the value of the CLFS UTLP, we interviewed two tenured biology professors who at the time of the interviews also held administrative positions related to the CLFS UTLP. We also posed several questions via email to the four research advisors of the CLFS UTLP participants who had completed their graduate programs (Robert had completed all the requirements of the CLFS UTLP certificate but not yet completed his Ph.D., so his advisor was not contacted). We received responses from two advisors.

One administrator whom we interviewed was the associate dean of graduate studies in CLFS at the time that the CLFS UTLP was initiated. He provided guidance in structuring the program to best meet the needs of CLFS graduate students and alleviate the potential concerns of CLFS faculty. While very supportive of the program, he was cognizant of the long-standing tension between research and teaching in graduate training: "The graduate school education system, has been set up financially to move the students through with grant funding that has time limits, therefore, most science faculty want their students to be laboratory workers, dedicated to their research." As a result, he continued, "the graduate students don't learn how to write a CV, talk to journalists, interview for jobs in business, or manage a staff." The associate dean explained that he supported the initiation of the CLFS UTLP, because in reality, most students who earn a doctorate in science will not have an academic career, because "these jobs simply don't exist in the numbers being graduated." Many Ph.D.s, he said, may find themselves teaching at community colleges or at the pre-college level, and academia, as a whole, is just beginning to address these realities. At the end of the interview he suggested that "older faculty were more conditioned to the model of using graduate students as lab workers who had no time to think

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about their teaching responsibilities for the present or future, and that younger faculty members might be more open to change.”

The other administrator interviewed, who was the director of the campus Center for Teaching Excellence (CTE), was also involved in the initiation of the CLFS UTLP. He had a broad familiarity with graduate programs in other countries, and he remarked that, “in one country abroad graduate students must have 12 hours of professional development in teaching, and the U.S. is behind in preparing students for the job market in terms of teaching efficiency.” Like the associate dean, he noted the issue of limited time and competing priorities, which were ever-present. He noted that research has shown that a change of physical space or focus may, in fact, increase productivity, not deter it, and therefore broad preparation programs that include professional development in teaching could be more effective than programs based solely on research. He concluded the interview optimistically, saying that he believed that our university was moving in the right direction.

Although we received only two responses to our request for the research advisor’s perspective on their graduate student’s participation in the certificate program, the two responses represent opposing ends of the spectrum. One advisor said, “I can’t say for sure [how her certificate program impacted her work with me]. She didn’t say much to me about it.” It is noteworthy that his student had not characterized him as supportive advisor. The other advisor said, “I was very supportive of her enrollment [in the program] even though it may at times have affected her time spent in the lab.... After graduation, she [obtained a science education postdoctoral position where she] helped develop a cell biology lab module. I think her [UTLP] experience may have helped her securing that position.”

Discussion

Given the changing nature of STEM careers for those with advanced degrees (Boyer Commission, 2002; Fox & Stephan, 2001) and the ongoing transformation of undergraduate education (Association of American Universities, 2011; NRC, 1996; NSF, 1998; President’s Council of Advisors on Science and Technology, 2012), it is important to go beyond a perfunctory, short-duration teaching preparation course to offer graduate students the opportunity to develop substantive expertise in teaching. We recognize that not all graduate students would or should avail themselves of this option, but programs such as the CLFS UTLP address a very real need in graduate education, and our experience shows that these disciplinary-centered programs

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can have a positive impact on the career development of the very large number of STEM graduate students who intend to become educators.

Our findings show that the GTAs' motivation to participate in the UTLP program came from a strong interest in communicating their own enjoyment of science to others and an awareness of the importance of developing good communication skills in general. Overall, we found that the disciplinary nature of the program and the opportunity for regular interactions with the college TLC were important to the GTAs, concurring with Shulman's support for disciplinary teaching approaches (Shulman, 1986). The quality of the science teaching course was appreciated. The flexibility of the program's design was valued by and useful to most participants.

One valuable UTLP participant recommendation for improving the program was to advertise the program to students in the early stages of their graduate training, so that they could plan to complete certain components of the program (e.g., being observed while teaching) during semesters in which they held teaching assistantships. It was also advantageous for participants to enroll in the two-credit course at this time, since the tuition for the course would be covered by the tuition remission provided by their teaching assistantship.

UTLP graduates also suggested the program would benefit from increased faculty support and involvement. They reported experiencing varying degrees of support from the faculty with whom they interacted. This was consistent with the relatively low survey ratings for the value of observing faculty, being mentored, and the advisor's encouragement. The students' comments were echoed by the administrators whom we interviewed. The issue of faculty endorsement of GTA professional development in teaching reflects the subtle but pervasive tension between research and teaching in academia, particularly within research intensive universities. This provides the underlying context for the experiences of graduate students. In addition, graduate programs value timely completion of degree requirements. Graduate student funding typically derives from faculty grant support or university teaching assignments, both of which require a substantial investment of time. Programs such as the UTLP are sometimes viewed as competing for a graduate student's limited time, and so are not always viewed favorably by faculty research advisors. Nevertheless, this research shows that the CLFS UTLP program is seen as a valued complement to research training for those who choose it. They are the few that have decided to take some time to concentrate on their teaching skills alongside their graduate research.

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In light of the growing emphasis on improving STEM learning in all educational contexts, we believe that the active endorsement of professional development in teaching is essential at all levels of university administration. University leaders can help by sending a strong and consistent message that high quality instruction is expected of all faculty and teaching assistants. Departmental leadership can reinforce this message by encouraging faculty to be more involved in (or, at least, more supportive of) graduate student teaching preparatory programs.

The staff of our disciplinary TLC work closely with the college and departmental leadership, serving as ambassadors for science education to communicate its importance to science researchers and advocate for including professional development in science teaching as an integral part of science graduate programs.

In our college, with the blessing of the department chairs, all biology and chemistry GTAs must complete a six-week preparatory course for teaching. The TLC director helps facilitate these courses and is therefore able to inform students of opportunities for more intensive science education training such as the UTLP. Students reported that they developed strong relationships with CLFS TLC staff, who helped them in finding jobs and in disseminating their teaching projects in science education conferences and journals. Although relatively few now spend the extra time and effort to earn additional teaching credentials, our experience indicates that these credentials broaden the job prospects of UTLP graduates and can perhaps even make them more attractive candidates for faculty positions. We hope that these positive outcomes will ensure growing support for the program among faculty. We further believe that the disciplinary focus of the certificate program, which relies on the deep involvement of the CLFS TLC, serves as a model for professional development that is responsive to the specific needs of STEM graduate students.

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