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Abstract: The graduate experience is a critical time for development of academic faculty, but often there is little preparation for teaching during the graduate career. Teaching self-efficacy, an instructor's belief in his or her ability to teach students in a specific context, can help to predict teaching behavior and student achievement, and can be used as a measure of graduate students' development as instructors. An instrument measuring teaching self-efficacy of science, technology, engineering, and mathematics (STEM) graduate teaching assistants (GTAs) was developed from a general university faculty teaching instrument to the specific teaching context of STEM GTAs. Construct and face validity, measurement reliability, and factor structure of the instrument were determined from survey data of 253 STEM GTAs at six universities. STEM GTA teaching self-efficacy correlated to various measures of GTA professional development and teaching experience. Implications and applications for faculty involved in GTA professional development, supervision, and research are discussed.

Keywords: Teaching self-efficacy; STEM GTA Professional Development; Faculty development; Teaching experience

Graduate teaching assistants (GTAs) in science, technology, engineering, and mathematics (STEM) disciplines have and are going to continue to have a large influence on the teaching of undergraduate students. Many of the first instructional experiences that undergraduates have in college are closely associated with their GTAs. STEM GTAs teach both major and non-major students, potentially impacting the scientific literacy of the college educated population and the knowledge and retention of STEM majors (Fencle & Scheel, 2005; Miller, Pfund, Pribbenow, & Handelsman, 2008; O'Neal, Wright, Cook, Perorazio, & Purkiss, 2007). STEM GTAs often have more contact hours with students than the professors do, especially in large introductory undergraduate courses where GTAs are usually responsible for teaching laboratory or recitation sections (Fagen & Wells, 2004; Golde & Dore, 2001). For example, GTAs provide 91% of biology and 88% of chemistry laboratory instruction at research universities (Abraham et al. 1997; Sundberg, Armstrong, & Wischusen, 2005). In addition, many STEM doctoral students are interested in an academic career where they will be the future professors teaching the next generation of undergraduate students (Golde & Dore, 2001).

Although the graduate experience is a critical time for development of future academic professionals (Austin, 2002), many receive no formal professional development in teaching (Abraham et al., 1997; DeChenne et al., 2009; Golde & Dore, 2001; Meyers, Lansu, Hundal, Lekkos, & Prieto, 2007; Piccinin & Fairweather, 1996-97; Prieto & Scheel, 2008; Rushin et al., 1997). While there are individual programs showing promising results (e.g., Burton, Bamberry, & Harris-Boundy, 2005; Davis & Kring, 2001; Webber, Gabbert, Kropp, & Pynes, 2007), many

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studies indicate that GTA professional development may be ineffectual (Commander, Hart, & Singer, 2000; Fagen & Wells, 2004; Jones, 1993; Luft, Kurdziel, Roehrig, & Turner, 2004; Prieto & Scheel, 2008; Shannon, Twale, & Moore, 1998). Most of the research about GTA professional development, however, is descriptive with few measures of the effectiveness of professional development (DeChenne, 2012). Reliable and valid measures of constructs related to improvement in teaching are critical for advancing the scientific knowledge base and teaching practice of STEM GTAs.

Teaching self-efficacy is a construct which is related to teaching effectiveness (Bandura, 1997) and is a domain specific construct focusing on teacher perceptions of their own ability to "organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context" (Tschannen-Moran, Hoy, & Hoy, 1998, p. 233). Teaching self-efficacy has been shown to be a valuable predictor for student achievement, teacher retention, and persistence in the face of teaching difficulties (for a review, see Tschannen-Moran, et al., 1998). Given the empirically established relationship to student and teaching outcomes, teaching self-efficacy can contribute to our understanding of STEM GTA teaching. Before this can be accomplished however, a valid and reliable measure of STEM GTA teaching self-efficacy is needed.

I. Literature Review.

A. Social Cognitive Theory.

Self-efficacy beliefs are a central component of skill development in social cognitive theory (Bandura, 1986, 1997), which provides a mechanism for development of skills through interactions of behavior, personal attributes, and environmental circumstances. According to Bandura (1997):

> Perceived self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments…[self-efficacy] beliefs influence the courses of action people choose to pursue, how much effort they put forth in given endeavors, how long they will persevere in the face of obstacles and failures, their resilience to adversity, whether their thought patterns are self-hindering or self-aiding, how much stress and depression they experience in coping with taxing environmental demands, and the level of accomplishments they realize (p. 3).

Research has demonstrated that with professional development for a specific skill, self-efficacy is positively correlated with performance (Bandura, 1997; Gist, Schwoerer, & Rosen, 1989; Pajares, 1996a). Self-efficacy beliefs can predict performance and have been used in the literature as a measure of such performance, especially when the performance is difficult to measure quantitatively, such as in teaching (e.g., Burton et al., 2005; Prieto & Altmaier, 1994; Young & Bippus, 2008).

According to social cognitive theory, there are four sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasions, and psychological states (Bandura, 1997). Mastery experiences are related to evaluation of performance in the task; successful performance increases self-efficacy, whereas failure decreases self-efficacy. The best mastery experiences are those that challenge the individual, but in which they are ultimately successful. Vicarious experience is provided through modeling. Being able to observe someone perform the skill successfully improves the observer's self-efficacy, especially when the model is someone similar to the observer. Verbal persuasions include feedback on performance; receiving timely feedback about how well a person performed a skill can influence self-efficacy. Psychological states such as how someone feels when performing the skill (e.g., anxious, calm, excited) can influence their perceived self-efficacy about that skill.

B. Teaching Self-Efficacy.

Research has demonstrated that teaching self-efficacy impacts many student outcomes and teacher behaviors. A teacher's self-efficacy beliefs positively impact student learning and the actual success or failure of a teacher's behavior (Henson, 2002). These beliefs are also related to teacher instructional practices (Borko & Putnam, 1996; Haney, Czerniak, & Lumpe, 1996) and to student achievement and psychological wellbeing; teachers with high teaching self-efficacy tend to perform better and their students benefit (Ashton & Webb, 1986; Tschannen-Moran et al., 1998).

Teaching self-efficacy usually develops early in a teacher's career and becomes relatively stable over time (Morris & Usher, 2011; Tschannen-Moran et al., 1998), which makes the graduate experience especially critical for developing teaching self-efficacy in future professors (Hoy, 2003-2004). Being a GTA is usually the first instructional experience for most university faculty, and GTA professional development is often the only education in instruction that faculty receive (Tanner & Allen, 2006). Morris and Usher (2011) found that early successful instructional experiences, which are a combination of mastery experiences and verbal persuasions, are important for developing high teaching self-efficacy of teaching award winning professors, and that their teaching self-efficacy solidified within the first few years as a faculty member.

C. Teaching Self-Efficacy Instrument Design.

Bandura (1997) proposed that because self-efficacy beliefs are explicitly self-referent in nature and directed toward perceived abilities about given specific tasks, they are powerful predictors of behavior. Teaching self-efficacy refers to organizing and executing courses of action required to successfully accomplishing *a specific teaching task in a particular context*. Many measures of self-efficacy address specific tasks, yet fall short of providing the particular context (Dellinger, Bobbett, Olivier, & Ellett, 2008; Henson, 2002; Pajares, 1996a).

In development of teaching self-efficacy instruments, it is important to address the situational specificity of different teaching contexts and tasks and to balance the general and specific tasks (Bandura, 1997; Henson, 2002; Pajares, 1996a). If too specific, the instrument is not likely to measure overall teaching self-efficacy, just a specific teaching task in a specific context. For example, a measure of a genetics GTA's belief in their ability to teach loading DNA samples into an agarose gel for electophoresis to freshman level biology students is too specific. If the context is too broad, however, the instrument may simply be measuring general personality traits instead of self-efficacy specific to the task (Pajares, 1996b). Given that self-efficacy refers to an individual's beliefs about his or her abilities to accomplish a behavior or task in a *specific context*, it is important to design the instrument to the context in which the person is performing the task (Bandura, 1997).

Recently, instruments have been designed with subscales for teaching self-efficacy (Chang, Lin, & Song, 2011; Skaalvik & Skaalvik, 2007; Tschannen-Moran & Hoy, 2001). These instruments measure teaching self-efficacy and specific types of tasks within teaching, providing subscales of efficacy and giving greater range in measuring teaching self-efficacy. These three instruments have between three and six correlated subscales including: student engagement, instruction, classroom management, motivation of students, course design, technology usage, learning assessment, etc. These instruments can be used as an overall measure of teaching self-efficacy or as a more specific subscale score.

D. GTA Teaching Self-Efficacy.

Teaching self-efficacy has been studied in GTAs both in individual programs and across multiple programs. Studies indicate that teaching experience seems to increase teaching self-efficacy, although it depends on the level of teaching responsibility. In an early study of teaching self-efficacy with new counseling psychology professors, Tollerud (1990) demonstrated that GTA teaching experience positively impacted teaching self-efficacy. Using a wider population of GTAs, teaching experience was correlated to teaching self-efficacy in several studies (Liaw, 2004; Prieto & Altmaier, 1994; Prieto, Yamokoski, & Meyers, 2007). However, in a study of business GTAs, Burton et al. (2005) found that teaching experience was not correlated to teaching self-efficacy. In a study of International Teaching Assistants (ITAs), Kim (2009) found that teaching experience was correlated with teaching self-efficacy related to instructional strategies and classroom management, but not those related to student engagement. Theoretically, experience should provide ample mastery experiences and verbal persuasions to impact teaching self-efficacy.

Level of responsibility for teaching can also have an impact on GTA teaching self-efficacy. In two studies, GTAs in non-instructive roles (e.g., graders) had significantly lower teaching self-efficacy scores than GTAs who had teaching roles (e.g., assistant, primary instructors; Prieto & Meyers, 1999) and there were significant differences between GTAs who were graders or assistants and those who had primary responsibility for the classroom (Prieto et al., 2007). Prieto and Altmaier (1994), however, found no significant differences in teaching self-efficacy based on amount of teaching responsibility (e.g., primary instructor, assistant instructor, general instructor). According to social cognitive theory (Bandura, 1997), GTAs in courses with more responsibility should have far more experiences that impact their teaching self-efficacy.

The impact of GTA professional development on teaching self-efficacy is not as well established. In four studies of GTAs from multiple programs, two studies found no impact of GTA professional development on teaching self-efficacy (Liaw, 2004; Tollerud, 1990). Two other studies, however, did find that GTA professional development increased teaching self-efficacy (Prieto & Altmaier, 1994; Prieto & Meyers, 1999). In a qualitative study of foreign language GTAs, Mills and Allen (2007) found that GTA professional development was highly influential. Studies of individual GTA professional development programs indicated that teaching self-efficacy increased after the GTA professional development program was completed (Burton et al., 2005; Hadre, 2003; Komarraju, 2008; Meyers et al., 2007; Sargent, Allen, Frahm, & Morris, 2009; Young & Bippus, 2008). These mixed results are likely due to the variable quality of GTA professional development available to study participants in the quantitative studies of multiple programs. If the quality of the GTA professional development was poor, then there should be little impact on GTA teaching self-efficacy.

Teaching self-efficacy of GTAs has been measured with an instrument originally designed for psychology students (Prieto & Altmaier, 1994) or one taken from the K-12 teaching context (often the Teacher Sense of Efficacy Scale; Tschannen-Moran & Hoy, 2001), but it has been recognized that teaching in STEM is fundamentally different from other disciplines and this difference should be recognized in roles of GTAs (Golde & Dore, 2004; Lindblom-Ylanne, Trigwell, Nevgi, & Ashwin, 2006; Torvi, 1994; Verleger & Velasquez, 2007). STEM GTAs are rarely responsible for a course (Abraham et al., 1997; DeChenne et al., 2009; Sundberg et al., 2005; Torvi, 1994), but instead teach laboratory and recitation sections, so usually act as a conduit between the students and course professor. STEM GTAs need to understand complex grading rubrics and have skills allowing them to facilitate questions without giving students answers. STEM students often work independently or in small groups on complex projects that can span a term or more of coursework (Moore & Diefes-Dux, 2004; Pomalaza-Raez & Groff, 2003; Taylor, Heer, & Fiez, 2003). GTAs must understand these long-term projects, how to facilitate learning, and help students at different points of scholarship and with often frustrating problems. All of these activities require STEM GTAs to have excellent interpersonal skills.

Given that the STEM GTA context is quite different from many other teaching contexts, measuring teaching self-efficacy in STEM GTAs arguably requires a context specific instrument. Published studies using teaching self-efficacy as a measure, however, are limited to inclusion of STEM GTAs within a study of multiple programs usually using a generic instrument originally designed for the psychology context (Prieto & Altmaier, 1994). A teaching self-efficacy instrument is needed for STEM GTA teaching context. To validly measure teaching self-efficacy, this instrument should correlate to measures of teaching experience and measures of GTA professional development. Like other newer teaching self-efficacy instruments, an instrument measuring subscales within STEM GTA teaching self-efficacy would provide the possibility of a more sophisticated understanding of STEM GTAs teaching self-efficacy. Such an instrument would be useful in further research on STEM GTA teaching self-efficacy and for faculty responsible for GTA supervision and professional development. The purpose of this study, therefore, is to develop and validate an instrument measuring STEM GTA self-efficacy in teaching, and explore relationships between STEM GTA teaching self-efficacy, GTA professional development, and teaching experience.

II. Methods.

A. Participants.

Data were collected from GTAs in various STEM departments at six USA universities; three in the Pacific Northwest, two in the Southwest, and one in the Midwest. Five universities (including the originating university) had a Carnegie basic classification of RU/VH (Research Universities with Very High research activity) and one was a DRU (Doctoral/Research University). Engineering and technology GTAs taught across various engineering disciplines (e.g., aerospace, biological, biomedical, chemical, civil, computer, construction, electrical, environmental, industrial, manufacturing, mechanical, and petroleum). Science GTAs taught biochemistry, biology, chemistry, geosciences, microbiology, molecular biology, and physics. Also included in the sample were GTAs who taught mathematics.

B. Instrument Development and Modification.

The instrument used in many GTA teaching self-efficacy studies was the Self-Efficacy Toward Teaching Inventory – Adapted (SETI-A) (Prieto & Altmaier, 1994), which had been adapted for general GTA use from a teaching self-efficacy instrument that was specific for counseling psychology educators (Tollerud, 1990). Another post-secondary level instrument, the College Teaching Self-Efficacy Scale (CTSES), had been recently developed (Prieto Navarro, 2005). A team, including two science educators and two engineering education faculty, discussed what types of items should be included in a STEM GTA teaching self-efficacy scale and reviewed the items on the CTSES and SETI-A. The CTSES was chosen since it required less extensive modification and the team collaborated to adapt the CTSES to the STEM GTA context.

As part of a larger study of STEM GTA teaching self-efficacy, the CTSES needed to be streamlined; items specific to STEM GTA teaching were added or modified from the general college instructor context and items not usually part of a STEM GTA duties were removed. The CTSES was long (44 items) and contained two six-point scales, one for self-efficacy and one measuring actual instructor action for each item. Only the self-efficacy scale was retained, but changed to a five-point scale because of limitations of data collection, as the instrument was distributed in print and the data were collected on a scantron bubble form with five response options per question.

Seven items related to overall course design and planning were removed because STEM GTAs were rarely involved in course design or were the primary instructors responsible for a course. The CTSES also contained five items on reflective practice, many of which required teaching the same course repeatedly. Many GTAs, especially in engineering, did not teach in the same course repeatedly, so these items were removed. Three items that were unclear to the researchers or included technical pedagogical language were removed. There were also two pairs of redundant items, so one item from each pair was removed. Four items were rewritten to be more specific to the STEM GTA context; and given the large amount of group work in STEM laboratory classes; one item related to student interaction was added. Face validity of the items was reviewed by two additional social science faculty members with knowledge of both social cognitive theory and instrument design; they were asked to evaluate whether each item represented an aspect of GTA teaching self-efficacy, comment on clarity, and suggest revisions or additions. The final STEM GTA-Teaching Self-Efficacy Scale (STEM GTA-TSES) as administered contained 28 items measured on a five point scale anchored with A (no confidence) and E (complete confidence).

At the five institutions outside the originating university, three extra questions were asked in addition to the items in the STEM GTA-TSES – two demographic questions (university and department affiliations) and a question indicating the GTA's primary teaching role (laboratory, recitation, lecturer, course instructor or grader). At the originating university, the instrument contained measures of STEM GTA-TSES, GTA professional development, GTA teaching experience, and additional demographic questions such as gender, nationality, department, and career interest. GTA professional development was measured at the originating university: (a) as the number of total hours spent in teaching professional development at the university, department, and through university coursework in teaching; and (b) through an instrument measuring the GTA's perception of their GTA professional development (DeChenne et al., 2012). Teaching experience was measured by totaling the number of quarters taught (semesters converted to quarters) and by two items asking GTAs to rate their own experience. One item asked GTAs to compare themselves to other GTAs in their department (less experience to more experience) and the other asked them to rate their own experience (beginner to expert).

C. Administration.

GTAs were administered the STEM GTA-TSES once near the end of the semester or quarter. Data were collected from the various sites from fall 2008 through fall 2010, with one of two administration techniques used depending on location. Questionnaires were distributed to the GTAs through the department mail system, collected in a sealed container in the departmental office, and returned to the researchers through the mail (or collected directly by a researcher). Alternatively, questionnaires were administered during a GTA professional development class, collected by a faculty or staff member not involved in the GTA professional development and returned through the mail (or collected by one of the researchers at that time).

D. Analysis.

STEM GTAs from all universities were used to run the reliability and factor analysis while a subset of the STEM GTAs from the originating university was used for correlational analysis. The 28 STEM GTA-TSES items were analyzed with all data using principle axis exploratory factor analysis (EFA) with Varimax rotation, Kaiser Criterion, and Scree test. Confirmatory factor analysis (CFA) was then used with all data to examine if a second-order factor structure provided good fit and demonstrated construct validity. A CFA of the GTA professional development items was also used to examine whether the variables measuring this latent factor provided good fit and demonstrated construct validity. EQS 6.1 software and Satorra-Bentler Robust estimation to correct for multivariate non-normality were used for the CFA analysis (Byrne, 1994). Robust corrected comparative fit index (CFI), non-normed fit index (NNFI), and root mean square error of approximation (RMSEA) were used to assess model fit. CFI and NNFI values ≥ 0.90 and RMSEA values ≤ 0.08 imply acceptable fit (Browne & Cudeck, 1993).

Internal consistency of multiple-item indices measuring these concepts was examined with Cronbach's alpha reliability coefficients. An alpha coefficient of approximately ≥ 0.65 indicated that items measure the same concept and justified combining items into a single index (Cortina, 1993).

Using the GTAs from the originating university, Pearson correlations (r) between the STEM GTA-TSES and GTA professional development and teaching experience measures were determined. According to Cohen (1988), correlations less than .10 are considered small or weak, those around .30 are moderate or medium and those greater than .50 are large or strong. Using GTAs from the originating university, differences in teaching self-efficacy by gender, career goals, and nationality were determined with t-tests and effect sizes were examined using point-biserial correlations (r_{pb}). Instructional role and college of instruction were similarly compared using data from all GTAs across institutions.

III. Results.

In total, there were 253 participants: 177 from the originating university and 76 across the other five universities. Engineering GTAs comprised 68% of participants with 32% in science or mathematics. Twenty-five percent of GTAs described their primary role as grading and the remaining 75% indicated classroom instruction as their main role, with laboratory instructor (42%) being the most common and course instructor the least common (5%). Twenty-seven percent of GTAs were female, 47% were ITAs, and 64% were interested in college or university teaching as a career. Seventeen percent of the sample had no GTA professional development of any kind. Sixty-seven percent had less than two years teaching experience and the GTAs had taught an average of 3.2 different courses.

A. GTA-Teaching Self-Efficacy Instrument.

The EFA of the 28 teaching self-efficacy items revealed four factors explaining 51% of the variance. Two of the factors had a Kaiser criterion (Guttman, 1954) greater than one and a Scree test (Cattell, 1966) also suggested that two factors could be found in the data. Since both of these indicated that there were two factors, the exploratory factor analysis was rerun forcing two factors. To strengthen the factors, all of the items that cross-loaded between the factors were removed, leaving 18 items (Costello & Osborne, 2005). An EFA with those 18 items revealed two clean factors explaining 46% of the variance (Table 1). The factors were labeled self-efficacy for learning environment (*learning* = 11 items) and instructional strategies (*instructional* = 7 items). All factor loadings were between .49 to .77 for learning environment and .51 to .71 for instructional strategies. Both factors were also highly reliable (*learning* α = .90, *instructional* α = .85). All variables met the criterion of item total item correlations being greater than .40, and deletion of any item did not improve reliability. Means for each factor were high (*learning* = 4.07, *instructional* = 4.20), indicating that for each factor the GTAs were confident in their ability to carry out these teaching duties and responsibilities.

Given the strong correlation between learning environment and instructional strategies with all GTAs (r = .66), a higher order structure was possible, which was not uncommon in teaching self-efficacy scales (Chang, Lin, & Song, 2011; Skaalvik & Skaalvik, 2007; Tschannen-Moran & Hoy, 2001) and was advocated in their development (Dellinger, et al., 2008). A second-order CFA was performed on the items and there was a good fit in the second order structure (NNFI = .92, CFI = .93, RMSEA = .04; Figure 1). All variables loaded between .62 to .74 for learning environment and .58 to .70 for instructional strategies, and each factor loaded highly on the second-order GTA teaching self-efficacy construct (*learning* = .87, *instructional* = .85). All factor loadings were significant at $p < .05$. Reliability of the single factor structure was .92 with a mean of 4.10, all variables met the criterion of item total item correlations being greater than .40, and deletion of any item did not improve reliability. These results indicated that this instrument could be used to measure the underlying concept of STEM GTA teaching self-efficacy; measuring total teaching self-efficacy as well as the *learning* and *instructional* subscale self-efficacies.

B. Correlational and Comparative Analysis.

The overall STEM GTA-TSES and the learning environment and instructional strategies subscales showed significant positive correlations with several measures of teaching professional development and teaching experience (Table 2). These measures (originating university GTA sample) indicated significant moderate positive correlations of the STEM GTA-TSES and both

Table 1. Factor Loadings for Exploratory Factor Analysis of STEM GTA-TSES Subscales with All GTAs.

		Factor Loadings[1]	
How confident am I in my ability too[2]…	V#	Learning[3]	Instructional[3]
Promote student participation in my classes?	1	**.77**	.13
Make students aware that I have a personal investment in them and in their learning?	2	**.70**	.22
Create a positive classroom climate for learning?	3	**.68**	.22
Think of my students as active learners, which is to say knowledge builders rather than information receivers?	4	**.65**	.22
Encourage my students to ask questions during class?	5	**.62**	.32
Actively engage my students in the learning activities that are included the teaching plan/syllabus?	6	**.61**	.31
Promote a positive attitude towards learning in my students?	7	**.59**	.33
Provide support/encouragement to students who are having difficulty learning?	8	**.57**	.34
Encourage the students to interact with each other?	9	**.54**	.34
Show my students respect through my actions?	10	**.50**	.34
Let students take initiative for their own learning?	11	**.49**	.35
Appropriately grade my students' exams/assignments?	12	.11	**.71**
Evaluate accurately my students' academic capabilities?	13	.23	**.69**
Prepare the teaching materials I will use?	14	.30	**.62**
Spend the time necessary to plan my classes?	15	.25	**.60**
Clearly identify the course objectives?	16	.32	**.58**
Provide my students with detailed feedback about their academic progress?	17	.32	**.55**
Stay current in my knowledge of the subject I am teaching?	18	.34	**.51**
Eigenvalue		7.67	1.63
Percent (%) of total variance explained		39.59	6.27
Cumulative percent (%) of variance		39.59	45.86
Factor Mean[2]		4.07	4.20
Cronbach α		.90	.85

[1] Principal axis factor analysis with Varimax rotation.
[2] Items coded on a 5 point scale of 1 = not at all confident to 5 = very confident.
[3] Factor loadings > .40 are in boldface.

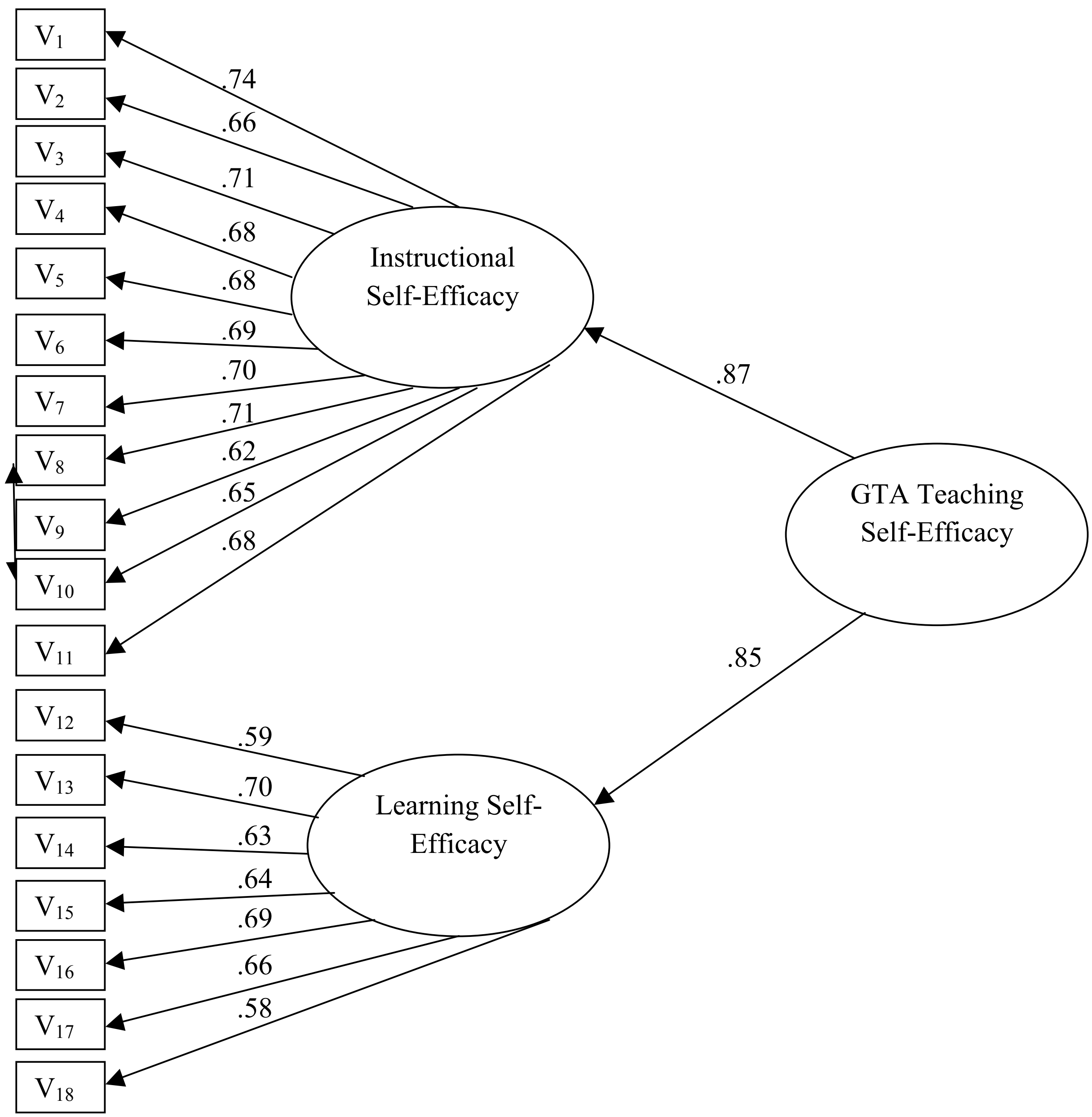

Figure 1. Second Order Confirmatory Factor Analysis of STEM GTA Teaching Self-Efficacy with All GTAs.
See Table 1 for variables corresponding to codes (e.g., V_1). All factor loadings indicated are significant at $p < .05$. Model fit indices are NNFI = .924, CFI = .934, & RMSEA = .043. To achieve these fit indices the errors between V_8 and V_{10} were allowed to co-vary.

subscales with GTAs perception of professional development (GTA-TSES $r = .30$). There was also a small significant correlation of the number of hours reported in GTA professional development with teaching self-efficacy and the two subscale measures (GTA-TSES $r = .18$). There were significant moderate correlations of the STEM GTA-TSES and both subscales with measures of teaching experience asking GTAs to rate themselves compared to their peers (GTA-TSES r = .34) and on a scale from beginner to expert (GTA-TSES r = .45). There was a small significant correlation with the instructional strategies subscale and the number of quarters that GTAs taught (*instructional* r = .16).

Table 2. Correlation Analysis with Originating University GTAs.

Measures[1]	Mean	GTA[2] TSES	A	B	C	D	E	F
<u>GTA-TSES[2]</u>	4.1							
A Learning	4.1	.95**						
B Instructional	4.2	.86 **	.66**					
<u>Professional Development</u>								
C Perception[3]	3.2	.30**	.27**	.29**				
D Hours[4]	20.8	.18*	.16*	.17*	.22**			
<u>Teaching Experience</u>								
E Compare[5]	3.3	.34**	.27**	.38**	.04	.12		
F Rating[6]	2.9	.45**	.38**	.44**	.22**	.22**	.67**	
G Quarters[7]	5.2	.11	.07	.16*	<.01	.10	.46**	.46**

*p < .05 (2 tailed), **p < .01 (2-tailed)
[1]All scales were rated on a scale of 1 to 5, with 5 being the best in each scale.
[2]GTA-Teaching Self-Efficacy Scale
[3]GTA ratings of how well they learned teaching skills
[4]Total hours of professional development including university, department, and credit coursework
[5]Item asking: Compared to other GTAs how much teaching experience do you have?
[6]Item asking: Rate your own teaching experience?
[7]Numbers of quarters as a GTA

Data collected with GTAs at the originating university indicated only one group difference in mean scores on the STEM GTA-TSES or the *learning* and *instructional* subscales. Consistent with Prieto and Altmaier (1994), teaching self-efficacy in STEM GTAs does not vary in this study by gender (STEM GTA-TSES males = 4.13, females = 4.09; t = .46 p = .646, r_{pb} = .04), career plans (STEM GTA-TSES academic = 4.18, other = 4.02; t = 1.65, p = .101, r_{pb} = .13), college of instruction (STEM GTA-TSES science/math = 4.06, engineering = 4.11; t = .711, p = .478, r_{pb} = .05), or instructional role (STEM GTA-TSES graders = 4.15, classroom instruction = 4.10; t = .56, p = .578, r_{pb} = .04). In two other populations, however, the teaching self-efficacy of GTAs varied by instructional role (Prieto & Meyers, 1999; Prieto et al., 2007). Unlike these studies, STEM GTAs were rarely the course instructor (<5% with this population) which was the instructional role reported to have different teaching self-efficacy (Prieto et al., 2007) and makes up almost half of the combined assistant/full responsibility group in Prieto and Meyers (1999).

The one group difference occurred with ITAs, who had significant higher instructional strategies self-efficacy than United States GTAs (USTAs) (*instructional* ITA = 4.34, USTA = 4.09; t = 2.73, p = .007, r_{pb} = .20). However, the overall teaching self-efficacy of ITAs and USTAs was similar (STEM GTA-TSE ITA = 4.17, USTA = 4.08; t = 1.01, p = .316, r_{pb} = .08). The effect size for the instructional strategies was close to moderate (Cohen, 1988), but as both means were greater than 4 (out of 5), ITAs and USTAs both felt confident in their abilities to plan, prepare, execute, and evaluate their classes, which is similar to other GTA results (Prieto & Altmaier, 1994; Prieto et al., 2007).

IV. Discussion.

The purpose of this study was to develop an instrument for measuring teaching self-efficacy of STEM GTAs and explore relationships between STEM GTA teaching self-efficacy, GTA professional development, and teaching experience. Essential to this process was to work toward establishing measurement reliability and both face and construct validity of the STEM GTA teaching self-efficacy measure. Assertions related to instrument validity, reliability, and correlations must be viewed, however, as sample dependent.

A. Instrument Modification and Development.

The STEM GTA teaching self-efficacy instrument as developed has two subscales, instructional strategies and learning environment, which may be used individually or combined as a single measure of teaching self-efficacy. This structure is not unlike the Teacher Sense of Efficacy Scale (Tschannen-Moran & Hoy, 2001); which has three factors – student engagement, instructional strategies, and classroom management – that could be used to measure overall teaching self-efficacy. The STEM GTA-TSES, however, did not include items relating to classroom management since STEM GTAs are teaching adults, not children. The two factor structure provides more flexibility in using the instrument. It not only provides a global score of teaching self-efficacy, but if self-efficacy of STEM GTAs relating to classroom instruction or ability to create an active and positive learning environment is needed, then this instrument also offers that option. When this instrument is used to evaluate GTA professional development or individual GTA development, the subscales can be useful in determining where changes are occurring in GTA teaching self-efficacy.

Possible limitations include sample size, scale sensitivity, and face validity with STEM GTAs. Costello and Osborne (2005) argue that in exploratory factor analysis, a ratio of at least 10 participants to each item in the instrument provides an average of less than one (0.70) item misclassified on the wrong factor. This study is close to achieving the desired sample size, with a ratio of nine participants per item. Also by Costello and Osborne's categorization, the individual factors in the STEM GTA-TSES (Table 1) are good; "a factor with…5 or more strongly loaded items (.50) are desirable and indicate a solid factor" (p. 5). Additionally, the CFA with all GTAs reveals a solid second-order factor structure (Figure 1), which indicates that the two specific self-efficacy subscales can collapse into one broader teaching self-efficacy factor. This could be predicted from social cognitive theory, which indicates that teacher efficacy should be task specific (Bandura, 1997; Pajares, 1996a). Given the complex nature of the teaching task, a multiple factor structure should be expected (Dellinger, et al., 2008; Henson, 2002), but additional research with this instrument should use CFA to confirm the two-factor structure. Another possible limitation is the sensitivity in a five-point scale, which is required by the data scanning software used. The measure might be more sensitive with a larger scale. Bandura (2006), for example, advocated for a 0 -100 scale in 10 point increments and there is evidence in a middle school environment that this scale may be more predictive in a regression equation on achievement than a 6 point scale (Pajares, Hartley, & Valiante, 2001). Although face validity was measured with research faculty, it was not determined for the respondents. Further research with this instrument should include a debriefing interview with STEM GTAs after they have completed the items in the measure. This interview can be used to determine how the STEM GTAs interpret the items and if they feel that these items represent the concept of teaching self-efficacy.

B. Related Relationships.

A correlation analysis with the originating university GTAs suggested that the STEM GTA-TSES and learning environment and instructional strategies self-efficacy sub-scales were related to both theoretical and empirical constructs. There was a high correlation between the two subscale factors in this instrument and the between each subscale and the overall teaching self-efficacy. The two subscales measure related activities in the classroom - learning environment and instructional strategies – and since overall teaching self-efficacy is determined from both subscales, they should be correlated.

Prior research (Burton et al., 2005; Liaw, 2004; Prieto & Altmaier, 1994; Prieto et al., 2007; Tollerud, 1990) has generally shown a positive effect of GTA teaching experience on self-efficacy. With this sample of STEM GTAs the *instructional* subscale correlated with all measures of teaching experience, but the *learning* subscale and STEM GTA-TSES did not correlate with quarters of teaching experience. With half of this sample ITAs, this is consistent with Kim (2009); who also found that the student engagement subscale of the Teacher Sense of Efficacy Scale (Tshannen-Moran & Hoy, 2001) did not correlate to teaching experience but the classroom management and instructional subscales did. Additionally, both sub-scales and the STEM GTA-TSES were highly correlated with measures of teaching experience that were GTA self-reports (Table 2). These self-reports asked the GTAs to rate their experience from beginner to expert and to rate how they compared themselves to others. Each of these should be correlated; all three are self-assessments that should be reinforcing each other. Award winning professors also use referential comparisons as a source for teaching self-efficacy, probably because there are few objective measures of teaching quality available in college instruction (Morris & Usher, 2011). It is not surprising that this is also appears true of STEM GTAs.

Examining the SETI-A (Prieto & Altmaier, 1994; Prieto et al., 2007; Tollerud, 1990) showed that most of these items are similar to the *instructional* factor rather than the *learning* factor. This may also account for the different results of *learning* factor and STEM GTA-TSES with teaching experience. The learning factor measured items that would be ideal in the learning environment of a student-centered classroom. There is evidence that student centered teaching is less common in hard scientific disciplines (Lindblom-Ylanne et al., 2006; Luo, Grady, & Bellows, 2001). If there is less student-centered teaching by these STEM GTAs then it wouldn't be surprising for teaching experience to be uncorrelated to the learning sub-scale.

The populations used in the prior studies on GTA teaching self-efficacy were very different in composition than the STEM GTAs in this study. Two-thirds of these GTAs had less than two years teaching experience compared to about 40% in other studies (Liaw, 2004; Prieto & Altmaier, 1994). Being completely responsible for a course was rare in this sample (5%) whereas over 40% of GTAs were completely responsible for a course in other studies (Prieto & Altmaier, 1994; Prieto et al., 2007). Additionally, this sample was completely STEM GTAs, whereas STEM GTAs comprised less than 50% of two of the studies (Prieto & Altmaier, 1994; Prieto et al., 2007), while the rest had no STEM GTAs (Burton et al., 2005; Liaw, 2004;

Tollerud, 1990). These demographic differences might have influenced the way teaching experience impacted teaching self-efficacy in these groups. In a detailed analysis, Liaw (2004) demonstrated that there was a high collinarity between years of teaching experience and the level of course (beginning or intermediate) the GTAs taught. Interestingly, for those GTAs who taught beginning courses there was no effect on teaching self-efficacy for teaching experience. Therefore the teaching experience effect on teaching self-efficacy may have been partially due to teaching advanced courses; the level of courses taught by this sample of STEM GTAs was not determined however it was fair to assume many taught in large introductory laboratory courses as was common in STEM departments. Finally, STEM GTAs taught many different courses during their teaching experience. In this sample the mean was 3.2 courses in 5.2 quarters of teaching. Since teaching self-efficacy was context specific, teaching a large number of different courses might have impacted and contributed to the lack of a correlation between the GTA-TSES and learning factor with quarters of teaching experience.

According to social cognitive theory (Bandura, 1997), professional development in a task should increase self-efficacy of the person in performing that task. Prior research has shown mixed results for effects of GTA professional development on teaching self-efficacy (Meyers et al., 2007; Prieto & Altmaier, 1994; Prieto & Meyers, 1999; Prieto et al., 2007; Tollerud, 1990), which may be because of the measures of professional development used in these studies, either time in professional development or simple presence/absence of professional development. In this study, GTA perception of professional development (DeChenne et al., 2012) correlated moderately with both subscales and the STEM GTA-TSES, whereas all three of these scales showed only a small correlation with hours of professional development. The mixed results from prior studies may be related to the quality of the GTA professional development received. Good GTA professional development would include mastery experiences, vicarious experiences, and verbal persuasions that should increase teaching self-efficacy. However, if the quality of the GTA professional development was poor, then there would be little or no correlation to teaching self-efficacy. In this study, this premise was demonstrated through the higher correlation to the GTA perception of professional development than to the hours of professional development.

C. Implications for Practice.

How do these results help us understand and improve the teaching of STEM GTAs? The STEM GTAs do have a relatively high teaching self-efficacy which is consistent with other GTA research (Prieto & Altmaier, 1994; Prieto et al., 2007) but it could be improved and that should improve the instruction of the STEM GTAs and then the learning of their undergraduate students. The STEM GTA-TSES can be useful in examining several aspects of professional development of STEM GTAs. It can be used by faculty working with GTAs to assess the impact of specific GTA professional development programs, supervision, and teaching experiences on GTA teaching self-efficacy. The *instructional* factor relates to activities needed to prepare and teach a class, and these are relatively concrete items. The *learning* factor focuses on more complex concepts involved in promoting and providing an active, positive, and respectful classroom environment, which can be more difficult to implement in an actual classroom or laboratory setting. This subscale will help GTA professional developers and supervisors evaluate their GTAs' readiness for classroom challenges.

Results of this study indicate that STEM GTA professional development needs to be increased and improved. The average STEM GTA had half a week of professional development in teaching which they rated as average (3.2 out of 5). Yet the perception of learning in their GTA professional development was moderately correlated with teaching self-efficacy and only mildly correlated with hours spent in GTA professional development. This indicates that good (or at least better) professional development improves GTA teaching self-efficacy. The types of GTA professional development within this sample ranged from a short (two to three days) professional development which discussed how to teach and how students learn in the last half day, to a required one quarter course in teaching and learning in addition to weekly group GTA meetings with the course instructor for the laboratory the GTAs were teaching (personal communication with the departments in the study). One department offered a year-long (three quarter) series on teaching and learning for their GTAs (although only the first quarter was required). Since there was a correlation between time spent in professional development and perception of learning, increasing the time GTAs spend learning about teaching and learning should improve their teaching self-efficacy. Additionally, more time spent within the professional development on teaching and learning would improve their teaching self-efficacy.

The participants in this sample had little to no feedback (verbal persuasions) on their teaching (personal communication with departments in the study). None of the departments' video recorded the GTAs teaching, most of the GTAs were never observed by either the course instructor or other GTAs, and over half of this sample did not even receive student evaluations. Teaching experience should provide mastery experiences, however without any feedback or reflection, the teaching experience does not provide the mastery experiences required to affect teaching self-efficacy. This is alternative explanation for the poor correlation between teaching self-efficacy and quarters of teaching experience in this study. This research suggests that the main vehicle for gaining experience in teaching, the teaching assistantship, is not providing an effective experience for these STEM GTAs. The teaching assistant experience needs to be moved beyond the need for instruction coverage by the department to consider the needs of preparing future faculty and the needs of the current undergraduate students served by the department. This lack of correlation between teaching experience and teaching self-efficacy suggests that only the first consideration is being utilized by many STEM departments for their GTAs.

The literature contains various suggestions for GTA professional development best practices (for a review, see Park, 2004). However, social cognitive theory (Bandura, 1986, 1997) suggests that also including several video recorded teaching sessions with both peer and instructor feedback would greatly improve GTA teaching self-efficacy (and therefore teaching effectiveness). This activity encompasses mastery experiences, vicarious experiences, and verbal persuasions, all of which will improve teaching self-efficacy. In this one exercise, which could be done either through a GTA professional development experience and/or within the teaching requirements for the GTA (for example during weekly GTA meetings), there is a chance to significantly effect GTA teaching. Repeating this exercise would greatly improve the teaching of the GTAs. Having the GTAs record a teaching session, showing that session to the GTA group, soliciting feedback from the group and feedback from the professional development or course instructor, would provide the GTA a chance to reflect on his/her own teaching. If repeated, various aspects of teaching could be focused on for each session. It is not even necessary for the whole teaching session to be watched by the GTA group; instead the GTA could pick a small section for feedback. This also increases the reflection of the GTA, since they must determine what to show their fellow students/instructor; they may emphasize a question they have about their teaching or something in which they excelled. Providing repeated experiences for mastery, vicarious, and verbal persuasions will greatly improve their teaching and turn the teaching experience into a true apprenticeship in teaching, one which improves the GTAs instructional abilities, prepares them for a future role as faculty, and improves the learning of their students.

This instrument will also be useful for research on STEM GTA teaching and can be used to study STEM GTA teaching self-efficacy. For any quantitative study in which teaching self-efficacy is a variable of interest, this could be a valuable instrument. The instrument could also be beneficial in research on longitudinal effects of GTA professional development and teaching experience on teaching self-efficacy. Henson (2001) expressed that it is time for teaching self-efficacy studies to move beyond correlations. Using this instrument, factors influencing the development of STEM GTA teaching self-efficacy have been modeled (manuscript submitted). Further research could explore the explicit relationships between STEM GTA teaching self-efficacy, teaching performance, and student achievement; determine other factors influencing STEM GTA teaching self-efficacy beyond teaching experience and professional development; and influence research into social cognitive theory based professional development for STEM GTAs.

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