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Article

Modeling Sources of Teaching Self-Efficacy for Science, Technology, Engineering, and Mathematics Graduate Teaching Assistants

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Graduate teaching assistants (GTAs) in science, technology, engineering, and mathematics (STEM) have a large impact on undergraduate instruction but are often poorly prepared to teach. Teaching self-efficacy, an instructor's belief in his or her ability to teach specific student populations a specific subject, is an important predictor of teaching skill and student achievement. A model of sources of teaching self-efficacy is developed from the GTA literature. This model indicates that teaching experience, departmental teaching climate (including peer and supervisor relationships), and GTA professional development (PD) can act as sources of teaching self-efficacy. The model is pilot tested with 128 GTAs from nine different STEM departments at a midsized research university. Structural equation modeling reveals that K–12 teaching experience, hours and perceived quality of GTA PD, and perception of the departmental facilitating environment are significant factors that explain 32% of the variance in the teaching self-efficacy of STEM GTAs. This model highlights the important contributions of the departmental environment and GTA PD in the development of teaching self-efficacy for STEM GTAs.

Science, technology, engineering, and mathematics (STEM) graduate teaching assistants (GTAs) play a significant role in the learning environment of undergraduate students. They are heavily involved in the instruction of undergraduate students at master's- and doctoral-granting universities (Nyquist *et al*., 1991; Johnson and McCarthy, 2000; Sundberg *et al*., 2005; Gardner and Jones, 2011). GTAs are commonly in charge of laboratory or recitation sections, in which they often have more contact and interaction with the students than the professor who is teaching the course (Abraham *et al*., 1997; Sundberg *et al*., 2005; Prieto and Scheel, 2008; Gardner and Jones, 2011).

Despite the heavy reliance on GTAs for instruction and the large potential for them to influence student learning, there is evidence that many GTAs are completely unprepared or at best poorly prepared for their role as instructors (Abraham *et al*., 1997; Rushin *et al*., 1997; Shannon *et al*., 1998; Golde and Dore, 2001; Fagen and Wells, 2004; Luft *et al*., 2004; Sundberg *et al*., 2005; Prieto and Scheel, 2008). For example, in molecular biology, 71% of doctoral students are GTAs, but only 30% have had an opportunity to take a GTA professional development (PD) course that lasted at least one semester (Golde and Dore, 2001). GTAs often teach in a primarily directive manner and have intuitive notions about student learning, motivation, and abilities (Luft *et al*., 2004). For those who experience PD, university-wide PD is often too general (e.g., covering university policies and procedures, resources for students), and departmental PD does not address GTAs'

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specific teaching needs; instead departmental PD repeats the university PD (Jones, 1993; Golde and Dore, 2001; Luft *et al*., 2004). Nor do graduate experiences prepare GTAs to become faculty and teach lecture courses (Golde and Dore, 2001).

While there is ample evidence that many GTAs are poorly prepared, as well as studies of effective GTA PD programs (biology examples include Schussler *et al*., 2008; Miller *et al*., 2014; Wyse *et al*., 2014), the preparation of a graduate student as an instructor does not occur in a vacuum. GTAs are also integral members of their departments and are interacting with faculty and other GTAs in many different ways, including around teaching (Bomotti, 1994; Notarianni-Girard, 1999; Belnap, 2005; Calkins and Kelly, 2005). It is important to build good working relationships among the GTAs and between the GTAs and their supervisors (Gardner and Jones, 2011). However, there are few studies that examine the development of GTAs as integral members of their departments and determine how departmental teaching climate, GTA PD, and prior teaching experiences can impact GTAs.

To guide our understanding of the development of GTAs as instructors, a theoretical framework is important. Social cognitive theory is a well-developed theoretical framework for describing behavior and can be applied specifically to teaching (Bandura, 1977, 1986, 1997, 2001). A key concept in social cognitive theory is self-efficacy, which is a person's belief in his or her ability to perform a specific task in a specific context (Bandura, 1997). High self-efficacy correlates with strong performance in a task such teaching (Bandura, 1997; Tschannen-Moran and Hoy, 2007). Teaching self-efficacy focuses on teachers' perceptions of their ability to "organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context" (Tschannen-Moran *et al*., 1998, p. 233). High teaching self-efficacy has been shown to predict a variety of types of student achievement among K–12 teachers (Ashton and Webb, 1986; Anderson *et al*., 1988; Ross, 1992; Dellinger *et al*., 2008; Klassen *et al*., 2011). In GTAs, teaching self-efficacy has been shown to be related to persistence in academia (Elkins, 2005) and student achievement in mathematics (Johnson, 1998). High teaching self-efficacy is evidenced by classroom behaviors such as efficient classroom management, organization and planning, and enthusiasm (Guskey, 1984; Allinder, 1994; Dellinger *et al*., 2008). Instructors with high teaching self-efficacy work continually with students to help them in learning the material (Gibson and Dembo, 1984). These instructors are also willing to try a variety of teaching methods to improve their teaching (Stein and Wang, 1988; Allinder, 1994). Instructors with high teaching self-efficacy perform better as teachers, are persistent in difficult teaching tasks, and can positively affect their student's achievement.

These behaviors of successful instructors, which can contribute to student success, are important to foster in STEM GTAs. Understanding of what influences the development of teaching self-efficacy in STEM GTAs can be used to improve their teaching self-efficacy and ultimately their teaching. Therefore, it is important to understand what impacts teaching self-efficacy in STEM GTAs. Current research into factors that influence GTA teaching self-efficacy are generally limited to one or two factors in a study (Heppner, 1994; Prieto and Altmaier, 1994; Prieto and Meyers, 1999; Prieto *et al*., 2007; Liaw, 2004; Meyers *et al*., 2007). Studying these factors in isolation does not allow us to understand how they work together to influence GTA teaching self-efficacy. Additionally, most studies of GTA teaching self-efficacy are not conducted with STEM GTAs. STEM instructors teach in a different environment and with different responsibilities than instructors in the social sciences and liberal arts (Lindbloom-Ylanne *et al*., 2006). These differences could impact the development of teaching self-efficacy of STEM GTAs compared with social science and liberal arts GTAs. To further our understanding of the development of STEM GTA teaching self-efficacy, this paper aims to 1) describe a model of factors that could influence GTA teaching self-efficacy, and 2) pilot test the model using structural equation modeling (SEM) on data gathered from STEM GTAs. The model is developed from social cognitive theory and GTA teaching literature, with support from the K–12 teaching self-efficacy literature. This study is an essential first step in improving our understanding of the important factors impacting STEM GTA teaching self-efficacy, which can then be used to inform and support the preparation of effective STEM GTAs.

MODELING PREDICTORS OF STEM GTA TEACHING SELF-EFFICACY

SEM

Prior research on GTA teaching self-efficacy has been done using basic correlational, regression, or comparative statistics (e.g., Prieto and Altmaier, 1994; Liaw, 2004; DeChenne *et al*., 2012b). In SEM, models can be developed, tested, and refined with multiple factor interactions and impacts on an outcome variable. The advantages of SEM over alternative methods include: estimates of measurement error in all variables, incorporation of both observed and latent variables, and estimation of indirect effects (Bryne, 2006). SEM allows the determination of direct and indirect effects of multiple factors on teaching self-efficacy to be tested within a single statistical model. The model to be tested is assembled from the theoretical framework of social cognitive theory and the GTA literature. To maximize the development of the model, the GTA literature searched includes GTAs from all disciplines. It uses conventions of SEM in which boxes indicate observed variables and ovals represent latent variables. Observed variables are those that can be directly measured, such as time spent in PD. Latent variables are those that cannot be directly observed, such as teaching self-efficacy, and are measured instead through a series of validated questions that implicitly measure the concept.

Social Cognitive Theory

Social cognitive theory (Bandura, 1977, 1986, 1997, 2001) describes human behavior from both internal (personal) and external (social and environmental) sources. Self-efficacy is a central concept in social cognitive theory. It plays such a pivotal role because it interacts with both internal sources (e.g., motivations and beliefs) and external sources (e.g., actions, experiences, and environments) to contribute to the acquisition of knowledge and skills (Bandura, 1997). Self-efficacy is not what a person does with his or her skills but what he or she perceives can be done with those skills under various circumstances. Self-efficacy affects perseverance, effort, and resilience in the face of difficulties as well as a person's thought patterns and emotional reactions (Bandura, 1997).

Self-efficacy beliefs are formed through four sources: mastery experiences, vicarious experiences, social persuasions, and physiological and affective states (Bandura, 1986, 1997). Mastery experiences result from actually performing the skill; some failure early on followed by striving and success seem to produce the highest levels of self-efficacy. It is not just the mastery experiences themselves but also how the person cognitively processes them that affect self-efficacy (Bandura, 1997). In STEM GTAs, teaching in a variety of settings should provide these mastery experiences. Vicarious experiences allow people to develop self-efficacy through watching a similar person model the skill being developed. Observing multiple skilled models produces a stronger self-efficacy than simply watching one person. Vicarious experiences can be built into a GTA PD through observation of other GTAs teaching. Mastery experiences and then vicarious experiences comprise the two most important sources of self-efficacy (Bandura, 1997). Verbal persuasion works best to improve self-efficacy when the persuader is a personal model who is encouraging during a struggle to master a skill. Verbal persuasion also has a stronger impact during the early stages of skill development. Mood and physiological feedback can influence how a person cognitively processes an experience, thereby affecting the self-efficacy derived from that particular experience (Bandura, 1997). Tschannen-Moran *et al*. (1998) theorize that these four sources of self-efficacy act through the individual's cognitive processing related to the teaching task, the context of the task, and the individual's assessment of his or her personal teaching competence. Then the experiences form a sense of self-efficacy about that teaching task.

Teaching self-efficacy in GTAs has been shown to have complex interactions with PD, supervision, and teaching experience across disciplines (Heppner, 1994; Prieto and Altmaier, 1994; Prieto and Meyers, 1999; Prieto *et al*., 2007; Liaw, 2004; Meyers *et al*., 2007). Teaching self-efficacy in the K–12 setting has also been shown to interact with the organizational teaching climate (Tobin *et al*., 2006). A thorough review of the GTA literature and the social cognitive theoretical framework suggests dividing the factors for the model into three areas: GTA PD, teaching climate of the STEM GTA's department, and GTA teaching experience.

GTA PD

GTA PD should provide plenty of sources for the improvement of teaching self-efficacy, including mastery and vicarious experience as well as verbal persuasion. However, prior research indicates mixed results for the impact of GTA PD on GTA teaching self-efficacy. Some studies of specific GTA PD courses show an increase in teaching self-efficacy after the PD (Hardre, 2003; Burton *et al*., 2005; Meyers *et al*., 2007; Komarraju, 2008; Young and Bippus, 2008; Sargent *et al*., 2009). Others show a minimal correlation between PD and teaching self-efficacy (Prieto and Altmaier, 1994) or no significant impact of PD on teaching self-efficacy (Tollerud, 1990; Prieto and Altmaier, 1994; Liaw, 2004). In prior studies, GTA PD is only measured directly: hours of PD, presence or absence of PD, or number of PD courses. Given the wide variety of quality in GTA PD (e.g., Bray and Howard, 1980; Jones, 1993; Shannon *et al*., 1998; Davis and Kring, 2001; Hardre, 2003; Luft *et al*., 2004), it is not surprising that direct measures of GTA PD have given rise to the contradictory results reported in the literature. Recently, latent measures of quality show a strong correlation between quality of PD and teaching self-efficacy (Knobloch, 2006; DeChenne *et al*., 2012b) and between quality of PD and hours spent in PD (DeChenne *et al*., 2012b).

Departmental Teaching Climate

Three departmental teaching climate factors are found in the GTA literature to have an impact on teaching self-efficacy or GTA teaching: a facilitating environment, supervisory relationships, and peer relationships. These three departmental teaching climate factors are also supported from the transfer of training literature, which indicates that for workplace training to be implemented successfully by the employee there needs to be a positive work climate and supervisor- and peer-support systems (Burke and Hutchins, 2007). In the only study on transfer of GTA PD, Notarianni-Girard (1999) found there are factors in the GTA work environment that facilitate the transfer of GTA PD to teaching in the classroom. A facilitating environment for the transfer of GTA PD is one in which the department provides GTA PD, supports new teaching ideas generated by the GTAs, and provides resources to implement ideas learned during GTA PD (Notarianni-Girard, 1999). GTAs are also most satisfied with their GTA PD when those PD methods relate directly to the practice of teaching (Prieto and Scheel, 2008). Although little effort has been made to link the effect of a facilitating environment to teaching self-efficacy for GTAs, similar items do predict teaching self-efficacy in K–12 teachers (Tobin *et al*., 2006).

A departmental relationship that could influence GTA teaching self-efficacy is one with their teaching supervisor, who could provide verbal persuasions through support, encouragement, and feedback on the GTAs' teaching, which should help them cognitively process their mastery experiences during teaching. Studies indicate that most GTAs have teaching supervision, usually from faculty (Prieto, 1999; Prieto and Meyers, 1999; Prieto *et al*., 2007), but the supervision varies highly in quality (Notarianni-Girard, 1999; Prieto, 1999; Calkins and Kelly, 2005). In a qualitative study of teaching self-efficacy, GTAs report supervisors' comments and support as important for their teaching self-efficacy (Mills and Allen, 2007). Quantitative effects for the impact of the supervisor relationship on GTA teaching self-efficacy are mixed; no impact in one study (Prieto and Meyers, 1999) and positive in another study but complicated by interaction effects with PD (Prieto *et al*., 2007).

Another component of the departmental teaching climate is the peer group with whom a GTA interacts. Although research on the effects of the peer group on GTA teaching self-efficacy is not found, support of colleagues is a significant predictor of teaching self-efficacy in novice teachers (Tschannen-Moran and Hoy, 2007). GTAs are similar to novice teachers in that they seldom have extensive teaching experiences to draw upon to form their teaching self-efficacy and are more likely to be influenced by other sources of teaching self-efficacy, such as support through verbal persuasions from their peers. Additionally, GTAs report peer mentoring to be beneficial to their teaching (Park, 2004), and

GTAs in the same department are also likely to experience the same PD.

Teaching Experience

Generally, mastery experiences have the largest impact on teaching self-efficacy development (Bandura, 1997). Reflecting this, prior teaching experience is predominantly found to have a positive effect on GTA teaching self-efficacy (Tollerud, 1990; Prieto and Altmaier, 1994; Prieto and Meyers, 1999; Prieto *et al*., 2007; Liaw, 2004; Parker, 2014), although there a few studies that show no correlation (Burton *et al*., 2005; DeChenne *et al*., 2012b). Studies indicate that experience as a GTA is positively correlated with teaching self-efficacy (Tollerud, 1990; Prieto and Altmaier, 1994; Prieto and Meyers, 1999; Liaw, 2004), although the level of teaching responsibility can impact that relationship (Prieto *et al*., 2007). There are mixed results for other types of teaching experience; K–12 teaching experience positively impacts teaching self-efficacy in mathematics GTAs (Parker, 2014), but psychology GTAs show no correlation between professional teaching experience and teaching self-efficacy (Tollerud, 1990).

Model Development

Based on the evidence from the literature and social cognitive theory, a model of the factors that impact GTA teaching self-efficacy is developed (Figure 1). It is theorized that GTA PD should impact teaching self-efficacy (red oval and box in Figure 1). The GTAs' perception of quality of their PD is correlated with GTA teaching self-efficacy and is modeled as a direct effect. Evidence that time in GTA PD is correlated with GTA teaching self-efficacy is reflected in the model as a direct effect. Given that the GTAs' perception of quality of PD increases with hours of PD, hours of PD is also modeled to directly impact the GTAs' perception of the quality of their learning about teaching from PD (Figure 1).

The departmental teaching climate also impacts teaching self-efficacy (purple ovals in Figure 1). Perception of a facilitating environment is predicted to impact GTA teaching self-efficacy and GTA perception of the quality of GTA PD. Because a facilitating environment is also important to transfer of GTA PD, hours spent in PD is also predicted to impact the perception of a facilitating environment for GTA teaching. Based on the empirical evidence and theoretical model, supervision is modeled to impact GTA teaching self-efficacy.

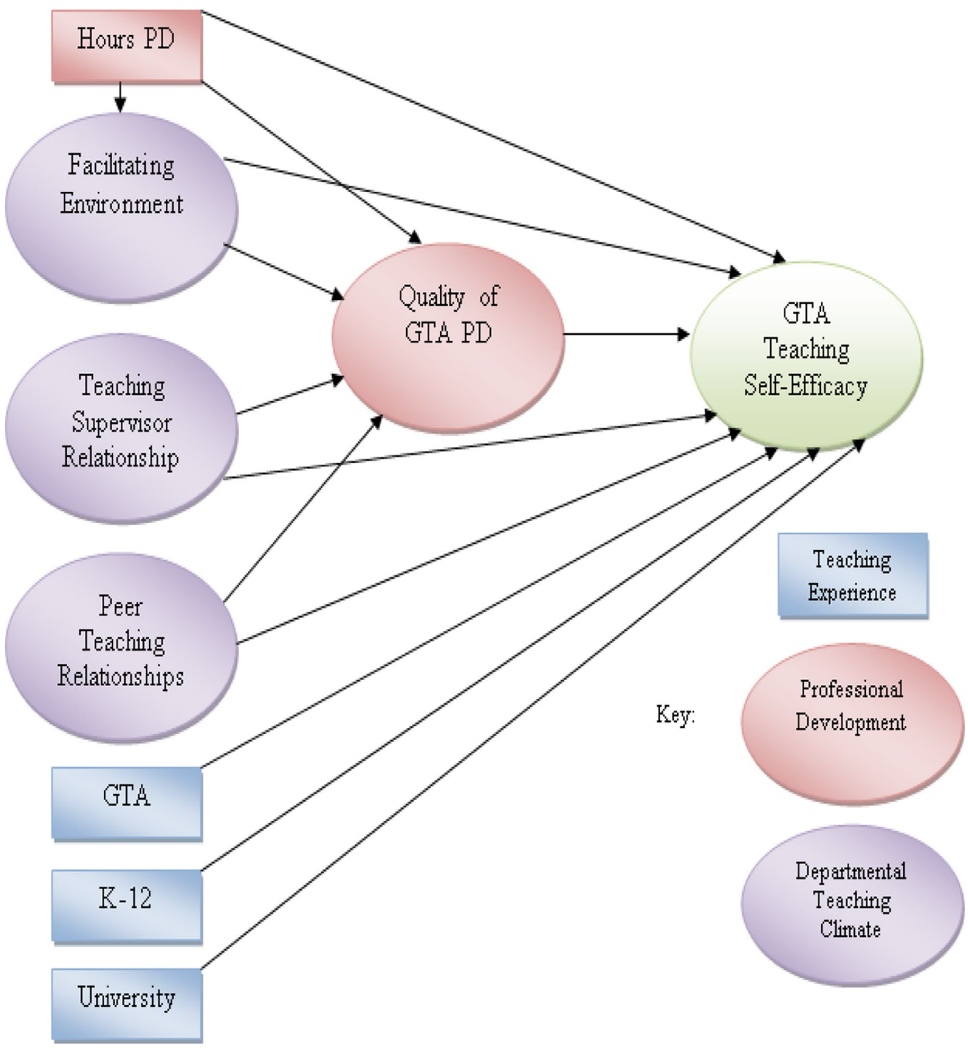

Figure 1. Proposed model of teaching self-efficacy for GTAs. In SEM, boxes indicate observed variables (directly measured), and ovals represent latent variables (indirectly measured). The blue boxes represent measures of teaching experience. The red oval and box represent measures of GTA PD. The purple ovals represent factors in the departmental teaching climate. These are all factors that are shown to impact GTA teaching self-efficacy (green oval) in the literature.

Also, because of the complex interactions seen between teaching supervision and GTA PD on teaching self-efficacy, supervision is also modeled to impact GTA perception of the quality of PD. Finally, GTA relationships with each other (peer teaching relationships) are modeled to impact both teaching self-efficacy and the perception of the quality of GTA PD (Figure 1).

In social cognitive theory, experiences are very important to the development of self-efficacy, which has also been shown in GTAs. Therefore, the teaching experience of GTAs impacts their teaching self-efficacy (blue boxes in Figure 1). It is expected that GTA teaching experience will affect GTA teaching self-efficacy. It is also possible professional (K–12 or university) teaching experience will impact GTA teaching self-efficacy (Figure 1).

METHODS

Context

Participants for this study were 128 STEM GTAs at a university in the western United States with a Carnegie basic classification of research universities with very high research activity. Participants were recruited from two colleges: science and engineering. Science departments were chemistry, geosciences, microbiology, physics, and mathematics. Engineering departments were chemical, biological, and environmental; civil and construction; electrical and computer science (EECS); and mechanical, industrial, and manufacturing.

GTA teaching assignments were variable among the STEM GTAs in this sample. In the College of Engineering, the GTAs were moved to research assistantships generally before the end of their second year in graduate school, while in the College of Sciences, that occurred later in their graduate studies, with more graduate students staying on teaching assistantships throughout their graduate degrees (Table 1). The College of Engineering and College of Sciences had a similar number of GTAs teaching in laboratories (54% vs. 43% respectively). However, there was a difference in recitation GTAs (21% engineering; 51% science) and GTAs in the lecture classroom (25% engineering; 6% science) between the colleges.

Hours of STEM GTA PD was determined from university-level and departmental-level GTA PD. Although this factor was statistically similar between the two colleges (Table 1), there was a large amount of variation in departmentally provided GTA PD between the departments in this sample. Some of the departments in the sample provided no departmental PD for their GTAs, although some of these departments allowed their GTAs to take other departments' GTA PD courses. Most departments had GTA PD for up to a week before the first quarter the GTA taught. Several of the departments required a quarter-long, one- to three-credit course in GTA PD during a GTA's first quarter. One department also had optional second- and third-quarter, three-credit courses in teaching for their GTAs (providing the possibility of a year of GTA PD for interested GTAs). This type of variation was common across the two colleges, with departments representing all the types of GTA PD (none, prequarter, and/or college credit) present in each college.

Administration

GTAs were administered a single questionnaire once near the end of the quarter. Data were collected from Fall 2008 through Fall 2009, and one of two administration techniques was used depending on department. The questionnaire was distributed to GTAs through the departmental mail system, collected in a sealed container in the departmental office, and picked up directly by a researcher. Alternatively, the

Table 1. Comparison of College of Science versus College of Engineering on demographics, teaching experience, GTA professional development, and departmental teaching climate

	College of Science[a]	College of Engineering[b]	Test statistic	p Value	Effect size	
					d	ϕ
GTA teaching self-efficacy	$M = 4.11$	$M = 4.19$	$t(126) = 0.97$	0.34	0.17	
Demographics						
Gender	39% female	15% female	$\chi^2(1) = 8.99$	<0.01		0.27
Nationality	33% international	50% international	$\chi^2(1) = 3.86$	0.05		0.17
Career choice	70% academic	63% academic	$\chi^2(1) = 0.72$	0.39		0.08
Teaching experience						
K–12 teacher	10%	8%	$\chi^2(1) = 0.16$	0.68		0.04
College teacher	56%	44%	$\chi^2(1) = 0.09$	0.77		0.03
GTA teaching experience	$M = 6.56$ quarters	$M = 4.08$ quarters	$t(122) = 2.84$	0.01	0.52	
GTA professional development						
GTA PD	$M = 22$ h	$M = 19$ h	$t(116) = 0.54$	0.59	0.10	
Quality of GTA PD	$M = 2.93$	$M = 3.31$	$t(120) = 2.11$	0.04	0.38	
Departmental teaching climate						
Teaching-supervisor relationship	$M = 3.87$	$M = 3.91$	$t(118) = 0.30$	0.77	0.05	
Peer teaching relationship	$M = 3.75$	$M = 3.80$	$t(122) = 0.40$	0.69	0.07	
Facilitating environment	$M = 3.35$	$M = 3.44$	$t(122) = 0.64$	0.52	0.12	

[a] $n = 67$.
[b] $n = 61$.

questionnaire was administered during a GTA PD class and collected by one of the researchers at that time. Care was taken not to duplicate GTAs in the sample. Departments, with the exception of EECS, were sampled one quarter only. EECS was sampled for two quarters (Fall 2008 and Fall 2009), and any GTAs who had participated in the prior Fall quarter were removed from the solicitation call. Therefore, each participant in this sample is represented once. There was a reasonable response rate (57% of all available GTAs; Baruch and Holtom, 2008); 186 GTA instruments were returned, eight instruments were not usable, and an additional 50 GTAs (who had primarily administrative duties such as grading and did not teach in the classroom) were not included in the analysis. The graders were removed, because Prieto *et al*. (2007) indicated differential teaching self-efficacy results for graders. Therefore, the participants in this study only included STEM GTAs with teaching responsibilities.

Statistical Analysis

SEM was used to test the hypothesized model (Figure 1) for factors that influence GTA teaching self-efficacy. Descriptive statistics, correlations, chi-square analysis, effect sizes, and t tests were evaluated in SPSS version 20. Confirmatory factor analysis (CFA) and SEM were evaluated in M*plus* version 6.1 (Muthen and Muthen, 1998–2010). Statistical significance was set a priori at < 0.05. Determining CFA for each instrument in the survey was the first step in running an SEM and was used in this study because there was an a priori theory-driven hypothesis that the individual items in each instrument were measuring that specific construct. Missing data at the item level was minimal (the average item nonresponse rate was 2%, with all items having a nonresponse rate < 0.07). However, for the overall SEM test, one case included missing data on one or more of the exogenous variables and was dropped (leaving the model test with 127 participants). Pairwise deletion was used in the calculation of descriptive statistics, correlations, chi-square analysis, effect sizes, and t tests. A full-information maximum likelihood estimator that provided chi-square statistics and SEs that were robust to nonnormality (denoted "MLR" in M*plus*) was used for handling missing data in the remaining analyses.

Analysis indicated that the GTAs from the two colleges were similar on several demographic characteristics and most of the factors in the model (Table 1). There was no significant difference in GTAs between the two colleges on the following characteristics: GTA teaching self-efficacy, interest in an academic career, K–12 and college teaching experience, hours of GTA PD, and all departmental teaching climate factors. Nationality was just above statistical significance ($p = 0.05$), but a comparison of teaching self-efficacy between U.S. and international students indicated no significant difference (U.S. $M = 4.08$, international $M = 4.24$, $t = 1.86$, $p = 0.07$). There were significant differences in quarters of GTA teaching experience and quality of GTA PD between the two colleges. There was also a significant difference by gender between the two colleges, with fewer female GTAs in the College of Engineering than the College of Science. The gender difference followed national trends in gender distributions in science and engineering. However, gender had not been shown to affect GTA teaching self-efficacy (Prieto and Altmaier, 1994; Prieto *et al*., 2007). Similarly, there was no difference in teaching self-efficacy between females ($M = 4.09$) and males ($M = 4.17$) in this sample ($t = 0.81$, $p = 0.42$). Given the preponderance of similarities between the two colleges, all GTAs in this sample were pooled for statistical analyses.

Instruments

In addition to the instruments discussed below, demographic data, including department, gender, nationality, primary teaching responsibility, and degree, were also collected. All the items used in each instrument are listed in Tables 2–4. The complete survey (including all the instruments) is available in the Supplemental Material.

GTA PD. There were two measures of GTA PD: hours of teaching PD and GTAs' perception of the quality of their teaching PD. Participants were asked to indicate how many hours they had in university-wide and departmental GTA PD, and they were also asked how many hours of college course work in teaching they had taken. These were summed to compute the total hours of PD in teaching. Quality of GTA teaching PD was measured with 17 items that described each GTA's perception of how well he or she had learned various teaching skills (DeChenne *et al*., 2012a) in all his or her GTA PD experiences. Fifteen specific PD items were scored on a five-point scale from "never learned" to "learned very well." Two items asked about overall effectiveness of GTA PD and were measured on a five-point scale from "not effective" to "very effective." In a prior study, CFA suggested that the items on this instrument could be combined into one factor that had a Cronbach's alpha reliability of 0.96 (DeChenne *et al*., 2012a).

Departmental Teaching Climate. There were three measures of departmental teaching climate: perceptions of a facilitating environment, teaching-supervisor relationship, and peer teaching relationships. The facilitating environment factor was developed from a study on transfer of PD principles to GTA teaching experiences (Notarianni-Girard, 1999). In this study, facilitating variables affecting transfer of GTA PD in the STEM department were investigated. These items were measured on five-point scales from "strongly disagree" to "strongly agree" and indicated departmental facilitation of GTA use of newly learned teaching techniques. The quality of the teaching-supervisor relationship was measured using the Collegial Leadership dimension of the Organizational Climate Index (Hoy *et al*., 2002/2003). This was adapted for STEM GTAs by replacing "principal" with "supervisor" and "faculty" with "GTAs." The teaching-supervisor relationship was the degree that the supervisory style was open and collegial with clear expectations for performance of the GTAs. Hoy *et al*. (2002/2003) reported a Cronbach's alpha reliability of 0.94 with a population of high school teachers. The quality of peer teaching relationships were measured with the Professional Teacher Behavior dimension of the Organizational Climate Index (Hoy *et al*., 2002/2003); adapted for STEM GTAs by replacing "teachers" with "GTAs." The peer teaching relationships were the degree that these relationships were respectful, student supportive, and provided mutual cooperation and support among the GTAs. Hoy *et al*. (2002/2003) found a Cronbach's alpha reliability of 0.88 with a population of high school teachers.

Teaching Experience. There were three measures of teaching experience in this study: GTA teaching, K–12 teaching, and college or university teaching. GTAs were asked how many quarters and/or semesters they had of GTA teaching experience. Because many GTAs had taught at more than one institution, both types of experience were measured. Semester experience was multiplied by 1.5 and added to the quarters of experience to achieve the quarters of GTA teaching experience. GTAs were also asked how many years of experience they had teaching at the K–12 level and as community college, college, or university instructors (outside their GTA experiences).

GTA Teaching Self-Efficacy. This was measured with a previously validated teaching self-efficacy instrument for STEM GTAs (DeChenne *et al*., 2012b). There were 18 items asking GTAs how confident they were in their ability to do various teaching tasks. Items were measured on five-point scales from "not at all confident" to "very confident." In a prior study, CFA indicated that this instrument had a second-order factor structure and measured two teaching self-efficacy subscales for learning environment and instructional strategies with an overall concept of teaching self-efficacy. Second-order factor structures, in which there are coherent subfactors within the overall construct, occur in other teaching self-efficacy scales (Tschannen-Moran and Hoy, 2001; Dellinger *et al*., 2008; Chang *et al*., 2011). The reliability of this instrument with STEM GTAs was 0.92 (DeChenne *et al*., 2012b).

RESULTS

Basic Statistics

Consistent with previous research, the teaching self-efficacy (M = 4.15, SD = 0.53) of STEM GTAs was high (Prieto and Altmaier, 1994; Meyers *et al*., 2007; Table 2). The average time spent in teaching PD was 20 h (SD = 32.49), but the median was 12 h. GTAs felt the quality of their PD was moderately good (M = 3.11, SD = 0.99). It appeared that the departmental teaching climate was relatively collegial (supervisor M = 3.89, SD = 0.75, and peer M = 3.77, SD = 0.72) and did contain some elements that facilitated GTA teaching (M = 3.39, SD = 0.74). All of the GTAs had at least a quarter of teaching experience (M = 5.39 quarters, SD = 5.11), 9% had K–12 teaching experience, and 13% had prior college teaching experience.

Not all of the correlations were consistent with the hypothesized relationships developed in Figure 1 (Table 2). None of the teaching experience variables were significantly correlated with GTA teaching self-efficacy, nor was hours of PD. The STEM GTAs' perception of a facilitating environment factor (r = 0.16) was also not correlated with hours of PD. The remaining correlations were statistically significant and supported hypothesized relationships in Figure 1. The quality of GTA PD (r = 0.33) was correlated to GTA teaching self-efficacy. All three of the departmental teaching climate factors were also significantly correlated to GTA teaching self-efficacy (facilitating environment, r = 0.34; supervisor, r = 0.27; peer, r = 0.23) and to perception of the quality of GTA PD (facilitating environment, r = 0.38; supervisor, r = 0.33; peer, r = 0.25; Table 2).

Instrument Reliability and Validity

GTA PD. Cronbach's alpha was 0.95 for the quality of GTA PD items administered to the present sample, with corrected item-total item correlations ranging from 0.63 to 0.81. A CFA was conducted to provide construct validity evidence (specifically the structural aspect; Messick, 1995) for a one-factor model. Model results were as follows: $\chi^2(117) = 229.54$, $p < 0.01$, comparative fit index (CFI) = 0.91, root mean square error of approximation (RMSEA) = 0.09, standardized root mean residual (SRMR) = 0.06 (Table 3). Because the chi-square test statistic is often criticized for being too stringent (e.g., Brown, 2006), emphasis is placed on the alternative fit indices. Hu and Bentler (1999) suggest that CFI > 0.95, RMSEA < 0.06, and SRMR < 0.08 indicate acceptable model fit. However, these guidelines are not absolute; rather, they depend on various modeling conditions. Other simulation studies have found that RMSEA between 0.08 and 0.10 is indicative of mediocre model fit (MacCallum *et al*., 1996), and CFI > 0.90 is indicative of good model fit (Bentler, 1990). Triangulation of the

Table 2. Correlational analysis of factors in the model of STEM GTAs teaching self-efficacy

Measures[a]	Mean	SD	GTA TSE[b]	A	B	C	D	E	F	G
PD										
A. Hours	20.16	32.49	0.17							
B. Quality	3.11	0.99	0.33**	0.22*						
Departmental teaching climate										
C. Facilitating environment	3.39	0.74	0.34**	0.16	0.38**					
D. Teaching-supervisor relationship	3.89	0.75	0.27**	–0.13	0.33**	0.46**				
E. Peer teaching relationships	3.77	0.72	0.23**	–0.01	0.25**	0.40**	0.71**			
Teaching experience										
F. Quarters GTA	5.39	5.11	0.13	0.03	–0.01	0.09	0.02	–0.015		
G. Years K–12	0.09	0.29	0.15	–0.00	–0.07	–0.12	–0.07	–0.07	0.01	
H. Years university	0.13	0.33	0.16	–0.04	0.01	–0.03	0.02	0.05	0.18	0.14

*$p < 0.05$ (two-tailed); **$p < 0.01$ (two-tailed).

[a]All scales were rated on a scale of 1–5, with 5 being the best in each scale.

[b]GTA teaching self-efficacy, M = 4.15, SD = 0.53.

Table 3. CFA of quality of GTA PD

	Standardized factor loadings[a]
Of the following teaching topics and skills, please rate how well you have learned these in GTA training.[b]	
Facilitating group discussions	0.83
Motivating students	0.82
Interacting professionally one-on-one with your students	0.82
Teaching students with different skill/knowledge	0.82
Teaching styles[c]	0.81
Teaching culturally diverse students	0.81
Learning styles[c]	0.79
Power/authority relationships in the classroom	0.79
Managing disruptive students	0.79
Assisting distressed students	0.78
Presenting material to large groups of students	0.72
Harassment	0.67
Communicating with course lead instructor	0.67
Grading	0.64
Developing quizzes/exams	0.63
Overall questions on GTA training[d]	
Overall, how effective has the TA training you have received been in preparing you to work with students?[c]	0.65
Overall, how effective has the TA training you have received been in preparing you to teach?[c]	0.62

[a]All factor loadings are significant at $p < 0.05$. Model fit statistics and indices are $\chi^2(117) = 229.54$, $p < 0.01$, CFI = 0.91, RMSEA = 0.09 (90% CI = 0.07–0.11), SRMR = 0.06.

[b]Items coded on a five-point scale of 1 = never learned to 5 = learned very well.

[c]Residuals allowed to covary to achieve fit indices.

[d]Items coded on a five-point scale of 1 = not effective to 5 = very effective.

three alternative fit indices suggests that the quality of GTA teaching PD construct is adequately measured.

Departmental Teaching Climate. Five items were initially included in the facilitating environment measure (Notarianni-Girard, 1999). Cronbach's alpha was 0.63. Based on corrected item-total item correlations, one item was dropped. The final corrected item-total item correlations ranged from 0.37 to 0.49, with Cronbach's alpha equal to 0.66. A CFA provided validity evidence for a one-factor model, $\chi^2(2) = 3.46$, $p = 0.18$, CFI = 0.97, RMSEA = 0.08, SRMR = 0.03 (Table 3). For the teaching-supervisor relationship, Cronbach's alpha was 0.88, with corrected item-total item correlations ranging from 0.54 to 0.74. A CFA provided validity evidence for a one-factor model, $\chi^2(11) = 20.48$, $p = 0.04$, CFI = 0.98, RMSEA = 0.08, SRMR = 0.04 (Table 3). For the peer teaching relationships, Cronbach's alpha was 0.83 with corrected item-total item correlations ranging from 0.45 to 0.64. A CFA provided validity evidence for a one-factor model, $\chi^2(12) = 16.16$, $p = 0.18$, CFI = 0.98, RMSEA = 0.05, SRMR = 0.04 (Table 4).

GTA Teaching Self-Efficacy. Cronbach's alpha for the teaching self-efficacy items was 0.90, with corrected item-total item correlations ranging from 0.45 to 0.64. A CFA provided validity evidence for a higher-order factor model with two lower-order factors, $\chi^2(134) = 190.49$, $p < 0.01$, CFI =0.91, RMSEA = 0.06, SRMR = 0.07 (Table 5).

SEM

Although it would be ideal to directly embed the aforementioned CFA measurement models into the remaining analyses, such an approach would require too many parameters to be estimated when considering the size of the sample in this pilot study. Conversely, simply summing or averaging the items to create scores would ignore the inherent unreliability of the measures. Thus, factor scores derived from the CFA estimated-item parameters were output for each measure. The correlations (Table 2) and structural equation model described were based on these factor scores.

The hypothesized relationships from Figure 1 were tested simultaneously using SEM. Figure 2 shows the standardized regression coefficients for all pathways that were significant at the $p < 0.05$ level. There is a good model fit: $\chi^2(df = 14) = 12.65$, $p = 0.56$, scaling correction factor = 1.31, RMSEA < 0.01 (90% CI = 0.00–0.08), CFI > 1.00 (Figure 2). Contrary to what was hypothesized, teaching-supervisor and peer teaching relationships did not predict the quality of GTA PD or GTA teaching self-efficacy despite the significant simple correlations described previously (Table 2). Also contrary to what was hypothesized, GTA teaching experience and college or university teaching experience did not predict GTA teaching self-efficacy.

All remaining hypothesized pathways were significant. Hours of PD in teaching, facilitating environment, K–12 teaching, and quality of GTA PD directly influenced GTA teaching self-efficacy, with a total of 32% of the variance in GTA teaching self-efficacy accounted for by all of the predictors in the model. Hours of PD in teaching and facilitating environment also directly influenced quality of GTA PD, with a total of 18% of the variance in quality of GTA PD accounted for by these predictors. Four percent of the variance in facilitating environment was directly accounted for by hours of PD in teaching. The strongest predictor of teaching self-efficacy was quality of GTA PD and facilitating environment ($\beta = 0.22$ for both pathways). Facilitating environment was also the strongest predictor for quality of GTA PD ($\beta = 0.22$). K–12 teaching experience ($\beta = 0.20$) was nearly as strong of a predictor of GTA teaching self-efficacy as facilitating environment and quality of GTA PD, whereas hours in PD was not as strong a predictor ($\beta = 0.12$) of teaching self-efficacy. Hours of PD was a stronger predictor of quality of GTA PD ($\beta = 0.19$) and facilitating environment ($\beta = 0.20$).

In addition to the direct effects, four indirect effects were evaluated based on bias-corrected bootstrapped 95% confidence intervals (MacKinnon *et al*., 2004). This approach was chosen over Sobel's test, which has been shown to be overly conservative (MacKinnon *et al*., 1995). The indirect effect of hours of PD in teaching on GTA teaching self-efficacy through facilitating environment and quality of GTA PD was nonsignificant ($B = 0.00$ with 95% CI = 0.00–0.00, $\beta = 0.01$). Likewise, the indirect effect of hours of PD in teaching on GTA teaching self-efficacy through quality of GTA PD was

Table 4. CFA of the departmental teaching climate factors

Items	Standardized factor loadings		
	Teaching-supervisor relationship factor[a]	Peer teaching relationships factor[b]	Facilitating environment factor[c]
The supervisor is willing to make changes.[d]	0.82		
The supervisor puts suggestions made by the GTAs into operation.	0.80		
During meetings, the supervisor explores all sides of a topic and admits that other options exist.	0.69		
The supervisor treats all GTAs equitably.[d]	0.69		
The supervisor is approachable and friendly.[d]	0.65		
The supervisor lets GTAs know what is expected of them.[d]	0.63		
The supervisor maintains definite standards of performance for the GTA.[d]	0.53		
GTAs in this school exercise professional judgment.		0.75	
GTAs respect the teaching competence of the other GTAs.		0.70	
GTAs "go the extra mile" with their students.		0.67	
GTAs accomplish their jobs with enthusiasm.		0.66	
The interactions between the GTAs are cooperative.[d]		0.64	
GTAs provide strong social support for other TAs.[d]		0.60	
GTAs help and support each other.[d]		0.38	
The department is supportive of innovations that TAs wish to try in their teaching.			0.70
The department encourages TAs to experiment with newly learned teaching methods.			0.67
The department provides sufficient resources for me to be successful in carrying out my job (e.g., equipment, secretarial help, mentors, etc.).			0.54
The department provides sufficient time to use newly learned teaching skills.			0.42
Mean	3.89	3.77	3.39
Cronbach's α	0.88	0.83	0.66

[a]Items coded on a five-point scale of 1 = rarely occurs to 5 = very frequently occurs. All factor loadings are significant at $p < 0.05$. Model fit statistics and indices are $\chi^2(11) = 20.48$, $p = 0.04$, CFI = 0.98, RMSEA = 0.08 (90% CI = 0.02–0.14), SRMR = 0.04.
[b]Items coded on a five-point scale of 1 = rarely occurs to 5 = very frequently occurs. All factor loadings are significant at $p < 0.05$. Model fit statistics and indices are $\chi^2(12) = 16.16$, $p = 0.18$, CFI = 0.98, RMSEA = 0.05 (90% CI ≤ 0.00–0.11), SRMR = 0.04.
[c]Items coded on a five-point scale of 1 = strongly disagree to 5 = strongly agree. All factor loadings are significant at $p < 0.05$. Model fit statistics and indices are $\chi^2(2) = 3.46$, $p = 0.18$, CFI = 0.97, RMSEA = 0.08 (90% CI ≤ 0.00–0.21), SRMR = 0.03.
[d]Residuals allowed to covary to achieve fit indices.

nonsignificant (B = 0.00 with 95% CI = 0.00–0.00, β = 0.04), and the indirect effect of hours of PD in teaching on quality of GTA PD through facilitating environment was nonsignificant (B = 0.00 with 95% CI = 0.00–0.01, β = 0.04). However, the indirect effect of facilitating environment on GTA teaching self-efficacy through quality of GTA PD was significant (B = 0.05 with 95% CI = 0.00–0.16, β = 0.05), indicating that quality of GTA PD was one mechanism through which a department's facilitating environment influences GTA teaching self-efficacy.

DISCUSSION

In this study of STEM GTAs, teaching self-efficacy results mostly from a variety of factors in the environment of the GTA (departmental teaching climate and GTA PD; Figure 2) rather than through GTA teaching experiences that should have provided mastery experiences. Prior experience as a K–12 teacher does impact GTA teaching self-efficacy, as expected. As seen in most prior studies, GTA PD is important for GTA teaching self-efficacy. Social cognitive theory supports this, because the more time spent in learning a skill, the higher the self-efficacy for that skill (Bandura, 1997). Departmental climate appears to be important in the development of teaching self-efficacy through the facilitating environment factor. A perception of an environment that facilitates teaching has a large impact on GTA teaching self-efficacy both directly and through the GTA's perception of the quality of the GTA PD. The departmental facilitating environment provides support for the GTAs to put their PD into effect in the classroom, encouraging the GTAs to utilize the skills they learned in PD.

Supervisor and peer relationships are not significant in the model, despite being correlated to teaching self-efficacy (Table 2). This is likely due to these predictors' moderately large correlations with the facilitating environment factor (see Table 2). That is, teaching-supervisor and peer teaching relationships did not account for significantly more variance in the outcomes that was not already explained by the GTAs perception of a facilitating environment. The facilitating environment

Table 5. Second-order CFA of GTA teaching self-efficacy

	Standardized factor loadings[a]	
	Learning	Instructional
Primary factor items[b]		
How confident am I in my ability to … [c]		
Make students aware that I have a personal investment in them and in their learning?	0.75	
Promote student participation in my classes?	0.73	
Create a positive classroom climate for learning?	0.68	
Encourage my students to ask questions during class?	0.67	
Think of my students as active learners, which is to say knowledge builders rather than information receivers?	0.67	
Promote a positive attitude toward learning in my students?	0.67	
Encourage the students to interact with each other?	0.64	
Actively engage my students in the learning activities that are included the teaching plan/ syllabus?	0.61	
Provide support/encouragement to students who are having difficulty learning?	0.56	
Let students take initiative for their own learning?	0.48	
Show my students respect through my actions?	0.45	
Evaluate accurately my students' academic capabilities?		0.67
Provide my students with detailed feedback about their academic progress?		0.68
Appropriately grade my students' exams/assignments?		0.65
Clearly identify the course objectives?		0.64
Prepare the teaching materials I will use?		0.61
Stay current in my knowledge of the subject I am teaching?		0.57
Spend the time necessary to plan my classes?		0.56
Secondary factor items		
Learning	0.79	
Instructional		0.87

[a]All factor loadings are significant at $p < 0.05$. Second-order model fit statistics and indices are $\chi^2(134) = 190.49$, $p < 0.01$, CFI = 0.91, RMSEA = 0.06 (90% CI = 0.04–0.08), SRMR = 0.07.
[b]Mean = 4.15, Cronbach's $\alpha = 0.90$.
[c]Items coded on a five-point scale of 1 = not at all confident to 5 = very confident.

factor encompasses a larger departmental climate for teaching but is highly dependent on the supervisor and peer interactions. Supervisors are part of the faculty who set the departmental standards and provide the resources for GTA PD. Therefore, both supervision and PD are likely intertwined in the development of STEM GTAs' teaching self-efficacy and, ultimately, their teaching effectiveness (Belnap, 2005; Hardre and Chen, 2005). This research also indicates that peers are an important part of the departmental climate (through the correlations between supervisor, peers, and facilitating environment factors; see Table 2). Further research on what is important to support GTA teaching self-efficacy and teaching effectiveness in the departmental teaching climate is needed.

With this sample of STEM GTAs, the model explains 32% of the variance in teaching self-efficacy. Because this is an exploratory study of factors that were suggested through the literature, social cognitive theory (Bandura, 1977, 1986, 1997) suggests other factors that might contribute to the development of GTA teaching self-efficacy. These could include cultural differences in teaching expectations (this sample is ~40% international students); personal interest in developing as an instructor; an expectation of becoming an academic faculty member; and, because facilitating environment was so important, other factors in a department that could affect its teaching climate. That GTA teaching experience is not contributing to the variance in this model is concerning. Mastery experiences should contribute heavily to the development of teaching self-efficacy. This result could possibly reflect a lack of feedback on teaching. In this sample, 38% of the GTAs received no feedback on their teaching, not even student evaluations (personal communication with departments). Without any feedback from students or a faculty supervisor, it could be very difficult for these STEM GTAs to know what they are doing well and where they need work.

There were several possible limitations in this study relating to the use of a self-reporting instrument, the nature of participant selection, generalizability, and sample size. The survey that measured the factors and variables in this study was a self-reporting instrument. In this case, it was possible that the items were more related than if independent measures had been taken. Measuring these items independently was difficult; however, getting the faculty to report the departmental climate around teaching by answering the same questions as the GTAs would provide another measure of the departmental teaching climate. There are also recent observation protocols that would indicate whether the GTA PD is being taught using current best practices in science teaching (e.g., Smith *et al.*, 2013; Eddy *et al.*, 2015). These could be used as another measure of GTA PD quality.

All of the departments with large numbers of STEM GTAs in both colleges were invited to join the study. Nine of those 10 departments joined the study. The amount of cooperation

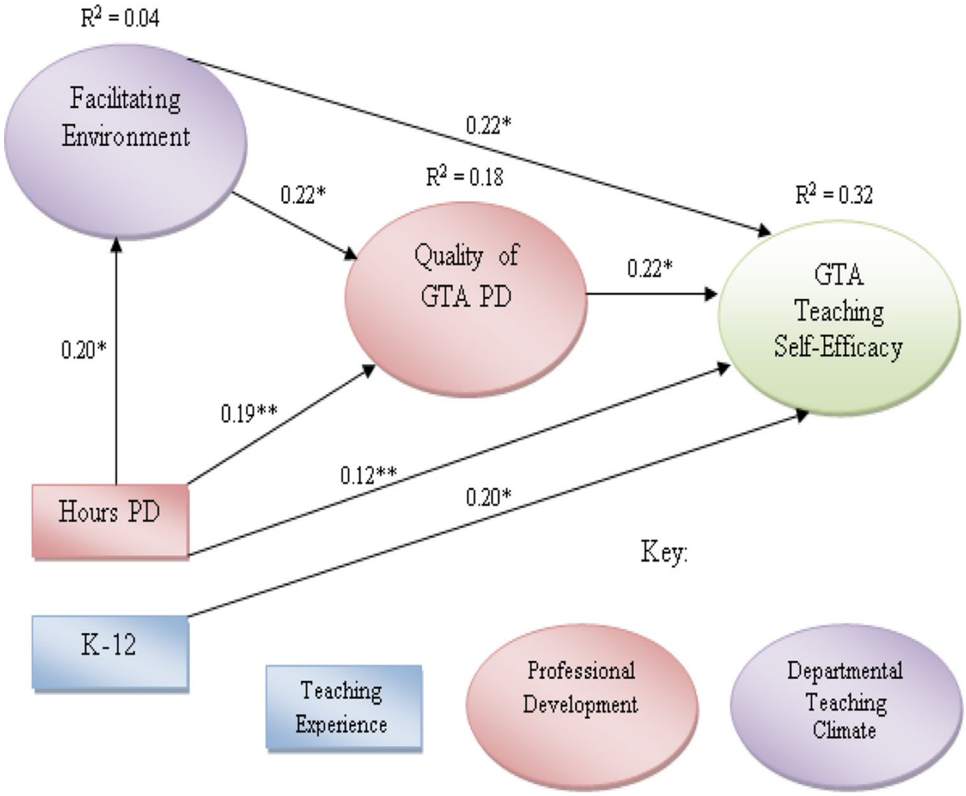

Figure 2. Model of teaching self-efficacy in STEM GTAs. $^{*}p < 0.05$; $^{**}p < 0.01$. Path coefficients are standardized regression coefficients. Model fit statistics are $\chi^2(df = 14) = 12.65$, $p = 0.56$, scaling correction factor = 1.31, RMSEA < 0.01, (90% CI = 0.00–0.08), CFI > 1.00. The blue box represents a measure of teaching experience. The red oval and box represent measures of GTA PD. The purple oval represents a factor in the departmental teaching climate. These are all factors that significantly impact STEM GTA teaching self-efficacy (green oval).

and support provided in data collection in each department varied greatly. Some departments made participation in the survey mandatory (although all GTAs were allowed to refuse to join the study) and were active in recruiting and collecting data; some strongly encouraged their GTAs and helped in data collection; and some simply asked their GTAs to participate and provided little or no help in data collection. No department had 100% of its GTAs participate, but there was higher participation in those departments that provided more support. This could have positively impacted the correlational results for the departmental teaching climate factors (Table 2) and the strength and statistical significance of the facilitating environment factor in the final model (Figure 2). Future research on correlations between department support of this type of research and measures of departmental teaching climate could help untangle these relationships.

This study was designed as an exploratory population survey of a single university rather than a sampling of the STEM GTA population. Despite a good participation rate, the relatively small population of STEM GTAs who primarily teach (rather than grade), even at a medium-sized research institution, made generating a sample size of sufficient power difficult. The ratio of sample size to number of estimated parameters was ~5:1, which was considered as a lower-bound sample size for SEM (Bentler, 1989). The results may not reflect the situation at other universities. Further research using STEM GTAs from several universities would increase both the power of the study and the variability of the factors included in the study, which would increase the generalizability of these results.

The sample contained 8–10% K–12 teachers, who presumably had education degrees (however, this was not explicitly assessed), which might be influencing these results, if that is an unusual percentage among STEM GTAs. In the STEM GTA literature, the range was from 2 to 15% K–12 teachers, with 8% or greater K–12 teachers in three out of five STEM GTA groups reported (Shannon *et al.*, 1998; Miller *et al.*, 2014; Parker, 2014; Wyse *et al.*, 2014). Based on these studies, the percentage of K–12 teachers in this sample is probably normal, and it is similar in both colleges (Table 1). However, further research should be done on the number of K–12 teachers among STEM GTAs, the impact K–12 experience has on GTA teaching self-efficacy, and the impact of experienced K–12 teachers on their GTA peers' teaching self-efficacy.

From these results, the GTA PD, teaching supervision, peer interactions, and department support for teaching need to complement each other to achieve the highest GTA teaching self-efficacy. We can see these characteristics in the literature of recent successful biology GTA PD programs (Schussler *et al.*, 2008; Miller *et al.*, 2014; Wyse *et al.*, 2014). These are continuous long-term (at least one semester) programs with regular meetings at least once a week. The PD is high quality, including instruction that is taught modeling the techniques the GTAs are expected to use, and is constructivist based. A facilitating environment with peer and supervisor support is also incorporated into these programs. In all of these programs, GTA peers work cooperatively or collaboratively. Two of these programs are embedded in the department and directly related to teaching specific courses (Miller *et al.*, 2014; Wyse *et al.*, 2014). Directly embedding these programs and including peer and supervisor observations enhances the teaching climate of the department. The GTAs are receiving similar messages about the importance of teaching from everyone involved, the department is providing support for the PD, and the GTAs are getting the opportunity to practice skills taught in the PD. As indicated by this study, this integrated approach should increase the GTAs teaching self-efficacy, which should improve their instruction.

Through the use of SEM, this exploratory study has shown relationships between GTA PD, a facilitating departmental teaching climate, K–12 teaching experience, and STEM GTA teaching self-efficacy. The correlations between departmental teaching climate factors and GTA self-efficacy, the relationship between the perceptions of a facilitating teaching environment and GTA PD, and the lack of GTA teaching experience showing a relationship to GTA teaching self-efficacy are important contributions of this work to our understanding of STEM GTA teaching self-efficacy. Presumably, departments that require multiple-semester pedagogical course work, provide teaching feedback to their GTAs, and insist upon evidence of good teaching (beyond student evaluations) for faculty tenure in the department will have a more supportive teaching environment than those with no teaching feedback to GTAs, little or no course work in pedagogy for the GTAs, and much stronger valuation of research over teaching for tenure. Between those two extremes however, how do we, as the faculty in science departments, encourage and develop a supportive departmental climate, one in which GTA teaching abilities are important and their development is supported? What is required in such a department? Why do some departments have this type of climate and others do not? How does the current trend of embedding science faculty with education specialists (Bush *et al*., 2013) within science departments impact the teaching climate? These and other factors to explore include the role of the department chair; amount and type of other instructional faculty; support of the GTA's major professor; university support through teaching centers and initiatives; the amount of teaching PD experienced by and expected of the faculty; and the expected balance of teaching, research, and course work expected of the GTAs. This study has highlighted the importance of these questions and invites further study.

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