A PERSONAL VIEW

Undergraduate teaching assistants can provide support for reformed practices to raise student learning

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INTRODUCTION

At universities, graduate teaching assistants (GTAs) have long played a central role in the teaching of STEM (science, technology, engineering, mathematics) courses in the United States (42). Instructors particularly value teaching assistants who can help students with experimental guided discovery. As graduate students, immersed in their own research, they are often considered essential mentors for undergraduates enrolled in inquiry or CURE (Course-Based Undergraduate Research Experiences)-based classroom laboratories (3). Additionally, the literature supports that, when they teach, graduate students gain not only just a pedagogical experience, but a deeper understanding of experimental design itself (6). They develop a more mature understanding of research when challenged to teach it, more than their peers who focus solely on benchwork (13). As a result, the model where graduate students serve as teaching assistants has become part of the common method used to develop future scientists and teachers (6).

When graduate students serve as teaching assistants, this also provides them with an important source of employment. If they teach, tuition is waived, and graduate students can earn a stipend, which permits them to work their way through a graduate degree. Thus, in some ways, the role of GTA could be seen as ideal. The GTA position can provide financial support, teaching experience, and deeper reflection on research. Yet, given that graduate students working at the bench are the engine that drives STEM research at large universities, a tension does exist between their teaching and research responsibilities. We might hope that GTAs, who are not experiencing the pressures associated with promotion and tenure, might be better prepared to make the systemic changes required to improve STEM education (21, 43, 44). Yet much like their research mentor, who often feels pressured to prioritize scholarship over teaching, graduate students are under great pressure to do the same.

Graduate students serve as the “right hand” of research-focused mentors. Unlike the instructors they work for as GTAs, their research mentors contribute considerable funds to pay them and their tuition at all times when they are not supported by GTA positions. Thus, away from their teaching duties, students on GTA support spend as many hours as possible working on completing the course work and research necessary to finish their dissertations. Under the watchful eye of their research mentor, every hour spent on instruction may be perceived as one taken away from research (5). As a result, it is not surprising that graduate students can underwhelm their students as often as they impress their instructors (17, 24, 38). This variability, plus great expense of GTAs, is one reason undergraduates have been recruited to join the ranks of instructors.

What Can UTAs Do?

Undergraduate teaching assistants (UTAs) have been a vital part of teaching at primarily undergraduate universities for decades (15). In the laboratory, in addition to preparing equipment and supplies, UTAs assist the students in idea development and project completion and provide support in a number of roles inside as well as outside the course (Table 1). While UTAs are common at small liberal arts universities in the
A range of publications have reported a variety of the outlined uses of undergraduate teaching assistants (UTAs) in the laboratory, recitation, or in supplemental (outside of class time) environments. There is a paucity of discussion of best practices performed by UTAs coteaching alongside faculty inside the lecture.

United States (11), the literature more often examines the use of undergraduates at large universities. At Stanford University, Roberts et al. (40) and later Reges (39) reported their computer science UTAs to be highly motivated, which in turn motivated the students taking the course. They also found that students more easily developed close relationships with UTAs, which led to more comfortable and productive interactions with UTAs and peers (39, 40). The UTAs often acted as role models for the students in the class, which they found to be especially important for women and nonmajority students.

As was found for GTAs, UTA programs were frequently reported to provide benefits to both the students and the UTAs (2, 7, 10, 16, 33, 48). There is much in the literature that demonstrates positive results with the use of UTAs in STEM courses. Even a quick survey yields reports from the fields of biology (20, 35), chemistry (28, 30, 45, 46), engineering (34), and nursing (8). A selection of these benefits and reports are discussed in their many roles in teaching.

**UTA Roles in Different Programs**

The literature reports on different programs and roles in which UTAs have served. One model using UTAs is called peer-led team learning (PLTL). PLTL was first developed by Woodward et al. (49) as an integrated method that promoted discourse and creative problem solving in chemistry at the City College of New York (12, 19, 41). The PLTL instructional model does not alter the lecture, but rather introduces a supplemental class meeting, the PLTL workshop, led by UTAs who completed training to serve as a facilitator for group work.

A number of studies examined UTAs serving in supplemental PLTL instruction for university chemistry courses (23, 46). Liu et al. (30) measured students’ motivation in an organic chemistry course and found that students developed more motivation in a PLTL environment. Tien et al. (45) reported that PLTL had positive social influences and in some ways replicated the social nature of science research. Wasmer (46) found that PLTL students outperformed peers, Lewis (28) reported improved course completion and retention, and Lyle and Robinson (32) found a positive impact on critical thinking, grades, and retention for women.

Another program, peer-led guided inquiry (PLGI), or peer-led process-oriented guided inquiry learning (POGIL), is a weekly implementation of cooperative learning within a college general chemistry course (27, 29). Peer-led POGIL uses guided inquiry for students working in small groups during class time led by peer leaders (UTAs). The POGIL sessions with peer leaders have been studied and found to increase student understanding and use of evidence and reasoning to support answers (26).

Another strategy, the Colorado learning assistant model, reported on the use of UTAs in response to inadequate preparation of undergraduates for college physics. They hired high-achieving undergraduates in physics as UTAs to join instruction in the lecture setting (36). Unlike most programs, in Colorado, UTAs regularly entered the lecture environment. Otero et al. (36) reported that they facilitated group discussions in large lectures to encourage debates, as well as find consensus among students. When adopted by others, this model “led to statistical improvement” of performance on the Force Concept Inventory in physics (17, 18).

Internationally, examples of institutional efforts to use UTAs are the programs called peer assistance support scheme (PASS)
and peer-assisted learning (PAL) utilized in Great Britain and Australia (4, 22, 47). PASS/PAL is based on the use of supplemental instruction and is similar to PLTL, where the UTAs do not enter the lecture environment but rather provide support elsewhere. Studies of these programs found that, in addition to higher course scores, students had gained critical thinking skills (47).

The majority of the articles in the literature report that most schemes employed undergraduates as assistants to provide support in the laboratory setting, or a supplemental setting, but not as frequently in lecture. This might be a result of UTAs following in the footsteps of GTAs. Yet no matter which programmatic strategy was used, well-trained and supported UTAs were found effective in every case (15).

Can UTAs Replace GTAs?

Shifts from GTAs to UTAs have often been catalyzed as a cost-saving measure (17, 18, 40) and the cost of employment of a single UTA can be 1/10th of that for a GTA. This dramatic difference in cost might raise the question: “Is a GTA ten times better?” Research comparing UTAs and GTAs in introductory biology courses suggest that both aid student learning in the laboratory, encourage positive attitudes toward science, and result in comparable average course grades (9, 47). In this case, however, course sections with UTAs received slightly better scores from two assessments looking at students’ attitudes toward science courses (9, 45). The authors felt that these results suggested that utilization of UTAs as a relatable group to students is not inconsequential (9). A number of authors promoted the idea that students can relate to UTAs more than GTAs or professors. Most UTAs are in similar degree programs, taking the same courses, and may provide unique resources to the students, as well as act as role models.

Unlike GTAs, UTAs have frequently been used to aid the faculty with teaching in lecture. In a lecture hall with both a professor and UTAs present, all students get substantially more opportunities for feedback during an active learning process compared with that when only a single instructor is present. In lecture, UTAs can be pivotal to providing an engaged and active learning experience for the students. Envisioning or understanding how to use UTAs in the course laboratory setting is not a great challenge for faculty, given that they have frequently observed and worked beside GTAs serving in that same role. On the other hand, some faculty report that they have a greater difficulty anticipating how to use UTAs in lecture. This is a more novel experience; some suggest that “rarely has such a luxury been afforded them.” As a result, in addition to best practices found in the literature, we have also curated a set of more novel roles in lecture where UTAs can better understand the mindset and challenges faced by their peers. Another report found that UTAs received comparable scores to GTAs on course evaluations for degree of helpfulness, accessibility, and level of qualification (14). While course evaluations are quite different than evidence of student learning, a number of articles report findings of increased student performance.

Does Use of UTAs Increase Student Scores?

UTA programs have been implemented in a variety of ways, and the majority of results show a positive relationship with student learning (37). For example, the PLTL model at Washington University was found to increase general chemistry course grades by approximately one-third of a grade point, compared with non-PLTL versions of the same class (23). In another evaluation at Kennesaw State University, the PLTL reform on a first-semester general chemistry courses led to a statistically significant improvement of 15% in the pass rate, whereas scores on a comprehensive American Chemical Society exam were comparable to those for non-PLTL classes (28).

The comparison between UTA-staffed classrooms and those without UTAs reveals a significant difference in learning. When a UTA model was applied to physics laboratory courses at Florida International University, the students made a mean raw gain of 0.243 on the Force Concept Inventory, compared with 0.159 in traditional laboratories (17, 18). Hierarchical linear modeling implemented to examine the effectiveness of PLGI showed that there was statistically significant improvement in academic performance over traditional pedagogy, although preexisting achievement gaps that existed in incoming students’ performance on the SAT (Scholastic Aptitude Test) remained present after the intervention (27, 29). While the gaps did not change, the academic progress of students who had UTAs in their classroom grew notably, compared with their traditional counterparts. Other studies reported that, not only can the presence of UTAs improve course grades and academic performance, they also assist in facilitating higher retention rates and stronger critical thinking, all skills that are hallmarks of improved student engagement and success (32, 45).

At our university, one example of outside-class support is the significant role UTAs play in providing training and practice to students so they succeed on summative oral exams known as the verbal final (VF) (31). Each week, UTAs regularly proctor numerous practice oral exams that are similar to clinical interviews, and our data suggest their role increases student learning (Fig. 1). While this training with UTAs was ongoing, well before the VF, a traditional rigorous written midterm exam occurred. The data from the midterm supported that students’ practice with UTAs raised their score on the traditional exam. Students who had made no practice attempts with UTAs for the VF earned, on average, a 33% on the midterm exam, whereas those who had made some practice attempts, but did not pass, fared better (55%), and those who made some attempts and passed the practice VF with UTAs (61%) performed best. Might the interaction with UTAs have led to higher exam performance as a result of other discussions or mentorship that was not directly related to the VF attempts themselves? Perhaps. We feel more certain that UTA instruction and support likely encouraged and increased student studying and time on task and, as a result, enhanced learning.

METHODS

With the approval of Michigan State University (MSU) Institutional Review Board (IRB x00–475 and 10–543), student data from the midterm exam were collected from students who completed the Introduction to Cell and Molecular Biology course at MSU. All
students were enrolled at MSU, and participant consent was obtained while students were enrolled in the course. These data were used to generate Fig. 1.

**DISCUSSION**

Recently a colleague asked, “What was the biggest surprise learned as a result of surveying the literature on undergraduate teaching assistants?” In truth, in reflection, there should not be a great surprise that much of the data suggest UTAs have similar abilities and skills to GTAs (9). A graduate student was just recently an undergraduate, perhaps even just months ago, and he/she likely came from a different university, and thus the graduate student had not previously taken the course he/she is assigned to teach. Thus it should not be a great surprise that an undergraduate who took the course, enjoyed the course, and had a good relationship with the instructor might be well qualified for this particular role.

For some reason, once we apply to a student the label “graduate student,” we assume he/she gains all of the experience and wisdom that comes from someone who has spent many years completing a PhD. Of course, this is not the case, not for many years, and not for all individuals. Sometimes graduate students themselves also gain self-confidence when they first receive the label. This confidence may help in their instruction, or alternatively it may permit them to feel emboldened to have a different vision for teaching than the professor (17). Once again, an undergraduate who did well in the course and had a good relationship with the professor tends to more likely be familiar and share the vision of the professor. He/she likely does not need to be convinced to support the instructor’s vision. As a result, a professor may have a more productive experience with UTAs and report greater variability of his/her support from GTAs (17, 24, 38).

The great surprise is the financial one. The fact that to employ a graduate student to help teach a course might cost 10 times as much as to employ an undergraduate of similar age and maturity is unexpected. The difference comes from that, on one hand, you are paying someone solely to be a good teacher, and, on the other, you are paying this person to immerse himself/herself in research and also help teach a course.

**You Can Reap What You Sow**

One does not have to professionally study human subjects to be aware that the variability between individuals can be great. Therefore, if you randomly pick any undergraduate from a course to become a teaching assistant for that class, a positive outcome is difficult to ensure. Yet when a faculty member gets the opportunity to select his/her best students, those who did well in his/her own course, and has the opportunity to train them personally and deploy them as teaching assistants in that

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**Table 2. Sample UTA roles practiced in lecture**

| Pre- and Postlecture | During Lecture | Beyond Lecture |
|----------------------|---------------|---------------|
| • Set up room: Arrive early to take materials from faculty office to lecture hall, prepare/organize classroom space (e.g., arrange seating, handouts, name placards) and set up all teaching technologies in advance of instructor arriving for lecture. | • Facilitate group discussions: When students are asked to solve a problem or discuss their ideas during a planned exercise, UTAs circulate among the students to pose and answer questions, as well as keep groups on task. | • Guide students to find answers: before and after lecture, at office hours, via e-mail, and on online forums. UTAs are often trained to answer students’ verbal questions by responses that, rather than provide a “correct answer,” instead pose guiding questions to aid in students’ finding an answer. This builds self-reliance, learning, and comprehension. |
| • Break down room: Stay after lecture to help instructor field active student questions, gather teaching materials used in classroom, ensure the room is cleared and ready for next class before leaving, help return materials to faculty office. | • Examples: When an instructor runs a think-pair-share exercise in lecture, UTAs will remind students to discuss “What was your reasoning?” If students get lost after missing the directions, UTAs can get them back on track. When students are supposed to be writing, but instead are just waiting, intervention by UTAs can return them to task. | • Grade immediately/automatically: UTAs can collect and score for effort, or accuracy, all in-class written exercises and online homework. Scores can be entered and maintained in a spreadsheet accessible to the other UTAs and professor. |
| • Novel example: If an instructor regularly uses random calling from a card deck or software system, but permits students to occasionally opt out, UTAs can manage each day’s “opt-outs” by removing names from the card deck or software system prior to the start of lecture. | • Lead cold-calling: UTAs can implement the random pick of a student (via deck of cards or software system) and, in larger classrooms, provide a hand-held microphone to each student so his/her voice is heard whenever he/she answer (or ask) questions. | • Maintain online forum to archive announcements from lecture, answer student questions in forums, and provide examples of excellent answers from peers to prior online homework questions. |
| • Novel example: If an instructor frequently and repeatably leads students in specific tasks during lecture, one example might be the regular critique of research figures in a shared discussion. UTAs can prepare in advance to always “take over” instructor duties at that moment and lead a discussion of, for example, the purpose, methods, and findings of figures at that point of the lecture. | • Example: If an instructor frequently and repeatably leads students in specific tasks during lecture, one example might be the regular critique of research figures in a shared discussion. UTAs can prepare in advance to always “take over” instructor duties at that moment and lead a discussion of, for example, the purpose, methods, and findings of figures at that point of the lecture. | • Novel Example: Lead the mentoring and training of students to succeed on high-stakes summative assessments. In this example, UTAs hold regular one-on-one practice oral exams (clinical interview setting called “verbal final”) appointments with students on a pass/fail basis in order to prepare them for a formal exam with the professor. Fig. 1 provides support for success in this role. |

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**You Can Reap What You Sow**

One does not have to professionally study human subjects to be aware that the variability between individuals can be great. Therefore, if you randomly pick any undergraduate from a course to become a teaching assistant for that class, a positive outcome is difficult to ensure. Yet when a faculty member gets the opportunity to select his/her best students, those who did well in his/her own course, and has the opportunity to train them personally and deploy them as teaching assistants in that
same course, a positive outcome is highly predictable. Perhaps all faculty should have an opportunity to reap what they sow. After their efforts to successfully challenge their students to become independent, resilient scientists and scholars, they then can greatly benefit from working with them as UTAs. Of course, every graduate student who serves as a GTA is also just a product that one reaps what “someone else” sowed. Thus one might expect UTAs to be the same.

A True Breakthrough?

Strong UTAs may be our best hope to improve student learning in STEM classrooms. They are perhaps uniquely qualified and positioned to be the optimal, the ideal, advocate to raise learning in their peers. Most of all, they are not exorbitantly expensive and are sometimes only paid in credits, and, as result, they can more easily go places graduate students have rarely gone. UTAs can enter the lecture room with the professor and help coteach. When a professor runs an active learning exercise, the professor and his/her UTAs can circulate the room and directly interact with student groups, clarify instructions, pose questions, and direct thinking, to get students back to the task at hand. When an instructor runs a think-pair-share exercise and knows from the literature that, when students speak to each other, they should focus on “what was your reasoning” (25), UTAs can help guide them back to that focus when they might naturally stray from it.

In lecture, one UTA can carry a microphone to every student who asks or answers a question, so they are heard. Another can randomly pick from a deck of cards with student names for random or cold calling. If students are drawing concept maps and become distracted with “Am I supposed to?”, UTAs can get them back on track. If students are creating phylogenetic trees and get lost in the forest of directions, UTAs can clarify on what they should focus. When students are supposed to be writing the “muddiest point” (1), but they do nothing because they expect the answer will soon be shared, intervention by UTAs can get them back on track.

Challenges in Using UTAs

UTAs bring energy, experience, and enthusiasm to their teaching, yet of course they also have their own challenges. Faculty might ask how best to recruit and interview them in hopes of finding the best. The best advice we have received was to recruit the students who we have been teaching for 15 wk. The UTAs who will be the most dependable and successful for you and your course are those who were the most dependable and successful students in your course. Some sage advice also includes that finding someone who is interested in teaching can also help one figure out who might become the best UTA. Another challenge that comes to mind is that undergraduates have very busy schedules. Faculty members with years of experience using UTAs have often shared the advice to “schedule first, hire last.” It is important to first confirm that the student’s schedule will permit him/her to teach in the time periods needed before officially hiring the student. In addition to schedule, extraordinary UTAs seem to graduate far too soon. Thus a limitation is only being able to use them for a few years. For great assistance in learning more how to optimize hiring and working with UTAs, seek out the Learning Assistant Alliance. Their website and conferences provide invaluable assistance.

Coteaching in Lecture

Beyond the assistant-only role, strong UTAs can literally coteach. As mentioned in the list provided in Table 2, creative faculty have successfully employed them to run 5-min “journal clubs” during lectures. In this approach, any time students are challenged to evaluate a figure from a publication, the UTAs immediately take over the discussion. Students are expected to come up with the “trifecta”: the purpose, methods, and findings of the figure. When UTAs take the lead, the change of pace and voice in the lecture room may awaken those who have become distracted. It also can serve as a Pavlovian signal that elicits practiced behaviors.

Whereas most UTA programs in the literature have disseminated models where UTAs are either present in the classroom laboratory or provide support in a supplemental classroom space, when possible, perhaps more colleges should consider introducing them into lecture with the professor. While providing a postdoc or graduate student (let alone two!) might be quickly considered a prohibitive cost most institutions could not sustain, in comparison one UTAs might be quickly considered a prohibitive cost most institutions could not sustain, in comparison one or two UTAs might be far more acceptable. Excellent UTAs in the lecture room can have a substantial impact at an affordable cost. This may be where the greatest breakthrough should be explored and exploited.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

D.B.L. conceived and designed research; D.B.L., B.W.M., N.A., A.K.K., A.C.U., and A.A.H. performed experiments; D.B.L., B.W.M., N.A., A.K.K., A.C.U., and A.A.H. analyzed data; D.B.L., B.W.M., N.A., A.K.K., A.C.U., and A.A.H. interpreted results of experiments; D.B.L., B.W.M., N.A., A.K.K., A.C.U., and A.A.H. prepared figures; D.B.L. drafted manuscript; D.B.L., B.W.M., N.A., A.K.K., A.C.U., and A.A.H. edited and revised
manuscript; D.B.L., B.W.M., N.A., A.K.K., A.C.U., and A.A.H. approved final version of manuscript.

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