The Undergraduate Teaching Assistant Experience Offers Opportunities Similar to the Undergraduate Research Experience†

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There has been a growing concern in higher education about our failure to produce scientifically trained workers and scientifically literate citizens. Active-learning and research-oriented activities are posited as ways to give students a deeper understanding of science. We report on an undergraduate teaching assistant (UTA) experience and suggest that students who participate as a UTA obtain benefits analogous to those who participate as an undergraduate research assistant (URA). We examined the experiences of 24 undergraduates acting as UTAs in a general microbiology course. Self-reported gains by the UTAs were supported by observational data from undergraduates in the course who were mentored by the UTAs and by the graduate teaching assistants (GTAs) with whom the UTAs worked. Specifically, data from the UTAs’ journals and self-reported Likert scales and rubrics indicated that our teaching assistants developed professional characteristics such as self-confidence and communication and leadership skills, while they acquired knowledge of microbiology content and laboratory skills. Data from the undergraduate Likert scale as well as the pre- and post-GTA rubrics further confirmed our UTA’s data interpretations. These findings are significant because they offer empirical data to support the suggestion that the UTA experience is an effective option for developing skills and knowledge in undergraduates that are essential for careers in science. The UTA experience provides a valuable alternative to the URA experience.

The goals for teaching science promoted in reports such as Project 2061, Science for All Americans (1), and National Science Education Standards (22) have focused on ways to use science as something that students actively do, rather than something that is done to or for them. Active-learning initiatives, especially in large classes, require significant instructor effort. To support student-centered methods, undergraduates acting as teaching assistants have been employed (https://listserv.umd.edu/cgi-bin/wa?A2=ind0411&L=life%20link&P=1 584) (9, 17, 28). An increasing body of research shows that undergraduates benefit from interactions with peers who help mentor their learning (14, 19, 20, 24, 26, 30). However, far fewer studies have investigated the benefits received by the undergraduates who are in a teaching assistant role. These roles include undergraduate teaching assistants (UTAs), peer guides in Peer-Lead Team Learning and Peer-Assisted Study Sessions, and learning assistants.

Fingerson and Culley described the effects of UTAs in a sociology course, where UTAs self-reported development in professional skills after assisting instructors with their general duties and answering students’ questions (6). Mckeeegan studied UTAs in a research methodology course with mentoring responsibilities that included giving a lecture and aiding students with library research skills and data collection and found that UTAs developed research abilities, teaching awareness and experience, and communication skills, as well as self-confidence (17). Mendenhall, who analyzed UTAs working in a psychology course, found that they developed teaching techniques, group-facilitating skills, leadership and counseling expertise, as well as administrative abilities (18). Studies of Peer-Lead Team Learning experiences in chemistry suggested that peer leaders develop cognitive abilities to integrate pedagogical ideas with the subject matter, learn to identify students’ motivational needs, and understand interpersonal dynamics (29). The Learning Assistant program, designed for future K-12 science and mathematics teachers, has been found beneficial as measured by increases in the grade point average (GPA) of students who continue in the program, pre- and post-conceptual knowledge evaluations, and rising recruitment rates (7, 8, 24). However, reports have yet to demonstrate professional gains experienced by the learning assistants themselves. Watters and Giins’s interpretation of peer leaders’ weekly journal entries and reports of anecdotal experiences showed development in peer leaders’ perceived sense of identity and technical skills for facilitating group activities (34).

Between the limited studies analyzing undergraduates acting in teaching assistantship roles and the speculation of science education researchers (9, 35), there is overall agreement in the value of these opportunities. But work remains to validate the specific claims.

We assert that the UTA experience can be compared to the undergraduate research assistant (URA) experience. URA
opportunities support the development of students’ conceptual knowledge and awareness of the progress of scientific research and enhance their professional development as researchers, objectives put forth by the National Research Council’s Advancing Scientific Research in Education Report (23). Data on the value of URA experiences preparing undergraduates for successful careers in science have been growing over the past decade. URAs develop communication and leadership skills, gain self-confidence, and increase their understanding of the nature and development of scientific knowledge (11, 25, 27). Seymour’s study of undergraduates participating in a summer research program revealed gains in areas of thinking and working like a scientist, research skills, clarification of career plans, and increased self-confidence (27). Kardash’s analyses of URAs’ self-reports revealed growth in basic research skills and oral communication of results, but found little formal writing or higher-order research skills development, such as forming hypotheses and synthesizing information (11). Although these studies suggest that being a URA is of significant value to students who participate, the number of URA opportunities is limited.

We hypothesized that a UTA apprenticeship in an undergraduate introductory science course would offer an opportunity analogous to that of the URA for developing skills crucial to success in science careers. To test our hypothesis that a UTA internship can offer similar opportunities to develop skills scientists acknowledge as critical for success in science-oriented careers (10), we based our research design on the reported benefits from URA experiences (27).

Research question. The guiding research question was “How does a UTA internship affect the development of communication and leadership skills, knowledge, and self-confidence considered valuable for careers in science?”

MATERIALS AND METHODS

General Microbiology (BSCI 223) is a sophomore-level, large enrollment, introductory microbiology course. It has two 50-minute lectures and two 1-hour and 50-minute laboratory sessions per week. The course has a significant online component supported by WebCT (Blackboard Inc.) and follows an active-learning format that has previously been described (https://listserv.umd.edu/cgi-bin/wa?A2=in d0411&L=lifelink&P=1584) (28).

In the fall of 2005, the class with an enrollment of 450 students was divided into two lecture sections, each with a distinct faculty instructor, and 24 lab sections of 18 students. Each lab section was staffed with a graduate teaching assistant (GTA) who performed the traditional teaching and safety oversight role and a UTA with the unique role of promoting a student-centered, active-learning environment. A third faculty instructor oversaw the laboratory portion of the course, held weekly meetings with GTAs, and served as instructor for the Scientific Teaching Internship (BSCI 348U) course required of all URAs. UTAs received three upper-level biology credits for participating in the course and serving as a UTA.

The UTA’s role was to provide feedback to undergraduates as they participated in various active-learning assignments. During meetings of the Scientific Teaching Internship course, UTAs discussed course goals and how to use published teaching methods to help students meet those goals. UTAs worked with students one-on-one and in groups and met with students in the lab setting as well as in online environments. UTAs supported student learning of content, lab skills, and research methods. They served as peer mentors and discussion leaders in face-to-face and online environments. They had opportunities to probe student understanding with questions, as well as instruct through lecture presentations. The Scientific Teaching Internship syllabus, containing weekly discussion topics and assigned readings, is found in Appendix A in the supplemental material.

This research focused on 24 students majoring in biological sciences who served as UTAs: 13 women and 11 men. The students had an average GPA of 3.41; 14 were juniors and 10 were seniors. Two students had previously participated as UTAs. Students were recruited to be UTAs via listing the Scientific Teaching Internship course in the schedule of classes and through list-serve announcements. Students were required to have completed General Microbiology with a grade of “A” or “B” to be eligible to serve as UTAs. All subjects participated in this study on a voluntary basis.

Our study employed a mixed methodology in analyzing UTAs’ self-assessed and observed growth over a semester with respect to professional scientific qualities. The UTAs self-evaluation instruments consisted of a weekly journal (Fig. 1, number 1), a pre- and posttest measuring actions and beliefs via a Likert scale (Fig. 1, number 4), and a self-evaluation of performance in areas of communication, leadership, knowledge, and self-confidence via a Likert scale that was delivered before and after the UTA experience (Fig. 1, number 3). The GTAs and undergraduates’ instruments, used to observe the UTAs’ growth and performances, were a rubric to measure UTA performance in communication, leadership, knowledge, and self-confidence that was used before and after the UTA experience (Fig. 1, number 2) and a posttest to allow undergraduates to rate UTA performance in communication, leadership, knowledge, and self-confidence that was used before and after the UTA experience (Fig. 1, number 5) and a posttest to allow undergraduates to rate UTA performance in communication, leadership, knowledge, and self-confidence that was used before and after the UTA experience (Fig. 1, number 2) and a posttest to allow undergraduates to rate UTA performance in communication, leadership, knowledge, and self-confidence that was used before and after the UTA experience (Fig. 1, number 5). The five instruments (see Appendix B in the supplemental material) were adapted from published studies (3, 2, 5, 12, 13, 15, 27, 31, 32, 33) and piloted in the spring of 2005. To increase the validity and reliability of the data, we modified the wording and the selection of the questions used in the spring of 2005 based upon convergent validity with comparable questions within and between UTAs, GTAs, and undergraduates’ instruments. Also, our Cronbach’s alpha values suggested that our questions produced reliable scores α > .70 (pre-Likert scale = .886; post-Likert scale = .837; prerubric = .741; postrubric = .786) (4).

Figure 1 represents our final five instruments and shows how each instrument measured skills of communication, leadership, knowledge, and self-confidence. This diagram indicates that each instrument was strengthened by converging data collected from the other instruments and shows how we used the data to synthesize understanding of the UTAs’ growth over the semester.
RESULTS

All data were collected through the use of the quiz tool in WebCT (Blackboard Inc.). Quantitative data were analyzed by one-way fixed effects analysis of variance (ANOVA), paired t tests, and descriptive statistics performed using the SPSS analytical software package (SPSS Inc.). UTAs’ journal entries and short answer responses were coded using an inductive coding scheme. Qualitative data from the journals and undergraduates’ short answer question responses were transcribed and coded using an analytic induction methodology and a Bloom’s taxonomy scoring scale (12).

Our journal question asked for examples from which we assessed levels of understanding and envisioned application. Therefore, the UTAs’ journals provided us with direct insight into how their laboratory experiences and the Scientific Teaching Internship course affected their confidence, conceptual knowledge, leadership abilities, thinking, and actions towards communicating scientific knowledge, as well as role-modeling scientists’ skills.

In the weekly journal entries, the UTAs were asked to design two to three questions that would lead students towards thinking about the main concepts of the laboratory. At the end of the semester, the UTAs were asked to reflect upon the experience of designing these questions prior to each laboratory and assess if they found it a productive learning experience. The results of the analysis of 9 weeks of UTAs’ responses are summarized in Table 1.

Our analyses focused on UTAs’ design of questions with respect to the six levels of the Bloom’s taxonomy schemata (2, 12). One of our interests was to determine if the UTAs would use this exercise to reflect and design active-learning approaches previously discussed in the Scientific Teaching Internship course to promote discussions, problem solving, and other higher-order, student-centered learning (16).

The results from these data indicated that the majority of UTAs tended to design questions an undergraduate might encounter on a traditional examination, testing their interpretive skills of knowledge, comprehension, and application. The UTAs were less likely to develop questions that would challenge undergraduates’ analytical and syntheses skills or require them to evaluate their theoretical beliefs about the material covered in the laboratory setting, indicators of a deeper understanding of science content. The UTAs tended to ask single- or best-answer questions and analyze material into parts to support causal generalizations. We only witnessed the UTAs considering higher-order nature of science concepts—such as thinking about the progress of scientific research or regarding scientific knowledge as tentative, theoretical, partly the product of human inference, imagination, and creativity (13)—about 20% of the
TABLE 1. Sample of UTA responses from the weekly journaling on leading questions

<table>
<thead>
<tr>
<th>Bloom’s taxonomy</th>
<th>% of Bloom’s score</th>
<th>Number of Bloom’s scores for 9 weeks</th>
<th>Examples of leading questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>9.91</td>
<td>43</td>
<td>What are probiotics?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>What test is done to determine if your organism is using fermentation or respiration?</td>
</tr>
<tr>
<td>Comprehension</td>
<td>42.66</td>
<td>183</td>
<td>Why is the yogurt stock added?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>What makes something bacteriostatic? Is that what is happening to the cells to make reproduction inhibited?</td>
</tr>
<tr>
<td>Application</td>
<td>26.57</td>
<td>114</td>
<td>Why is it suggested that people eat yogurt when they are on antibiotics?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Why do we add oil and what does it do when viewing a specimen at x100?</td>
</tr>
<tr>
<td>Analysis</td>
<td>18.88</td>
<td>81</td>
<td>Do you think that it is “bad” to eat foods with bacteria? Can you give me other examples of when we use bacteria in foods?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Well the light microscope is simple, it just passes light through a specimen into the objective lens then into the ocular, but the contrast is poor if I don’t stain the specimen. Name another type of microscope that I can use to increase the contrast if the specimen is not stained.</td>
</tr>
<tr>
<td>Synthesis</td>
<td>1.98</td>
<td>9</td>
<td>Why is it important to be able to recognize a pure culture versus a mixed culture? Use real life situations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aerobic vs. anaerobic vs. facultative anaerobe. If oxygen is so prevalent in the atmosphere why would there still be anaerobic bacteria out there? Wouldn’t it be an evolutionary disadvantage?</td>
</tr>
</tbody>
</table>

time over the course of the semester. Our data also showed that the UTAs thought that they benefited greatly from this exercise. One UTA wrote:

“I think the questions did help me make sure that I thoroughly understood the material, and I often did use the questions that I wrote in my journal to engage my students in the material being covered; which gave me insight into their strengths and weaknesses regarding the material and procedures.”

Frequency counts conducted of the UTAs’ end-of-the-semester responses showed that all of the UTAs agreed that designing two to three questions that would lead students toward thinking about main concepts in the laboratory and reporting these each week in their journal prepared them for their teaching roles in the laboratory. Consequently, although our data did not suggest this question promoted higher-order nature of science concepts, we did find this exercise served to improve the UTAs’ conceptual understanding of the microbiology content and laboratory procedures. The UTAs believed their time was well spent, ensuring their own knowledge and laboratory techniques were accurate, as well as ensuring the undergraduates had a similar grasp of the laboratory information.

The second journal entry asked the UTAs to write about an unclear concept they believed the undergraduates might have each week and then use their knowledge from the UTA experience, previous classes, and/or life experiences to help students effectively conceptualize the muddy point. The muddiest point is a technique suggested by Angelo and Cross (3) to assess what questions the students might still have with respect to the presentation of a learning concept. The muddiest point can be assessed by asking students to identify a question that remains unanswered, the least clear concept, or the most important idea they felt they learned (to determine if it correlates with the teacher’s perception) (3). The intent of this entry was to assess what areas the UTAs would target as being conceptually difficult and what type of leadership approach UTAs would employ to communicate clarification. In addition, at the end of the semester, the UTAs were asked to reflect upon the learning approach they believed was most effective for leading the undergraduates to a deeper understanding of science and if they found this journaling activity beneficial.

The analysis of the UTAs’ muddiest points suggests that the UTAs tended to reflect upon their own knowledge, comprehension, and application of the laboratory material.
TABLE 2. Sample of UTA muddy point responses from the weekly journaling

<table>
<thead>
<tr>
<th>Bloom’s taxonomy</th>
<th>Number of Bloom’s scores for 9 weeks</th>
<th>Example of muddiest point concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>9</td>
<td>Learning the terminology for the different types of antimicrobial chemicals.</td>
</tr>
<tr>
<td>Comprehension</td>
<td>97</td>
<td>How the toxin breaks down in our guts and why it isn’t harmful to humans.</td>
</tr>
<tr>
<td>Application</td>
<td>67</td>
<td>“Differentiating between anaerobes, aerobes, and facultative anaerobes.”</td>
</tr>
<tr>
<td>Analysis</td>
<td>40</td>
<td>The effects of Bt corn on the monarch butterfly population: what does the majority of research state on the issue? Is there a direct effect on the monarch population through the use of Bt corn?</td>
</tr>
<tr>
<td>Synthesis</td>
<td>2</td>
<td>I think it is important to discuss the fact that people fear all bacteria because of a few bad ones, which is the reason why we will use stock yogurt in the yogurt lab instead of bacteria culture to inoculate the milk. The questions I would ask are whether it is a good idea to educate people about beneficial and safe microorganisms and whether people will ever feel comfortable about consuming microorganisms in any form.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>1</td>
<td>The muddiest point will probably be the lack of consensus on the issues, but this is inherent because of the lack of consensus in the scientific and environmental community. There isn’t enough long-term data about how Bt corn and other genetically modified crops will affect the environment. A lot of the potential problems of transgenic crops are still unforeseen, but does that mean we shouldn’t forge ahead with genetic engineering? I think the hardest part for the students will be coming to a conclusion on whether or not it is safe for the environment, because it’s more of a personal choice than a scientific fact.</td>
</tr>
</tbody>
</table>

We found that the UTAs often considered their prior undergraduate experience. Their journals were almost exclusively centered on those concepts they found difficult to understand in their first exposure to the general microbiology course or their recently realized misinterpretations after having the opportunity to revisit the laboratory material as a UTA. Consequently, the UTAs most commonly discussed muddy points at the comprehension and application cognitive domain level. Table 2 provides examples of the UTAs’ muddy points scored with respect to Bloom’s taxonomy.

The data in Table 2 show that the majority of UTAs’ perceived difficulties lay in comprehending the meaning behind the scientific material and applying their knowledge to the laboratory goals. It was much less common to find UTAs questioning scientific knowledge with respect to synthesizing and evaluating the progress of scientific research. Further, the majority of UTAs tended to use traditional teaching methods. These traditional teaching techniques included lecturing, repetition, memorization, demonstrations, diagramming, asking quiz-like comprehension questions, and reiterating information online. Less commonly, the UTAs also used reformed active-learning approaches such as encouraging group work, answering questions with questions, referencing source information, relating material to prior knowledge, and stimulating discussion of data. Positively, each UTA acknowledged that this activity was helpful in preparing them to be more effective communicators. For example, as one UTA stated, “Determining the muddiest point of each lab before we started the lab was really helpful. It had never really occurred to me to think about what the students would probably find most confusing until we did this exercise. Often times the point that I thought was the muddiest was the same point that the students really did have a

TABLE 3A. Samples of Bloom’s taxonomy scored responses for modeling a successful scientist characteristic activity

<table>
<thead>
<tr>
<th>Bloom’s taxonomy level defined</th>
<th>Sum of 9 weeks of Bloom’s taxonomy scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = Knowledge</td>
<td>3</td>
</tr>
<tr>
<td>2 = Comprehension</td>
<td>15</td>
</tr>
<tr>
<td>3 = Application</td>
<td>117</td>
</tr>
<tr>
<td>4 = Analysis</td>
<td>56</td>
</tr>
<tr>
<td>5 = Synthesis</td>
<td>19</td>
</tr>
<tr>
<td>6 = Evaluation</td>
<td>6</td>
</tr>
</tbody>
</table>
There are several characteristics of a good scientist. Scientists must be thorough, completing a task to its end and controlling for several variables. In doing so, scientists are confident in their results and answer their questions with few things left to chance. A scientist must also be well-read and prepared. In order to approach an investigation, a scientist needs to know certain background information and what other scientists have discovered. This elucidates concepts about his/her own findings and puts them into perspective. Preparation is important in the laboratory because it helps experiments run smoothly. Scientists should also proceed with care and safety, since they often work with dangerous items. Finally, a scientist should be meticulous and record their observations exactly as described in the manual. It is very easy to mess up any one of them by losing focus and/or not following directions exactly as described in the manual. It also takes precision to focus the microscope effectively to be able to visualize the appearance or absence of endospores and/or capsules.

The ability to solve problems is important to being a scientist because solving problems is the whole basis of science. Scientists want to understand how things work, what causes things to happen, etc., and there is no lab manual telling them how to discover these things. They must think about what they are trying to figure out, devise a plan of attack, overcome any problems that arise, and constantly revise their plan of attack. All these things require good problem-solving skills. Nothing could ever be discovered in science if scientists could not solve problems.

The journal also asked the UTAs to identify a characteristic of a successful scientist they saw as essential and to model it. Over the 9-week assessment time UTAs, with only one exception, defended each characteristic chosen as being an important attribute for a future career in science. The intent of this journal question was to stimulate UTAs to consider professional skills that they believed are necessary for success in scientific fields. Table 3B show examples of
UTAs’ scored responses.

Table 3A indicates the majority (54%) of UTAs’ responses focused on the difficulties that accompany the application of research and laboratory skills. Although we did see some questioning of the empirical evidence, theoretical bases, and progression of science, these questions were secondary to the UTAs’ main objective of correctly passing on the scientific content that supported the most favored theoretical perspective. In addition, as with the first two journaling questions, the UTAs were asked at the end of the semester to comment on whether they believed the experience of role modeling a successful scientific characteristic helped them get a feel for what a future career in science may demand. Eighty-five percent of the UTAs believed journaling was useful and helped them develop an understanding of the professional skills needed by scientists.

All UTAs reported increased self-confidence at some point over the course of the semester in their journals and in the end-of-the-semester evaluation. UTAs gained confidence in their ability to work with others, being more comfortable in front of people, and having more assurance of their microbiology knowledge and laboratory skills. Examples of UTA quotes include:

“The UTA experience definitely did increase my self-confidence when talking to and working with others.”

“The UTA experience allowed me to be a more comfortable speaker in front of a large group of people.”

“By having the opportunity to practice and interact with others, I was able to gain confidence in myself.”

“I am more confident in my knowledge of the subject.”

In summary, the weekly journaling data and end-of-the-semester evaluations supported the hypothesis that the UTA experience would aid in developing microbiology knowledge and lab skills, communication and leadership abilities, an understanding of the professional skills needed to be successful in science professions, and self-confidence.

Quantitative data gathered from the UTAs further strengthened our qualitative analyses. A one-way ANOVA was used to quantitatively analyze the variance between

FIG. 2. A bar graph summary of the undergraduates’ positive and negative responses. The green bars are positive comments made in response to “state what you liked most about your UTA.” The red bars are those comments made in response to: “state if there was anything you didn’t like about your UTA experience.” In the first column there were 220 responses where students reported “nothing negative” (no neg) to the question: “state if there was anything you didn’t like about your UTA experience.” Thus, this bar has a green and red pattern. Overall, there were 715 positively scored undergraduates’ responses and 84 negatively scored responses.
UTAs’ self-evaluation pre- and post-UTA experience Likert scale responses. We noted the UTA responses lacked normality by demonstrating an overall slight positive skew for data collected both before and after the UTA experience. However, this is not uncommon for limited response scale surveys, and the ANOVA has been shown to be robust against this type of assumption violation (35). Our one-way ANOVA results, F (1, 94) = 6.51, P < .05, showed a statistically significant difference in the way the UTAs responded to the 48-item instrument over time.

To understand more about the statistically significant difference between the pre- and post-UTA experience Likert scale response scores, we performed paired t tests and found only two questions varied with statistical significance after considering Bonferroni’s adjustment α = (.05/48) = .0010. However, the descriptive statistics indicated the UTAs’ overall mean score increased from 3.084 to 3.320 (n = 23). Looking at the 48 questions individually, we found 44 out of the 48 questions showed a positive trend from pre- to post-UTA experience scores. The two questions that showed the greatest increase over the semester related to the UTAs’ skills using web page technology. However, overall 44 questions support growth in laboratory and research skills, conceptual knowledge, and online communication skills.

As with our UTA Likert scale data, we ran an ANOVA to quantitatively analyze the variance between UTAs’ self-evaluation rubric responses over time. We also found a statistically significant difference in the UTAs’ mean pre- and post-UTA experience responses, F (1, 10) = 12.57, P < .01. We followed up our ANOVA results with paired sample t tests α = (.05/6) = .0083 after considering Bonferroni’s adjustment. Two statistically significant questions were identified. All six rubric questions showed an increase in post-UTA experience responses. The two questions that showed the greatest increase over the semester asked the UTAs to rate their performance in providing effective instruction and their ability to integrate knowledge across subject areas. Responses to all the questions indicated that the UTAs perceived themselves as becoming more effective communicators and leaders as they gained confidence in their scientific knowledge and laboratory techniques.

We utilized the observations of those who interacted with the UTAs, the undergraduates and GTAs, to further assess the UTAs’ self-reports. At the end of the semester undergraduates commented upon what they liked most and if there was anything they didn’t like about interaction with their UTA through open-ended and Likert-scaled questions (Fig. 1, number 5). As with the UTAs’ journal responses, we used analytic induction to score the undergraduates’ comments. We did not interpret the level of cognitive thought behind their reply, but simply identified and then counted similar responses. Overall, 89% of the 327 undergraduates who voluntarily evaluated their UTA reported positive benefits and/or nothing negative about having a UTA help guide their learning. Figure 2 is a graphic representation of the undergraduates’ positive and negative comments about their UTAs’ performance.

The most positive comments reported were directed toward the UTAs’ communication and leadership skills as well as their knowledge: easy to talk to, helpful, knowledgeable, friendly/nice, and a reliable source of information. The majority of the complaints were from having a UTA who did not do much, was hard to understand, did not know the material, and was shy. The Likert scale of undergraduates’ responses further supported our interpretation of their short answer responses by showing very positive assessments. However, these data also supported our interpretation of the UTAs’ tendency to give answers rather than questioning students to find their own solutions.

We also examined results from the GTAs’ Likert scale for evaluating each UTA’s performance (Fig. 1, number 2) to further triangulate our data. We ran an ANOVA to quantitatively analyze the variance between GTAs’ pre- and post-UTA experience rubric responses and found a statistically significant difference for the GTA responses over time, F (1, 10) = 5.84, P < .05. We followed up our ANOVA results with six paired sample t tests with α = (.05/6) = .0083 and found three statistically significant questions, although five out of the six questions showed an increase from pre- to post-UTA experience responses. The three questions which showed the greatest increase over the semester asked the GTAs to rate their UTAs’ performances in managing an active-learning environment, reflecting upon their content knowledge, and integrating knowledge across subject areas. Examples of GTAs’ comments about their UTAs include:

“Correctly draws on knowledge of the material and extrapolates crucial points from the question to enhance students’ understanding of the material. Has examples from physics and advanced biology so students are learning with the broader picture.”

“Very active in fielding questions and forwarding issues that need clarification on to me. Shown significant amount of content knowledge in terms of microbiological procedures.”

The GTAs’ data further support the UTAs’ growth in integrating their knowledge across subject areas, developing self-confidence, using prior experiences to help communicate understanding, demonstrating the ability to lead group and individual participation, and confirming an understanding of the laboratory techniques and material. Additionally, the GTAs pointed out frequently the UTAs’ tendencies to use traditional methods of teaching such as lecturing, repetition, and memorization.

**DISCUSSION**

Many studies have demonstrated the value of using undergraduates in a teaching role with the enrolled undergraduates and course instructors (14, 19, 20, 24, 26, 30). These studies have focused on the benefits to undergraduate learning. We
believe that this is the first report of an undergraduate teaching experience in a microbiology course and the first comparison of the values and skills UTAs acquire with respect to those acquired in an undergraduate research assistantship.

Our UTA program was initially developed to support active learning for students enrolled in our general microbiology course (https://listserv.umd.edu/cgi-bin/wa?A2=ind0411&L=lifelink&P=1584) (28). The UTAs made the active-learning opportunities in this large enrollment course manageable (28), and from results reported here and in unpublished observations we found that students in the course benefited from their interaction with UTAs. Further, the opportunity for undergraduates to serve as UTAs provided an authentic active-learning experience for these students; consequently, we developed the Scientific Teaching Internship course. This course was designed to increase the scholarship associated with the UTA role. Within the context of this course and the UTA teaching experiences, participating undergraduates had opportunities to review published literature on scientific teaching, experiment with teaching methods, further their skills and understanding of microbiology, as well as practice leadership and communication skills.

Here we reported the results of our in-depth UTA study. We analyzed and compared data from UTAs’ self-reports as well as the observations by undergraduates and GTAs. Our findings offer empirical evidence to support and extend what previous studies on students in organized teaching experiences have suggested (14, 17, 19, 20, 24, 26, 30). We showed that students who participate in teaching experiences reap significant benefits. We also expanded what is known about UTAs to microbiology and extended the analyses of the way UTA growth can be evaluated.

Our analysis underscores the value of the UTA experience by suggesting it is comparable to the URA internship. Studies of the URA experience show that undergraduates who complete a research internship begin to think and work like a scientist, develop research and oral communication skills, form clearer career aspirations, and increase their self-confidence (11, 25, 27). In our detailed study of the UTA experience, we found that undergraduates participating in a scientific teaching internship gain benefits similar to those of students interning in a research laboratory. Our data support that UTAs develop skills valued by practicing scientists.

However, contrary to our expectations, but similar to the findings in Kardash’s study of a URA experience, we found little evidence of higher-order thought processes in our students’ daily thoughts and actions (11). Data from the UTAs’ journals indicated that our teaching assistants were most commonly focused on comprehending and using scientific material and knowledge and less on synthesizing knowledge to produce original thoughts or evaluating evidence based on personal values and opinions with no clear-cut answer. We speculate that this unanticipated result may be because this teaching opportunity required UTAs to revisit their conceptual understanding of microbiology. We observed UTAs becoming aware of their own misconceptions, challenging their initial conceptual microbiology understanding, and searching for a deeper level of content knowledge. Consequently, the majority of the UTAs’ journals focused more on designing questions that ensured students had an accurate definitive understanding of the microbiology concepts and less on applying or integrating teaching methods that they discussed in the scientific internship course. In this study, we had two students who were participating as UTAs for a second time. We found that these students more consistently demonstrated higher-order thinking in their journal entries. This hints that the UTA experience may offer opportunities for developing higher-order thinking but prior knowledge and experience play a role.

Our findings show that the UTA experience provides a valid option to the URA experience in offering authentic opportunities to build professional career skills for students in the sciences. Offering UTA experiences also increases the number of opportunities available to undergraduates to work closely with a faculty member in developing skills valuable to success in scientific careers. Nagda et al. reported URA student-faculty research partnerships promote student retention and success (21). In our study, one faculty member supported the experience of 24 undergraduates. In most URA internships, because of the cost of lab supplies and space limitations, one faculty member generally has significantly fewer opportunities to work with URAs in a semester.

This study reported the triangulated data of 24 UTAs, 13 GTAs, and 327 undergraduates. However, future studies in this area of investigation would benefit from interviews, videotaping, and tracking the UTA after several years. Although the instruments in this study were created from other research instruments, piloted, and accordingly modified, they lacked the validity and reliability confirmation that comes from a more thorough psychometric instrumentation development. However, since this study has been completed, the journaling exercise continues to be implemented as a tool to help UTAs reflect on and develop professional qualities for a future in a science career. Since the fall of 2005, when this study was completed, through the date of publication of this article, 77 additional students have completed the UTA experience. Instructional observations, journal analyses, and UTA self-reporting continue to show student gains in self-confidence, a deeper understanding of microbiology (including laboratory and research skills), as well as skills to lead and more effectively communicate with others, all of which are valuable to careers in science. Further, the majority of UTAs include the UTA experience on their resumes and request letters of recommendation for applications to jobs and professional schools. In all instances where employers have called to discuss the skills and attributes of former UTAs (prior to and after employment), the employers highlighted the value of the UTA experience.

Consequently, this study suggests that URA and UTA experiences offer many analogous opportunities for developing professional scientific skills. Additionally this study has revealed areas in microbiology that students consider to be most confusing (muddy points). We are interested in further investigating these points and developing teaching and as-
essment techniques that better address these challenging topics in our general microbiology course.

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**REFERENCES**


