PILOTing Undergraduate Students to Hands-On Teaching and Research Skills  

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Undergraduate research can make a positive impact on science education. Unfortunately, the one student-one mentor paradigm of undergraduate research generates a wide range of variability in the student’s experience and further limits its availability to a select few students. In contrast, a single faculty member can offer multiple undergraduate teaching positions that provide a consistent experience for the student. We attempted to combine the undergraduate research and teaching experiences in an internship practicum called Peer Instruction and Laboratory Occupational Training (PILOT). Students enrolled in PILOT served as teaching assistants for the upper division Quantitative Biological Methods (QBM) laboratory course. In addition, PILOT students worked on an independent lab project that provided them with hands-on training and supported the QBM course. The development of presentation and teaching skills was also emphasized in PILOT. These activities were designed to improve student communication skills, lab skills, and knowledge of molecular biology content. Here, we describe the PILOT curriculum and report the results of an anonymous assessment survey administered to 75 students who had completed PILOT in the previous five semesters. Our data indicate that PILOT provides an effective format to expand undergraduate opportunities for research and teaching experiences.

INTRODUCTION

Undergraduate research offers students a unique opportunity to apply their knowledge of biomedical science, to gain hands-on training, to implement the scientific method, and to formulate an accurate view of the research enterprise (5, 9). Practical, job-related training is another benefit of undergraduate research: students report improved lab skills and increased confidence in the research environment after the completion of a research experience (2, 3, 6). Unfortunately, the one student-one mentor paradigm of an undergraduate research assistantship (URA) presents a significant challenge to science education. The quality of the research experience will obviously be highly dependent upon the faculty sponsor. It is therefore difficult to provide, within a Department, a consistent experience that provides a positive outcome for most students. In addition, student researchers can lack peer support and a sense of community because they are the only undergraduate working in the lab. Peer support resulting from a network of interacting undergraduate researchers is often cited as a positive influence on student satisfaction with the URA (1, 3, 7, 10). Finally, the inefficiency of the traditional model for undergraduate research limits its utility to a few select students. For example, the University of Central Florida (UCF) Burnett School of Biomedical Sciences (BSBS) educates more than 2,300 undergraduates majoring in either Biotechnology or Molecular Biology and Microbiology. Approximately 100 students are working on research projects in faculty labs. This is a substantial number, but it only represents 4% of our undergraduate majors. Many more talented students desire a research experience, but there are no available positions for them. Students lacking a URA are limited to taking laboratory courses which have pre-designed experiments and pre-determined results. These activities do not necessarily help students develop independent research skills. Thus, two major challenges arise from using URAs as a means to train students in the biomedical sciences: (i) how to ensure a consistent, positive learning experience for most students; and (ii) how to expand undergraduate research opportunities to encompass an even greater number of students. To address the relatively limited availability of URAs, the BSBS has been developing alternative programs to provide substantial numbers of students with practical, hands-on training in the life sciences.

A recent study has suggested that students receive many of the same benefits from an undergraduate teaching assistantship (UTA) as they receive from a URA: both groups report gains in self-confidence, communication...
skills, leadership skills, laboratory skills, and knowledge of microbiology content (8). Graduate teaching assistantships (GTA) likewise improve research skills and the ability to design appropriate experiments (4). These studies indicate a well-organized teaching experience will enhance the professional development of participating students. A structured UTA program could therefore expand undergraduate training opportunities by providing an efficient alternative to the one student-one mentor model for URAs.

Given that students benefit from both teaching and research, we developed a fusion of UTA and URA experiences in an internship practicum called Peer Instruction and Laboratory Occupational Training (PILOT). This course is designed to improve student communication skills, laboratory skills, and knowledge of molecular biology content. Participating students serve as UTAs for the BSC 3403 Quantitative Biological Methods (QBM) laboratory course. Participating students are also assigned a laboratory project that will support QBM and provide the PILOT student with hands-on laboratory experience. This format is designed to provide PILOT students with beneficial experiences related to both UTA and URA activities.

We hypothesized that PILOT students would report gains in professional development relating to self-confidence, communication skills, research skills, and conceptual learning. This prediction was tested and validated with the administration of an online, anonymous self-satisfaction survey to 75 students who had enrolled in PILOT over the previous five semesters. Although PILOT was originally designed to expand hands-on training opportunities, the resulting data indicated that participating students were as interested in gaining teaching experience as research experience. Valuable experiences and gains in self-confidence linked to both the teaching and research components of PILOT were consistently reported by the students. Furthermore, in contrast to the traditional one student-one mentor model for URAs, a single faculty member effectively trained 20–30 PILOT students per semester. The PILOT format thus improves the efficiency of faculty mentoring and expands training opportunities to many additional students. Here, we describe the PILOT course and report the results from the student self-satisfaction survey.

METHODS

Course setting

QBM is a laboratory-based molecular biology course with an emphasis on recombinant DNA and protein purification techniques. The syllabus for QBM is provided in Appendix 1. The class is required for graduation with a BSBS major and is offered to juniors and seniors who have completed General Microbiology. Approximately 220 students enroll in the course each fall and spring semester. All students attend three 50-minute lectures a week and then attend a four-hour lab where they work with a lab partner to perform DNA- and protein-based experiments. Nine QBM lab sections of approximately 24 students each are offered throughout the week.

PILOT utilizes QBM as a foundation for further hands-on learning and student development. PILOT students must complete QBM with an “A” grade and are selected for PILOT based on their final ranking in the QBM class. The majority of PILOT students therefore rank in the top 15% of BSBS students. In addition, potential PILOT students must have been actively engaged in the QBM lab. PILOT is an established course offering at UCF (MCB 4941). However, PILOT is not listed in the UCF course catalog; students must either be invited or express an interest in the class by contacting the instructor. These criteria help ensure that PILOT UTAs will have a positive impact on the QBM lab.

PILOT has been run six times to date, with enrollments of 13, 21, 26, 36, 20, and 28 students. Variations in enrollment reflect (i) the availability of a second QBM laboratory instructor to assist with the organization of PILOT and (ii) the number of offered QBM lab sections, with 3–4 PILOT students assigned to each section. Each QBM lab has an additional GTA who is responsible for supervision of the lab. PILOT counts as a 3-credit restricted elective for BSBS majors and is graded on a Satisfactory/Unsatisfactory scale. It can also be applied to the research experience required for graduation from the BSBS Biotechnology Program.

Course description

PILOT provides training in both teaching and research. The syllabus for PILOT is provided in Appendix 2. Students meet with the instructor in a group setting to review the upcoming laboratory experiments, practice lecturing the upcoming material, learn how to manage the lab equipment, and discuss any questions or concerns. This weekly meeting, which is held before the QBM labs take place, provides consistency to the UTA experience and promotes peer interaction and support. Each PILOT student then serves as a UTA in one weekly laboratory section where she or he interacts with the QBM students. PILOT students also work week-to-week on individual or group-based laboratory projects. They work on these projects at the end of the weekly PILOT meeting, in the QBM lab when time permits, or at additional times outside of scheduled PILOT and QBM classes. A comparison between the QBM lab schedule and the PILOT schedule is shown in Table 1.

Peer instruction. PILOT students are given the opportunity to teach throughout the course (Table 2). In the weekly PILOT meeting, students practice presenting their upcoming lectures for the QBM lab. They are provided feedback on their presentation and are taught techniques to improve audience engagement. Small group presentations of journal articles, as well as discussions of review articles, are also conducted during the PILOT meetings. Each PILOT student gives at least one lecture for her or his QBM lab
Laboratory training. As UTAs, PILOT students perform many lab-related activities: they help set up the lab exercise, prepare reagents, and train on the laboratory equipment they will manage in the QBM lab (Table 3). Students also work on an independent or group laboratory project over the course of the semester (Table 4). Several projects involve glutathione-S-transferase (GST) or green fluorescent protein (GFP) because these proteins are routinely used in the QBM lab. Protocols, reagents, and results generated from PILOT projects can thus be used to enhance future offerings of the QBM lab. These projects provide students with a research experience, and they are an integral part of PILOT. Students are assigned an appropriate project based on their research interests, the size of the research group, and instructor assessment of student ability. The projects allow students to apply the techniques they learned in their previous QBM class, follow and optimize protocols, use external resources, troubleshoot, and develop experiments on their own. Thus, while not identical to a URA and an independent research project, the PILOT projects still provide students with potentially valuable hands-on training and laboratory skills.

Course assessment

The 116 students enrolled in PILOT between fall 2009 and fall 2011 (five semesters during the academic year) were e-mailed a URL link for an anonymous self-satisfaction survey hosted on SurveyMonkey. The survey instructions clearly stated that survey respondents would remain anonymous. The URL link was open for a total of 35 days, and 75 students completed the survey for a response rate of 65%. The survey took approximately five minutes to complete. The date, time, and IP address of each respondent were recorded to
### TABLE 2.
Peer instructional activities.

| Peer Instruction                                                                 | Frequency       | Location |
|----------------------------------------------------------------------------------|-----------------|----------|
| Practice lecturing upcoming material                                             | 3–4 Students    | PILOT    |
| Engage students in lab, answer questions, solve problems                          | Weekly          | QBM      |
| Teach and answer questions on advanced class assignments                          | Weekly          | QBM      |
| Class message board—answer and post questions                                     | Weekly          | Online   |
| Teach students how the lab equipment runs                                         | Weekly          | QBM      |
| Oversee quiz                                                                      | Weekly          | QBM      |
| Teach students to make buffers, dilutions, and pH solutions                       | Three times     | QBM      |
| Correct assignments and give students feedback                                    | Three times     | PILOT    |
| Critical thinking assignments on upcoming lab                                     | Three times     | PILOT    |
| Journal article review and presentation                                           | Twice           | PILOT    |
| Help students load DNA and protein gels                                           | Twice           | QBM      |
| Lecture lab material to students                                                  | Once or more    | QBM      |
| Verify that students can pipet correctly                                          | Once            | QBM      |
| Provide sample quiz questions                                                      | Once            | PILOT    |
| Presentation on a faculty member’s research                                       | Once            | PILOT    |
| Presentation on student’s own research                                             | Once            | PILOT    |
| Group discussion on a scientific news article                                     | Once            | PILOT    |
| Group discussion on a review article                                              | Once            | PILOT    |
| Sample lab report grading                                                         | Once            | PILOT    |
| Teach students protein crystallization                                            | Once            | QBM      |

### TABLE 3.
Laboratory training activities.

| Laboratory Training                                               | Frequency      | Location     |
|------------------------------------------------------------------|----------------|--------------|
| Laboratory research project                                      | Weekly         | PILOT and QBM|
| Updates on lab projects, discussion of goals                      | Weekly         | PILOT        |
| Train on lab equipment that students will run in lab             | Weekly         | PILOT        |
| Manage and troubleshoot various lab equipment                     | Weekly         | QBM          |
| Teach/train students on the proper use of lab equipment           | Weekly         | QBM          |
| Set up lab                                                       | Weekly         | PILOT and QBM|
| Prepare reagents for lab                                         | Weekly         | PILOT and QBM|
| Help clean up at end of lab                                      | Weekly         | QBM          |
| Clean glassware                                                  | Weekly         | QBM          |
| Oversee buffer training of students                               | Three times    | QBM          |
| Make extra gels for students                                     | Once           | PILOT        |
prevent duplicate responses from the same individual. The survey consisted of multiple-choice questions, free-response questions, and three tables that allowed the students to rate (i) their experience in PILOT; (ii) how PILOT affected their confidence; and (iii) the importance of each class activity.

RESULTS

Raw data from the PILOT survey, including all free-response answers, are provided in Appendix 3. Here, we tabulate the multiple-choice answers and summarize the free-response answers.

Student motivation

Free-response questions asked students to provide their primary and secondary reasons for enrolling in PILOT (Fig. 1). Students responded with answers such as “teaching,” “to help improve my communication skills by trying to convey information during the lecture as well as on the
individual level," and "I felt I understood the material well enough to help other students." These types of responses were categorized as Teaching, Helping Others, Improve Public Speaking. Other responses such as "to master lab techniques" and "to gain a fundamental understanding of the basics of research experience" were grouped together as Research Experience and Improve Lab Skills. Although a desire to master laboratory techniques is not always linked to the desire for a research experience, these rationales were placed in a single category because (i) many responses mentioned both research and lab skills and (ii) we did not want to engage in subjective partitioning of broad responses to one of two possible categories. The majority of students enrolled in PILOT mainly for either a teaching- or research-related experience.

Surprisingly, 50% of PILOT students already had an undergraduate research experience before enrolling in the course (Fig. 2(A)). By cross-referencing the responses within a single student survey, we found that more than half of PILOT students with previous research experience enrolled in the course primarily for a teaching experience (Fig. 2(B)). Only 17% of students with prior research experience enrolled primarily for additional research experience. For students who had not previously served as an URA, nearly two-thirds enrolled primarily for the research experience (Fig. 2(C)). Only 19% of those students enrolled primarily for the teaching experience. PILOT is therefore fulfilling multiple student needs, and students are enrolling in the course to gain new experiences.

Impact of PILOT on student self-satisfaction and self-confidence

A table of multiple-choice questions was used to assess student satisfaction with the overall PILOT program and specific PILOT activities (Table 5). More than 90% of students ranked all categories as Good or Excellent, demonstrating a high level of consistency in the PILOT experience across five semesters involving 116 students. Four of the six categories were ranked as Excellent by about 80% of the respondents: Overall Experience in PILOT, Experience with Peer Instruction, Interaction with Other PILOT Students, and Interaction with QBM Students. The two remaining categories, Experience with Laboratory Occupational Training and Interaction with QBM GTAs, were ranked as Excellent by approximately 60% of the respondents and Good by about 30–35% of respondents. The data indicate PILOT students had favorable experiences with both the teaching and research components of PILOT. However, more students reported an Excellent experience for peer instruction than for laboratory training.

A table of multiple-choice questions was also used to gauge gains in student confidence related to teaching and/or research activities (Table 6). The majority of students reported Somewhat Increased or Greatly Increased Confidence in all categories. Gains in confidence were distributed across both teaching and research activities: about 50% of students reported Greatly Increased Confidence in Teaching, Performing Experiments, Understanding Protocols, and Understanding Fundamental Concepts in Molecular Biology. However, a substantial number of students (20–30%) reported no change in confidence in three other activities: Reading Papers from the Primary Literature, Creating Protocols, and Working as Part of a Team. Only one student reported a loss of confidence, and this was for a single activity of Reading Papers from the Primary Literature. Overall, the data demonstrate a positive impact for PILOT on student self-confidence.

Evaluation of PILOT activities

A table of multiple choice questions asked students to identify the valuable aspects of PILOT. Approximately 90% of students ranked all activities as Somewhat Important or Important (Table 7). Four of the seven activities, encompassing both teaching and research, were ranked as Important by at least 66% of the students: Teaching, Performing Experiments, Understanding Protocols, and Working as Part of a Team. However, Teaching was the only activity ranked as Somewhat Important or Important by all students. Two
activities were ranked as Not Applicable, Unimportant, or Somewhat Unimportant by 11–12% of students: Reading Papers from the Primary Literature and Creating Protocols.

A free-response question asked students to state the most valuable part of their PILOT experience (Fig. 3). Students responded with “I absolutely loved teaching and interacting with the students,” “I learned about how to interact with students,” and “to be able to help the students in setting up, breaking down, and understanding the experiment itself.” Responses of this type were grouped as Teaching and Interacting with Students. Other students responded “performing our own project,” “being able to interact and get one-on-one help with the project,” and “I am really glad that I was able to work as a team on a project.” Responses of this type were grouped as Performing Experiments, Working as a Team, Developing Projects and Protocols. Other common sentiments were divided into the five additional categories listed in Figure 3. Several answers to this question were counted in more than one category because the responses listed multiple valuable experiences. Teaching and Interacting with Students was cited as the most important aspect of PILOT far more often than any other category.

Free-response questions also asked students about the least valuable aspect, the most difficult aspect, and the most surprising aspect of PILOT. When asked about the least valuable part of PILOT, the top response by a wide margin was “Nothing.” No other trends were observed. Public speaking was listed as the most difficult aspect of PILOT by 34% of respondents. This was the most common answer, followed by 20% of respondents who listed completion of the lab project as the most difficult aspect (Fig. 4). When asked about the most surprising aspect of PILOT, the top responses related to the satisfaction of teaching (Fig. 5). Given the necessary connection between public speaking and teaching, it appeared that the most difficult aspect of PILOT was linked to the most rewarding aspect of the class.

DISCUSSION

PILOT was designed to address the relatively limited number of URA positions by expanding opportunities for original, hands-on training in lab techniques. The structured fusion of URA and UTA activities is meant to improve student communication skills, laboratory skills, and knowledge of molecular biology content. Anonymous survey responses from 75 previous PILOT students indicate these goals are being met by providing new teaching and research experiences.

Our assessment revealed that PILOT is addressing a previously unrecognized demand for UTA positions. Half of the PILOT students had already served as URAs before participating in the course. Far more of those students enrolled in PILOT primarily for teaching experience (54%) than for research experience (17%). In contrast, far more students with no prior research experience enrolled in PILOT primarily for research experience (63%) than for teaching experience (19%). Thus, with its unique UTA/URA format, PILOT was able to provide a range of new experiences to students with varied interests.

Overall, 36% of students enrolled in PILOT mainly to teach and help others. Another 30% enrolled primarily for the research experience. However, 70% of students found teaching and presenting to be the most valuable experience in the course: 51% of students reported the most valuable part of their PILOT experience was teaching and interacting with the students, while another 19% stated the most valuable aspect of PILOT was either improved confidence in public speaking or learning how to give effective presentations. The percentage of students listing a teaching-related activity as the most valuable aspect of PILOT thus
TABLE 5.
Student evaluation of PILOT experiences.

|                          | No Opinion | Poor | Fair | Good  | Excellent | n  |
|--------------------------|------------|------|------|-------|-----------|----|
| Overall Experience in PILOT | 0.0%       | 0.0% | 0.0% | 18.9% | 81.1%     | 74 |
| Experience with Peer Instruction | 0.0%       | 0.0% | 0.0% | 17.6% | 82.4%     | 74 |
| Experience with Laboratory Occupational Training | 1.4%       | 0.0% | 2.7% | 35.1% | 60.8%     | 74 |
| Interaction with Other PILOT Students | 0.0%       | 0.0% | 1.4% | 20.3% | 78.4%     | 74 |
| Interaction with QBM GTAs | 0.0%       | 1.4% | 8.2% | 28.8% | 61.6%     | 73 |
| Interaction with QBM Students | 0.0%       | 0.0% | 0.0% | 20.3% | 79.7%     | 74 |

TABLE 6.
Impact of PILOT on student confidence.

|                                      | Greatly Decreased Confidence | Somewhat Decreased Confidence | Did Not Affect Confidence | Somewhat Increased Confidence | Greatly Increased Confidence | n  |
|--------------------------------------|------------------------------|-------------------------------|---------------------------|-------------------------------|-------------------------------|----|
| Teaching                             | 0.0%                         | 0.0%                          | 2.7%                      | 45.9%                         | 51.4%                         | 74 |
| Public Speaking                      | 0.0%                         | 0.0%                          | 13.5%                     | 48.6%                         | 37.8%                         | 74 |
| Reading Papers from the Primary Literature | 0.0%                     | 1.4%                          | 24.7%                     | 38.4%                         | 35.6%                         | 73 |
| Performing Experiments               | 0.0%                         | 0.0%                          | 13.5%                     | 39.2%                         | 47.3%                         | 74 |
| Understanding Protocols             | 0.0%                         | 0.0%                          | 16.2%                     | 32.4%                         | 51.4%                         | 74 |
| Creating Protocols                  | 0.0%                         | 0.0%                          | 28.4%                     | 40.5%                         | 31.1%                         | 74 |
| Working as Part of a Team           | 0.0%                         | 0.0%                          | 20.5%                     | 46.6%                         | 32.9%                         | 73 |
| Understanding Fundamental Concepts in Molecular Biology | 0.0% | 0.0% | 12.2% | 37.8% | 50.0% | 74 |

TABLE 7.
Importance of PILOT activities.

|                                      | Not Applicable | Unimportant | Somewhat Unimportant | Somewhat Important | Important | n  |
|--------------------------------------|----------------|-------------|----------------------|--------------------|-----------|----|
| Teaching                             | 0.0%           | 0.0%        | 0.0%                 | 24.3%              | 75.7%     | 74 |
| Public Speaking                      | 0.0%           | 1.4%        | 5.4%                 | 40.5%              | 52.7%     | 74 |
| Reading Papers from the Primary Literature | 2.7%       | 4.1%        | 5.4%                 | 32.4%              | 55.4%     | 74 |
| Performing Experiments               | 0.0%           | 1.4%        | 6.8%                 | 21.6%              | 70.3%     | 74 |
| Understanding Protocols             | 1.4%           | 1.4%        | 1.4%                 | 14.9%              | 81.1%     | 74 |
| Creating Protocols                  | 2.7%           | 0.0%        | 8.1%                 | 41.9%              | 47.3%     | 74 |
| Working as Part of a Team           | 0.0%           | 0.0%        | 4.1%                 | 29.7%              | 66.2%     | 74 |
outweighed the percentage of students who initially joined PILOT for a teaching experience.

Peer interactions may explain, in part, the value of the teaching experience for PILOT students. Public speaking was commonly listed as the most difficult aspect of the course, but public speaking was also correlated with the most surprising aspect of the class: the satisfaction PILOT students received from teaching, helping others, and earning the respect of the QBM students. This suggests the initial discomfort with public speaking was overcome by continued interaction with the QBM students. The weekly PILOT meetings held in preparation for the coming QBM class may also contribute to student confidence with the conceptual and technical material. Indeed, 97% and 86% of students had increased confidence in Teaching and Public Speaking, respectively. The format of PILOT apparently helped convert the most difficult aspect
of the course (Public Speaking) into its most valuable aspect, with correspondingly large increases in self-confidence.

Most students also reported gains in self-confidence related to lab activities, and 61% of students rated the laboratory occupational training component of PILOT as Excellent. The PILOT projects were not intended to replicate an URA, but instead to provide students with experiences (technical training, protocol optimization, troubleshooting, etc.) that would be useful in a lab setting. Students could choose from a large number of potential lab projects that ranged from basic to advanced. The difficulty of the project did not seem to impact learning, and the diversity of available projects allowed students with varying levels of laboratory skills to have an engaging and successful project. Regardless of project difficulty, students were expected to perform background research, design the project, create a protocol, and troubleshoot on their own. The instructors did not issue directions for these tasks but instead took more of an advisory role in overseeing the project. This likely contributed to student independence and improved confidence in the laboratory.

For the research project, students usually worked in pairs to discuss ideas, follow protocols, and solve problems. Working as Part of a Team and Understanding Protocols were ranked as Important by 66% and 81% of students, respectively. These rankings were similar to the 70% of students who scored Performing Experiments as Important (Table 7). The team approach to developing an experiment thus seemed to be as important as completing the experiment itself. Instructors noted considerable student enthusiasm for the research projects, especially (but not exclusively) when the projects produced a tangible end product. The availability of simple projects such as modifying an existing lab exercise allowed inexperienced students to gain confidence through a trial-and-error process of protocol optimization. Other students with more experience chose advanced projects which allowed them to apply their knowledge of molecular biology from the QBM course. Many students were so interested in their projects they opted to come into the lab outside of normal class hours, and even after the semester was over, to work on them. In some instances students who had not previously considered getting involved in research sought out individual research positions on campus presumably due to their increased confidence in the lab. One student learned cell culture as part of her project, and she subsequently completed an Honors undergraduate thesis in a campus lab where she primarily performed cell culture-based experiments.

Many students enroll in PILOT during their last one or two semesters at UCF and, consequently, do not have an opportunity to utilize their new technical skills for a standard independent research project. However, several PILOT students without previous research experience used their training to secure an URA. Some faculty now preferentially accept PILOT students into their laboratories because those students are independent, well-trained, and can provide a detailed letter of recommendation from the PILOT instructor. Faculty have also suggested PILOT projects that evolved into independent research projects with the faculty sponsor. These examples suggest PILOT could further expand research opportunities by (i) serving as a venue to initiate new undergraduate-driven projects and (ii) producing a pool of experienced, independent researchers who require less faculty-led training time than new URAs, thus allowing faculty to accept more students into the lab.

Although students reported consistently high levels of satisfaction with both the teaching and research components of PILOT, it appeared they valued the teaching experience more than the research experience. Student pre-conceptions and previous experiences may help explain this discrepancy. Students without prior research experience may have expected a more traditional URA project from PILOT, which might consequently have lowered their satisfaction with the lab training component of PILOT. The lab projects would also have produced variable levels of success due to the inherent nature of research, whereas the preparatory PILOT meetings for QBM teaching assignments offered more consistent, standardized content for the students. The teaching experience was also new to most students: BSBS offers very few UTAs. In contrast, the 50% of PILOT students with previous research experience may have felt some of the laboratory training exercises were redundant with their URA and therefore less valuable than the teaching experience. This would be consistent with the lower percentage of student gains in self-confidence for research-related activities (with which some students are already familiar) in comparison with teaching-related activities (which are new to most students).

Future focus group sessions with PILOT alumni should clearly elucidate why the teaching experience was viewed as more valuable than the research experience. These sessions can also be used to (i) distinguish between student desire for a research experience vs. additional training in lab skills; (ii) determine if the Reading Papers/Creating Protocols activities were ranked as less important and had lower reported gains in confidence due to redundancy with other student experiences; (iii) ascertain how to improve interactions between the UTAs and GTAs (see Table 5); and (iv) establish which activities are of greater interest to students with a teaching, research, or lab skills focus. These results will allow us to provide a better match between PILOT activities and student needs. In addition, by analyzing responses from the subset of students with previous research experience, we should be able to determine whether PILOT’s standardized format does a better job of reinforcing soft skills such as teamwork and communication than the less-structured format of a traditional URA. Pre- and posttesting of conceptual and technical knowledge will further provide an objective measure of student gains resulting from participation in PILOT.

The available data demonstrate a high level of satisfaction with PILOT activities and a positive impact of PILOT
on student development. There is a degree of self-selection in our results, as the data were collected from a voluntary online survey instrument. Yet the high response rate (67%) to an e-mail solicitation for survey participation suggests, in itself, a high level of satisfaction with the class. The success of the class may also reflect the selection of top-performing students for participation in PILOT. This screening process is necessary to help ensure the PILOT UTAs provide a positive impact on the QBM lab.

As with any new course, the implementation of PILOT takes time and effort. Managing dozens of UTAs can require focus, and keeping all of the students engaged in the open format of the weekly meetings can be a task. The instructor must also assign journal papers that are relevant and at the right level for undergraduate students. Other small classroom exercises relevant to the course must be developed as well. In addition, the instructor must devise starting points for many of the research projects, manage the projects to ensure they are being completed, and help the students when necessary. It can be difficult to keep up with 10–15 different projects and ensure that all students are actually completing them. In future semesters, students will be required to submit an involved laboratory report on their project. This assignment will provide another format for learning, data analysis, and critical thought development.

Although PILOT requires additional time and management from the QBM instructor, PILOT students can enhance the quality of the QBM lab: they are knowledgeable about the class, familiar with lab specifics, comfortable teaching the material, enthusiastic about teaching, and often more experienced than GTAs who have not taken the course. The weekly meeting with the instructor also helps to prepare and train the PILOT students for the upcoming lab. QBM students now have regular contact with 4–5 supplemental instructors (1 GTA and 3–4 PILOT students) in their lab sections, and this has improved the QBM lab experience as indicated by the positive feedback from QBM students on Student Perception of Faculty Instruction forms (not shown) and a short survey on QBM student perceptions of the PILOT program (see Appendix 4). Occasional negative comments from these assessment tools were usually directed toward specific UTAs who reportedly were more concerned with their research project than with teaching, were inexperienced with effective presentation techniques, or could not provide assistance with lab protocols and homework. Students have since been more thoroughly critiqued when giving the practice lecture, and those who were unprepared were not allowed to lecture that week. They have also been more thoroughly trained on the lab protocols homework and instructed to work on their projects only when most QBM students have completed the lab. PILOT students have also contributed to the optimization and generation of experiments for the QBM lab, with protocol changes and entirely new assays resulting from PILOT projects. The extra manpower provided by PILOT students has thus allowed QBM instructors to explore protocol improvements and potential experiments for the QBM lab that would have otherwise gone untested. Finally, the course instructors have noted an additional effort on the part of many QBM students who want to be considered for a future position in PILOT. These collective observations strongly suggest that PILOT provides tangible benefits for both PILOT and QBM students as well as for QBM instructors.

Overall, feedback from PILOT students through the survey, instructor evaluations, and personal conversations has been overwhelmingly positive. PILOT not only helps to alleviate the demand for undergraduate research and experiential learning, but also provides students with an additional opportunity to teach and improve their confidence in public speaking. There are a large number of students interested in enrolling in PILOT each semester, and many students choose to repeat the course in subsequent semesters to further focus on teaching or a lab project. Survey data demonstrate both the peer instruction and laboratory occupational training components of PILOT are beneficial to participating students, while instructor observations further emphasize the value of PILOT to QBM. Although initially designed to specifically support QBM, the core structure of PILOT could be easily expanded and adapted to other laboratory courses.

SUPPLEMENTAL MATERIALS

Appendix 1: QBM syllabus
Appendix 2: PILOT syllabus
Appendix 3: Survey data
Appendix 4: QBM survey results

ACKNOWLEDGMENTS

The authors declare that there are no conflicts of interest.

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