Partnership for Persistence: Exploring the Influence of Undergraduate Teaching Assistants in a Gateway Course for STEM Majors

Stephanie B. Philipp
University of Louisville, USA

Thomas R. Tretter
University of Louisville, USA

Christine V. Rich
University of Louisville, USA

Abstract

Nine science, technology, engineering, and mathematics (STEM) departments across our university developed a program to increase persistence of undergraduate STEM majors. Trained and supported undergraduate teaching assistants (UTAs) implemented active learning strategies such as guided questioning, formative assessments, and metacognitive awareness activities. UTAs also prepared to act as informal peer advisors to novice STEM majors. UTA-led students were three times more likely to persist into the second semester of general chemistry. Students in UTA sections rated their TAs as better at impacting academic success and building rapport than did students in traditional GTA-led recitations. Mutually reinforcing elements of the program (building UTA-student rapport, bolstering student STEM identity, and strengthening student perceived impact on academic success) that support student persistence in STEM are discussed.

Key Words: undergraduate teaching assistants, retention, persistence, chemistry; STEM

Please direct all correspondence to: Stephanie B. Philipp, College of Education and Human Development, University of Louisville, Louisville, Kentucky, 40292; stephanie.philipp@louisville.edu.

Introduction

Many universities and colleges have a goal of increasing retention rates of students majoring in science, technology, engineering, and mathematics (STEM) fields to meet future employment demands. The Bureau of Labor Statistics projects that by 2018 the combination of newly created jobs and replacement of retired workers will create more than 3 million job openings in STEM (Lacey & Wright, 2009). The report also states that many of the fastest growing occupational areas are in STEM fields that require at least a bachelor's degree in a STEM discipline. The percentage of college students earning bachelor's degrees in STEM is flat or falling, now at around 33% of all bachelor's degrees awarded each year (National Science Foundation [NSF], 2012). Hence, universities are motivated to encourage more students to stay in

STEM majors to take advantage of the favorable labor market and higher than average compensation associated with STEM jobs.

Likewise, the research university at the center of this study sought to increase the retention of STEM students. Faculty from nine STEM departments across three colleges within the University worked together to develop and implement a cross-disciplinary program. This program was based on science education research and was designed to strengthen STEM student learning and support student persistence by using trained and supported undergraduate teaching assistants (UTAs) to lead small groups in active learning experiences and to engage in informal peer mentoring (Philipp, Tretter & Rich, 2016a). Our UTA initiative was the major strand in a more comprehensive STEM retention proposal funded by NSF-STEP (STEM Talent Expansion Program). This paper describes how we structured and evaluated the UTA program in one department (chemistry), how we examined STEM student persistence from first to second semester of a two-semester general chemistry course, and the implications for sustaining a new institutional program that has been shown to support student persistence in STEM majors.

Background

The research literature provides evidence of concern about student persistence in undergraduate STEM majors over recent decades (e.g., Johnson, 2007; Maltese & Tai, 2011; Seymour & Hewitt, 1997; Strenta, Elliott, Adair, Matier, & Scott, 1994). Causative factors and possible interventions continue to be examined. From recent studies on STEM student persistence, two factors to support STEM student persistence are repeatedly recommended: using active learning strategies in the classroom and fostering learning communities (Freeman et al., 2014; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Lewis, 2011; Perez, Cromley, & Kaplan, 2014; Watkins & Mazur, 2013). Active learning inspires students by encouraging them to apply knowledge and skills, create products, and solve problems (Graham et al., 2013). The use of active learning strategies has been associated with higher student achievement, perhaps because it gives context and purpose to learning (Freeman et al., 2014). Membership in a learning community supports mentoring students and helps them assimilate into the STEM culture, particularly in introductory level classes (Graham et al., 2013). The goal of the UTA training program in this study was to teach UTAs to facilitate active learning strategies within weekly 25-student recitation sections, and to encourage informal peer mentoring, career discussions, and reflective thinking in a welcoming community of STEM learners.

The decision to train and support experienced, successful, undergraduate STEM major teaching assistants as the focus of our retention improvement program was made, in part, for practical reasons. We aimed to develop a successful program that could be sustained beyond an external grant period. It would provide an increased number of teaching assistants to work with the growing number of introductory level students intending to major in STEM disciplines at our institution. To increase the number of student groups supported by teaching assistants, we looked for a reliable pool of instructors other than our limited numbers of graduate teaching assistants (GTAs). The teaching assistants had to have sufficient content knowledge, be willing to learn and apply evidenced-based pedagogical strategies and be given the opportunity to reflect on their teaching practice. The cost and training for each teaching assistant had to be sustainable by the STEM departments or university after grant money was exhausted. Experienced undergraduates who have been successful in their major discipline have the required content knowledge (Chapin, Wiggins, & Martin-Morris, 2014), and a previous report on the development of this program showed that pre and post semester content knowledge test scores were not significantly different from the graduate teaching assistants (Philipp, Tretter & Rich, 2016a). As shown by the numbers of undergraduates who have applied to the program, these experienced STEM majors were extremely willing to attend teaching seminars, apply evidence-based teaching practices in the classroom, and to share their teaching successes and struggles with other teaching assistants and faculty. Stipends and associated costs for trained UTAs were substantially less than for sustaining GTAs. Moreover, UTAs hold a unique position in the undergraduate STEM community as an intermediary between instructor and student (Romm, Gordon-Messer, & Kosinski-Collins, 2010). Unlike most traditional GTAs, our UTAs have experienced successes and challenges in the exact same courses they lead, often with the same professors. Additionally, UTAs are not under the same pressure as GTAs to join a research group and publish a dissertation (Golde & Dore, 2001), so they may have more time and motivation for learning to teach.

In our new program, UTAs were selected to participate based on academic success in the courses in which they wanted to assist (minimum 3.0 GPA), a desire to teach as indicated in an application essay, and professor recommendations based on communication skills and positive attitude. The UTA training and support program consisted of a three-day pre-semester workshop, monthly, hour-long seminars led by STEM and science education faculty, and weekly planning meetings for the UTAs with the instructors of the course. The workshop introduced learning theories and active learning strategies appropriate for small group settings, such as questioning strategies, metacognitive skills, development of mental models, and formative assessment in STEM contexts. These topics were elaborated upon in the semester-long seminar series, requiring the UTAs to use the strategies with their students, reflect on their teaching experiences and student learning in writing, and share successes, challenges, and improvements with each other. Weekly meetings with course instructors provided opportunities for the UTAs to plan active learning tasks and to discuss common misconceptions and challenges that students might have with that week's learning objectives. Curricular materials were developed based on the topics discussed in the seminars and were shared among the UTAs. Further description of the UTA training and support program, including benefits reported by the UTAs, can be found in an earlier report (Philipp, Tretter & Rich, 2016a).

As an example of an activity that UTAs were likely to develop and use with their students, we describe a 45-minute activity observed in multiple UTA recitation sections when the topics of ions and ionic compounds were being introduced. The UTA gave each student a small index card with the name of an ion written on it. A student might receive the words "sodium ion" or "chloride ion" on their card, for example. Most students had a different ion on his or her card. Students were asked to get out of their seats and sort themselves into two groups: anions (negatively charged ions) or cations (positively charged ions). A periodic table of elements was posted in the classroom. Students who could not immediately decide to which group they belonged examined their classmates' ion cards and made the decision of which group to join based on clues from these classmates' choices. The UTA did not give any hints or information, but did ask leading questions of the students who had some difficulty deciding to which group they belonged. After all students had joined their ion group successfully (as determined by the students) then the UTA asked the students to create neutral ionic compounds by joining other students in small groups. Students had to balance charges, so, for example, a student who had "calcium ion" with two positive charges had to find two other students who had a “chloride ion” (one negative charge) card in order to create calcium chloride ($CaCl_2$). The UTAs had each group assess other groups and make any needed corrections. All twenty-five students were engaged and actively discussing strategies and facts needed to make these required decisions. Meanwhile, the UTA could easily spot who was having difficulty with the concepts and help them with leading questions or have other students explain their decision-making process. At the lesson closure, students completed a short worksheet on ions and ionic compounds as an exit slip to formatively assess the success of the activity.

In contrast, employing pedagogically untrained GTAs to lead small group instruction in science, mathematics, and engineering courses resulted in instructor-centered review sessions of example problems like those found in a text book and is the reality of our instructional setting as well as in most other research university STEM departments (Golde & Dore, 2001; Luft, Kurdziel, Roehrig & Turner, 2004). The success of our UTA training program described here has precipitated a request from graduate school leaders to design and implement a STEM-focused GTA mini-academy (launched 2 years subsequent to this study). The mini-academy was collaboratively developed by select STEM faculty already overseeing the preparation of our UTAs with professionals in our university center for teaching and learning. The training includes many of the same pedagogical strategies emphasized with our UTAs (e.g., effective questioning, mental models & preconceptions). It is open to graduate students in any STEM discipline, including those matriculating at our Health Sciences/Medical School and Engineering campus. While administration has demonstrably embraced the added value of trained TAs, this new culture has not yet filtered down to the department level. Taking time from research for pedagogical training is not yet universally encouraged or rewarded by faculty research advisors, even in those departments that heavily utilize our trained UTAs. For instance, the Departments of Chemistry, Mathematics, and Physics collectively employed at least 77 GTAs each year. Only 4 GTAs from those departments enrolled in the STEM mini-academy during a two-year period. Until the culture changes in STEM departments, we can more easily work to improve the quality of teaching assistants by using undergraduates who consider teaching to be a valuable professional development experience and are receptive to learning research-based pedagogical skills. Therefore, in this study we are comparing two working programs: the “business as usual” program of GTA-led recitation groups and the new program of UTA-led recitation groups, in a general chemistry course required for STEM majors.

The purpose of this study was to evaluate the impact of trained and supported UTAs on student persistence. We asked the following research questions: (1) Were students who had UTAs for recitation in a first-semester general chemistry course more likely to persist to the second semester general chemistry course (if required by their intended major) than students who had “business as usual” GTAs? (2) How did students in UTA-led sections rate their TA on rapport and effectiveness for academic support compared to students in GTA-led sections?

Methods

This study evaluated a new program of using trained and supported UTAs alongside the business-as-usual program of GTAs who had neither received nor sought pedagogical training and support. The evaluation included student perceptions of course experience, student recognition of themselves and recognition by others as a “science person,” and persistence into the next semester of general chemistry as required for the STEM majors. Statistical models included pre-college academic covariates (e.g. ACT scores, number of high school AP courses taken, gender, minority status, and parental college experience) to account for incoming differences, if any, between the UTA-led and GTA-led student groups. Persistence data were collected from enrollment records of students in the first-semester general chemistry course whose major also required them to take the second semester general chemistry course and who subsequently enrolled in that second semester course. Official programs of study at our university plan for students to take these two courses in consecutive semesters to maintain timely progress toward completion of the major. A Course Experience Survey, taken anonymously by nearly all the undergraduate students at the end of semester, measured student perceptions of course experience (quality of teaching assistant, quality of instruction, learning climate, and recognition by self and others as a “science person”). The validity of factors measured by the survey was confirmed by principal components analysis, and reliability within the student sample was estimated by computing Cronbach alpha. The outcomes of these analyses, as well as the specific items on the survey, are described in a separate Instrument Validity and Reliability section.

Study Site and Sample

The research site of this study was located at a large, urban U.S., research-intensive university. The study took place in the context of CHEM 201, the first semester of a two-semester general chemistry course sequence designed for students intending to major in a science or engineering discipline. All undergraduate students enrolled in CHEM 201 during the fall semester were invited to participate in the study. Institutional review board permission was given to the researchers to collect human subjects’ data for this study. All research participants were provided with information detailing their rights as human subjects. Almost 600 undergraduates were asked to complete a voluntary and anonymous end of semester survey during the recitation section of CHEM 201 in which they were enrolled. Seventy percent of the undergraduates (414 students) agreed to take part in the study by completing and submitting the survey.

Undergraduate Student Sample

The UTA-led group consisted of 284 undergraduates in fourteen UTA-led recitation sections across all four instructors of the associated large lecture course. The GTA-led group consisted of 310 undergraduates enrolled in fifteen recitation sections led by the GTAs. Characteristics of the UTA group and the GTA group are found in Table 1 and are described in more detail in the Results section of this paper.

Teaching Assistant Sample

The combined Teaching Assistant (TA) sample included nine teaching assistants (6 UTAs, 3 GTAs) assigned to lead multiple 25-person recitation sections that ran 50 minutes per week. The UTA sample included six trained and supported UTAs who took part in a semester-long pedagogy practicum course. The UTAs were selected from chemistry major applicants based on excellent chemistry grades and recommendations from chemistry faculty that confirmed certain qualities about the UTA applicant: desire to work with less-experienced peers, skills in communication, and a good work ethic. All UTAs were of traditional college age (20-24 years) and were chemistry majors. The UTAs earned a stipend for their work and college credit for taking the required practicum. Four of the six UTAs had also participated as a trained and supported UTA in another chemistry course during the previous spring semester and had returned to the program to repeat participation in the UTA practicum and teach CHEM 201 recitation sections in the fall semester. While five of the UTAs taught two recitation sections per week, one of the veteran UTAs taught four recitation sections. Researchers visited all UTAs in their teaching assignments multiple times and no noticeable differences between this veteran UTA's teaching activity and other UTAs' activities were noted. As noted in the Background section, UTAs planned learning activities together, so it was not surprising that implemented activities were similar in scope and sequence between all UTAs.

The GTA sample included three graduate students who had been awarded traditional departmental teaching assistantships that provided tuition remission and a stipend. Teaching assistantships generally expected 15-20 hours of work per week from the graduate student and required English-language competency measured by a minimum TOEFL score or successful completion of the Intensive English as a Second Language Program at the university. Because two of the GTAs were not native English language speakers, the researchers confirmed through classroom observation that each graduate student was proficient in speaking English as an instructor. While it is not trivial that two of the GTAs were not native English speakers, it is, however, the reality of the graduate student population in STEM disciplines at our university. In the past several years, approximately 60% of the GTAs spoke English as a second language. The instructors in charge of making GTA assignments take into account the content knowledge, teaching experience, and language proficiency of GTAs who need departmental support through a teaching assignment, and try to make the best instructional fit possible for both GTAs and students. The GTAs in this study were neither trained in pedagogy nor did they take advantage of optional teaching and learning training offered by the university's graduate school for any GTA.

The CHEM 201 recitation sections were scheduled at various times during the day and each day of the week. The recitation sections had been scheduled in the university course catalog in advance of students registering for the course. The four instructors of the course made the assignment of specific UTAs and GTAs to the recitation sections a few days before classes began but well after the enrollment period. Specific section assignments were mainly based on TA availability, as well as an attempt to balancing teaching assignments across instructors, days of the week, and time of the day.

Chemistry Faculty

Four chemistry instructors taught the lecture portion of CHEM 201. Each instructor taught one large lecture section of CHEM 201 with approximately 150 students that met three days per week (Monday, Wednesday, Friday) for 50 minutes per day or twice per week (Tuesday, Thursday) for 75 minutes per day. Three of the four instructors had taught the course multiple times. The fourth senior instructor was new to CHEM 201, but had previous instructional experience as a graduate teaching assistant (GTA) and further professional development as a National Science Foundation Graduate STEM Fellow in K-12 Education. The three experienced instructors were undergraduate advisors in the chemistry department and had been named 'faculty favorites' by students multiple times in previous years.

The four instructors used a common textbook, written by the most senior instructor who is also the director of the general chemistry curriculum. The director coordinated the pacing of the course sequence, the use of common supplementary materials, and a common final exam. While each instructor taught his/her lecture section independently, they did meet before the semester to plan TA assignments and discuss course objectives, opportunities, and challenges, and to minimize any substantial differences in course experiences among their lecture sections. The instructors worked collaboratively with undergraduate teaching assistants (UTAs) in weekly planning for recitation sections including developing engaging formative assessments to support conceptual learning. Typical for CHEM 201 courses offered in the last five years, the instructors met with GTAs only occasionally during the semester, at the request of the GTA or when a problem was brought to the attention of a course instructor.

Undergraduate Perception of TA Support Value

The researcher adapted survey questions from the Learning Climate Questionnaire (Williams & Deci, 1996) to evaluate the value of the UTA or GTA to the undergraduate students. The Learning Climate Questionnaire measures instructional support for learner autonomy. Other items on the survey were straightforward inquiries about identifying as “science or math people” and about interest in math and science. The complete survey was pilot field tested for clarity and content with a group of ten volunteer undergraduate STEM majors who were not students in CHEM 201. As a result of the pilot field test, no substantive changes were made to the survey.

The CHEM 201 undergraduates submitted the surveys anonymously to encourage students to candidly answer questions about the types of experiences they had with the UTA or GTA leading their recitation section. We performed principal components analysis (PCA) with the survey responses to address content validity for this sample of students.

Data Collection Procedures

The university’s institutional research database furnished additional student data (student demographic and persistence data), and each UTA and GTA collected the anonymous end-of-semester surveys in a sealed manila envelope after one of the last two recitation sections at the end of the semester.

Results

Student Attrition

A total of 711 students were enrolled across the four lecture sections and associated 29 recitation sections of CHEM 201 at the start of the Fall 2012 semester. There were 369 students in GTA-led sections and 342 students in UTA-led sections. A total of 117 students (16.5%) withdrew from the course early in the semester. Fifty-nine students were from GTA recitation sections (16%) and 58 students from UTA recitation sections (17%). The students who withdrew had an average Math ACT score of 25.2, an average high school GPA of 3.01, an average college GPA of 2.01, all well below the average of these scores for the students who completed the course. We examined data from the remaining 594 students: 310 students in GTA-led sections and 284 students in UTA-led sections in this study.

During the last weeks of the semester, an end-of-course survey was administered to the 594 students who were still in the course and attended the recitation section in which the survey was administered. Seventy percent of the students (414 students) responded to the end-of-course survey, 202 students from the GTA recitation sections and 212 from the UTA sections. Because the students responded to the survey anonymously, the specific demographics of the survey sample cannot be determined.

Undergraduate Student Characteristics

Table 1 displays characteristics of all students who enrolled in and finished CHEM 201. There were more males than females in this course and the majority of students had at least one parent with college experience. The students in the GTA and UTA groups were very similar in terms of the academic covariates of parent college experience, math z-score, current college GPA and the number of advanced placement STEM courses taken in high school, so a potential selection bias was avoided. In particular, mathematics competency as measured by Math ACT or Math SAT score averaged 26.9 (ACT) or 643 (SAT) for students in GTA-led recitation sections and 27.5 (ACT) or 654 (SAT) for students in UTA-led sections. While the means for these two groups are not significantly different, they are well above the national mean of 21 (ACT) or 514 (SAT) on the college entrance tests for that year. From this information, we assumed that competency in mathematics was not an issue for most students in the course.

Table 1

Demographics of CHEM 201 Student Sample in Each TA Group

TA Group	n	Male	Non-white	Parents with college experience	ACT/SAT Math Z-Score (SD)	College GPA (SD)	Number of STEM AP Courses (SD)
GTA	310	64%	25%	75%	1.1 (0.80)	2.81 (0.85)	0.84 (1.21)
UTA	284	64%	17%	79%	1.2 (0.80)	2.86 (0.80)	1.00 (1.23)

[a]Z-score calculated using ACT or SAT national means and standard deviations (2012). National Mean Math ACT (SD) =21.1 (5.3) (ACT, Inc., 2012); National Mean Math SAT = 514 (117) (College Board, 2012)

Instrument Validity and Reliability

We conducted validation of the Undergraduate Course Experience Survey by performing principal component analysis (PCA) on the survey items to extract orthogonal variables from the multiple items used on the survey measuring student perception of the TAs and the student STEM identity aspects. Varimax rotation was chosen for the cleanest interpretation of components, which were retained if their eigenvalues were greater than unity (Kaiser-Guttman criteria).

The items loaded onto one of four factors with eigenvalues greater than 1 as shown by loading coefficients in Table 2. These four factors explained 69.5% of the variance in student responses. The researchers reached a consensus for the following titles of the four factors, along with the number of items per factor and the Cronbach alpha estimate:

1. Perceived TA Impact on Academic Success (10 items, α = .95)
2. Perceived Rapport Building Skills (4 items, α = .77)
3. Student STEM Recognition (3 items, α = .84)
4. Student STEM Interest (3 items, α = .82)

The overall reliability coefficient (Cronbach α) for the 20-item survey was .91. The reliability coefficients were well within the norms of social science research.

Table 2

Factor Loadings for Principal Component Analysis with Varimax Rotation of Undergraduate Course Survey Items

Survey Item	Component 1	2	3	4
Course was enjoyable	.723	.357	-.002	.016
Course was valuable experience	.850	.240	.014	-.031
TA had strong content knowledge	.709	.033	.068	.117
TA gave clear explanations	.824	.171	.061	.027
TA led effective discussions	.783	.291	.037	-.023
Overall TA was excellent	.846	.312	.057	.008
TA gave choices for learning	.697	.434	-.018	.041
My success in future courses due to TA	.781	.316	.055	.024
My grade is higher due to TA	.781	.267	-.007	.052
I understand more content due to TA	.820	.223	.003	.024
I am able to be open with TA	.294	.732	.113	-.033
TA encouraged questions	.355	.670	.102	.064
TA cares about me	.404	.722	-.014	.078
TA tries to understand me	.293	.599	.044	.109
I am a science or math person	.033	.078	.884	.195
Family/friends think I am science or math person	.043	.030	.905	.117
I want others to see me as science or math person	.044	.085	.711	.365
I am interested in experiments	.093	.004	.114	.843
I like talking to others about science or math	-.004	.090	.191	.865
I want to know more about science or math	.005	.076	.399	.738

Survey Results

The results from the survey were reported separately for UTA-led students and GTA-led students as scores on the Perceived TA Impact on Academic Success Scale, the Perceived Rapport Building Scale, the STEM Student Recognition Scale, and the STEM Student Interest Scale. For each of these 4 scales, the individual items comprising them were weighted by the loading factors in Table 3 and then summed to create an overall score (See Table 3).

Table 3

Comparison of Survey Scale Scores Between UTAs and GTAs

		GTA	UTA				
Variable	***Maximum Score***	***M*** **(*SD*)**	***M (SD)***	***df***	***t***	***p***	**Cohen's d**
Perceived TA Impact	39.07	26.79 (6.64)	30.15 (6.02)	399	5.355	<.001	0.53
Perceived Autonomy Support	13.62	9.92 (1.92)	10.64 (1.89)	410	3.856	<.001	0.38
Student STEM Recognition	12.50	9.94 (2.14)	10.44 (1.63)	374	2.643	.04	0.54
Student STEM Interest	12.23	9.83 (2.14)	10.12 (1.82)	391	1.485	.353	-

Comparison of means. We conducted independent-samples t-tests to evaluate whether the GTA mean was significantly different from the UTA mean on each scale in Table 4. Levene's test for equality of variances was significantly non-equal at $p < .05$ for TA Impact; therefore the corrected degrees of freedom and t statistics were reported for TA Impact assuming the variances were not equal. The analyses indicated that students in UTA sections rated their TAs significantly higher on both TA Impact and Rapport Building Skills than did students in GTA sections. Cohen's effect size value ($d = .53$) suggested that being in a UTA section had a moderate practical significance for TA Impact score and a small to moderate effect ($d = .38$) for Rapport Building score (Cohen, 1988**.** The analysis also indicated that students in UTA-led sections had a higher STEM recognition score than students in GTA-led sections, with a Cohen's d of 0.54. Students in UTA-led sections recognized themselves and were recognized by others as 'science or math persons' at a higher level than did students in GTA-led sections. However, we found no significant difference between the TA groups in STEM interest.

Persistence Results

We performed a chi-square test of independence to examine the relationship between TA Type (GTA or UTA) and enrollment in the next semester of general chemistry for all 594 students participating in this study. The relationship between these variables was significant, χ^2 (1, N = 594)

= 13.64, $p < .001$. Therefore, students having UTAs as recitation section leaders were more likely to enroll in the next semester of general chemistry, CHEM 202. We wondered how much more likely were students who were required to take CHEM 202 and in UTA sections to enroll in CHEM 202 for the subsequent spring semester.

Of the 343 students declared or intending to declare majors requiring CHEM 202, 189 students were in UTA-led recitation sections and 154 students were in GTA-led recitation sections. Of the 189 UTA-led students, 135 students (71%) enrolled in CHEM 202 while 82 out of 154 GTA-led students (53%) enrolled in CHEM 202. A chi square test confirmed that proportionally more students required to take CHEM 202 who had UTAs as recitation section leaders enrolled in CHEM 202 than did those who had GTA-led recitation sections: χ^2 (1, N = 343) = 12.07, p =.001).

Because persistence is a categorical dependent variable, logistic regression was used to explore the predictors of persistence. Variables tested to predict persistence were TA type (GTA = 0, UTA = 1), CHEM 201 final exam score, college GPA, math z-score (ACT/SAT), and gender, minority status, and parent education level. We fitted a five-predictor logistic model (obtained from backwards entry) to the data to test the research hypotheses regarding the relationships between the likelihood that a student would enroll in CHEM 202 and TA Type: final exam score, college GPA, math z-score, and parent education (See Table 4). Examining the odds ratios, having a UTA and controlling for all other variables resulted in a student being three times as likely to enroll in CHEM 202 compared to those having a GTA. Several of the other variables also were predictive of the likelihood for subsequent enrollment in CHEM 202. Not surprisingly, the higher the final exam score, college GPA and math score, the more likely the student would enroll in CHEM 202.

Conclusions

The purpose of this study was to evaluate the impact of trained and supported UTAs on student persistence in STEM. This study examined mathematics competency of the students, attrition from the course, student evaluations of TA qualities, student STEM recognition and interest, and persistence of students to the subsequent second semester of general chemistry.

The average math competency for students enrolled in CHEM 201 was high enough (as measured by standardized college entrance exams) so as not to be a substantial concern that students were not prepared for college STEM study. By including a pre-existing math competency measure that students brought to the program, the analyses controlled for any potential impact of that variable in order to more carefully investigate the impact of STEM recognition and STEM interest above and beyond math competency.

Table 4

Logistic Regression for Persistence

Predictor	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**
TA Type Code (GTA = 0; UTA =1)	1.160	.319	13.191	1	.000	**3.188**
Final Exam (%)	.025	.009	7.008	1	.008	1.025
College GPA	1.064	.251	17.943	1	.000	2.899
Math z-score	1.313	.252	27.188	1	.000	3.718
Constant	-4.989	.813	37.695	1	.000	.007

The characteristics of students who withdrew from the course paint a picture of students who were less prepared for college, with lower mean ACT/SAT scores and high school GPA, and who were not as successful in college with a lower mean college GPA. Student achievement measured by grades and test scores do impact student persistence in STEM programs (Rask 2010). These characteristics do not tell the whole story, and it is possible that the active learning strategies used by the UTAs were not helpful for these students or that the students who withdrew were not supported psychosocially by the UTAs. However, students in the GTA-led sections withdrew from the course at nearly the same rate as students in the UTA-led sections, so the type of TA did not significantly impact the attrition rate from the course.

Students in UTA-led recitation sections rated their TAs as having a more positive impact on academic success than did students in GTA-led sections. It is important to note that we could not detect a significant difference in average final exam grades between students in UTA groups and students in GTA groups (Authors, 2016b), but that the students in this study attributed their academic success to the UTAs at a higher level. Students in UTA-led sections also rated their TAs higher on rapport building skills than did GTA-led students. The type of training received by the UTAs aligned with these skills essential to building a learning community. The UTAs reported that their goal for working with less-experienced peers was to provide a higher quality instructional experience that supported all students in a more relaxed and engaging environment than the usual lecture experience. The UTAs also reported that their students often came to them with questions calling for the unique UTA perspective: how to best study and learn the material, which courses to take next, what their future career plans might be, and how they were planning to achieve career goals.

It was not surprising to find little difference between the perceived STEM interest for students in UTA-led sections and students in GTA-led sections. Interest in STEM was probably initiated in childhood or early adolescence (Maltese & Tai, 2011). By contrast, we found an association between higher STEM recognition and having a UTA. Student STEM recognition as operationalized in this study included not only students' perception of themselves as a 'science person' but also a belief that meaningful others also saw the student as a 'science person' (Carlone & Johnson, 2007; Hazari , Sonnert, Sadler & Shanahan., 2010). For this study, a meaningful 'other' person could have been a role played by the UTAs, successful STEM students only a few years ahead of the student, which likely puts the UTA in the role of a credible proxy for social comparison to assess ability to succeed in a STEM program (Wheeler, Martin, & Suls, 1997). The strength of the social comparison students may have made with UTAs was likely closely related to the reported stronger rapport these students had with UTAs over GTAs.

There are several possible ways to evaluate a retention improvement program. One way is to investigate grades, which are important for student progression in a STEM program. An equally or perhaps even more relevant consideration is to examine enrollment in the next course as a measure of persistence, particularly if that enrollment could be increased among those students who achieved at least adequate grades in the first course. Given the hierarchical and structured nature of most STEM degrees, there is little room for deviating from the sequential path of prerequisite foundational courses (such as CHEM 201 and CHEM 202) if one is to stay on track to graduate with the degree in four or five years at our university. Because the two-semester general chemistry sequence is a gateway to over half of STEM majors at our university, departure from the course sequence after the first semester may indicate a departure from a STEM major intention. Data on course enrollment and status of declared majors that we examined from 2010 through 2015, obtained from our university's institutional research office, supports this statement.

Based on the results of this study, a set of mutually reinforcing elements of the UTA-led experiences combined to positively influence their students' retention on a STEM program track as documented by their stronger persistence into the subsequent STEM course. These program elements included stronger rapport building with students, greater student-perceived UTA impact on academic achievement, and higher UTA-led student STEM recognition. Any one of these elements alone may or may not have had a measurable impact on persistence, but combined they correlated with a substantial (more than three times more likely) influence of the UTA program on students to persist in a STEM program of study. The elements described here correlate with the active learning strategies used by the UTAs in their small (25 student) recitation sections. Freeman et al. (2014) also reported that active learning strategies in mathematics, engineering, and science courses had the greatest positive effect on student performance in smaller class sizes, and that results were robust to variations in active learning strategy interventions. In addition, our UTA program aligns strongly with the evidenced-based framework called for by Graham et al. (2013) to increase student persistence in STEM. Two major components of the framework are student learning and student identification as a scientist. Positive increases in these two components through active learning in introductory courses and early participation in learning communities result in increased confidence and motivation for persisting in STEM. We also found this to be true in our program. This article also mentioned that STEM faculty members are often reluctant to take up new active learning strategies; however this is where the UTAs served as an effective intermediary (Romm et al., 2010). UTAs learning to teach using methods discussed in workshop and seminar shared and modeled active learning strategies with our university faculty. This has resulted in an increase in faculty requests for UTAs and a growing acceptance by the faculty of using evidenced-based teaching strategies to positively impact student learning.

Therefore, the UTA program described here positively impacted persistence to the next chemistry course for students required to take that course for their intended or declared major. This was a measureable outcome within a one-semester timeframe and could be viewed as part of an overall retention goal that would span several years. Given this positive outcome on the first steps of the student STEM experience, and given the critical role of the first-year college experiences, decisions, and behaviors for launching students successfully toward a STEM degree, longer-term program goals for increased STEM student retention may be achieved. Following students from this course as they progress through upcoming course work and possible future interaction with UTAs in second year courses will provide more longitudinal information about the effectiveness of the UTA program for increased STEM student retention toward degree completion.

Implications

Students reported that UTAs more strongly supported those factors of quality instruction and informal mentoring in a learning community. The encouragement to persist may be far more valuable for STEM student retention than increasing grades. Further research, including a deeper investigation of student perceptions of UTAs and persistence in STEM majors using more extensive surveys of students or interviews with students, UTAs, and GTAs, is warranted. More information is also needed to fully characterize the types of interactions that UTAs tend to have with their students that are different from those between GTAs and their students. For instance, UTAs did mention during conversations held in seminars that many students often came to them for course or professor selection recommendation, as well as career advice. We did not observe or hear about students in GTA-led sections asking for such advice to that extent.

This study described the UTA selection process, semester-long training workshops and seminars, and STEM support given to the UTAs. This program was developed to be institutionally sustainable after grant funding is completed. Are all these program elements critical? Are there some elements more critical than others? We plan to examine factors that could be improved so that not only encouragement to persist, but also STEM academic achievement improves for more students. Whatever elements are found to foster increased student persistence, they must not be so onerous to implement that the institution cannot or will not support the program. Moreover, a GTA training program was developed in response to the success of the UTA program to further impact student learning and persistence.

Although this was the first research investigation into this particular program, the results showed that the way in which the UTAs are being supported and used in the Chemistry Department is effective for student STEM persistence. Future work will examine if UTAs in other STEM departments are as successful in encouraging STEM persistence.

Therefore, although many questions about the effectiveness of trained and supported UTAs on student performance and persistence remain to be answered, this initial investigation into general chemistry recitation sections suggests promising results for supporting retention of students in STEM fields.

Acknowledgments

The UTA training and support program and this study were funded by the National Science Foundation under grant #106830 from the Division of Undergraduate Education.

References

ACT, Inc. (2012). *2012 ACT Profile Report - National.* Retrieved from: http://forms.act.org/newsroom/data/2012/pdf/profile/National2012.pdf

Philipp, S.B., Tretter, T.R., Rich, C.V. (2016). Development of undergraduate teaching assistants as effective peer mentors in STEM courses. *Journal of College Science Teaching, 45*(3), 74-82.

Philipp, S.B., Tretter, T.R., Rich, C.V. (2016). Undergraduate teaching assistant impact on student academic achievement in general chemistry. *Electronic Journal of Science Education, 20*(2), 1-13.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*, 1187-1218. Retrieved from http://www.oswego.edu/Documents/STEM/8.3b_Carlone_Understanding%20Sci%20Experiences%20of%20Sucessful%20WOC_2007.pdf

Chapin, H. C., Wiggins, B. L., & Martin-Morris, L. E. (2014). Undergraduate science learners show comparable outcomes whether taught by undergraduate or graduate teaching assistants. *Journal of College Science Teaching*, *44*(2), 90-99.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

College Board. (2012). 2012 College-bound seniors total group profile report. Retrieved from http://media.collegeboard.com/digitalServices/pdf/research/TotalGroup-2012.pdf

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415. Retrieved from http://www.pnas.org/content/111/23/8410.full

Golde, C. M., & Dore, T. M. (2001). At cross purposes: What the experiences of today's doctoral students reveal about doctoral education. (www.phd-survey.org). Philadelphia, PA. Report prepared for the Pew Charitable Trusts. Retrieved from: http://eric.ed.gov/?id=ED450628

Graham, M.J., Frederick, J., Byars-Winston, A., Hunter, A-B., & Handelsman, J. (2013). Increasing persistence of college students in STEM. *Science*, *341*, 1455-1456. Retrieved from http://portal.scienceintheclassroom.org/sites/default/files/post-files/science-2013-graham-1455-6.pdf

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*, 978-1003.

Johnson, A. C. (2007). Graduating underrepresented African American, Latino, and American Indian students in science. *Journal of Women and Minorities in Science and Engineering*, *13*(1). Retrieved from http://faculty.smcm.edu/acjohnson/PREP/Johnson%202007a.doc

Lacey, T. A., & Wright, B. (2009). Occupational employment projections to 2018. *Monthly Labor Review, 132*, 82-123. Retrieved from http://stats.bls.gov/opub/mlr/2009/11/art5full.pdf

Lewis, S. E. (2011). Retention and reform: An evaluation of peer-led team learning. *Journal of Chemical Education*, *88*(6), 703-707. Retrieved from http://cpltl.iupui.edu/media/dec741f4-438b-41f0-8745-e4df4998b577/u5pKng/cPLTLContent/2013/PLTL%20Literature%20PDFs/Lewis_2011.pdf

Luft, J. A., Kurdziel, J. P., Roehrig, G. H., & Turner, J. (2004). Growing a garden without water: Graduate teaching assistants in introductory science laboratories at a doctoral/research university. *Journal of Research in Science Teaching*, *41*(3), 211-233. Retrieved from https://www.researchgate.net/profile/Julie_Luft/publication/227535791_Growing_a_garden_without_water_Graduate_teaching_assistants_in_introductory_science_laboratories_at_a_doctoralresearch_university/links/00b49519f376e08c5e000000.pdf

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*, 877-907. Retrieved from http://www.socialimpactexchange.org/sites/www.socialimpactexchange.org/files/A+B-Tai__Maltese-Pipeline(2011).pdf

National Science Foundation (NSF). (2012). Integrated postsecondary education data system completions survey [data file]. Retrieved from https://caspar.nsf.gov/

Perez, T., Cromley, J. G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of Educational Psychology, 106*, 315. Retrieved from https://www.researchgate.net/profile/Avi_Kaplan/publication/256112544_The_Role_of_Identity_Development_Values_and_Costs_in_College_STEM_Retention/links/55f584b208ae63926cf4c185.pdf

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review, 29*, 892-900. Retrieved from http://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?article=1141&context=workingpapers&sei-redir=1&referer=https%3A%2F%2Fscholar.google.com%2Fscholar%3Fq%3DRask%2Battrition%26btnG%3D%26hl%3Den%26as_sdt%3D0%252C15#search=%22Rask%20attrition%22

Romm, I., Gordon-Messer, S., & Kosinski-Collins, M. (2010). Educating young educators: A pedagogical internship for undergraduate teaching assistants. *CBE-Life Sciences Education*, *9*(2), 80-86. Retrieved from http://www.lifescied.org/content/9/2/80.full

Seymour, E., & N.M. Hewitt. (1997) *Talking about leaving: Why undergraduates leave the sciences*. Bolder, CO: Westview Press.

Strenta, A. C., Elliott, R., Adair, R., Matier, M., & Scott, J. (1994). Choosing and leaving science in highly selective institutions. *Research in Higher Education, 35*(5), 513-547. Retrieved from http://www.jstor.org/stable/40196139?seq=1#page_scan_tab_contents

Watkins, J., & Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching*, *42*, 36-41. Retrieved from http://dosen.narotama.ac.id/wp-content/uploads/2014/11/Retaining-students-in-science-technology-engineering-and-mathematics-STEM-majors.pdf

Wheeler, L., Martin, R., & Suls, J. (1997). The proxy model of social comparison for self-assessment of ability. *Personality and Social Psychology Review*, *1*, 54-61.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology*, *70*, 767–779. Retrieved from https://www.researchgate.net/profile/Edward_Deci/publication/14563458_Internalization_of_biopsychosocial_values_by_medical_students_A_test_of_self-determination_theory/links/0c960529b5f3048f5d000000.pdf