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Training the Foot Soldiers of Inquiry: Development and Evaluation of a Graduate Teaching Assistant Learning Community

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As part of a Howard Hughes Program for Innovation in Science Education grant at Iowa State University, a series of interdisciplinary graduate teaching assistant learning communities (TALC) were developed. The purpose of these communities was to create an environment to facilitate teaching assistants' pedagogical development and training to enhance the implementation of inquiry experiences in the undergraduate laboratories. The TALC evaluated in this study were held for two consecutive semesters and included teaching assistants who facilitated multiweek coursebased research experiences in their respective STEM courses. Topics discussed during the TALC were based on the teaching assistants' concerns related to teaching this type of course. Evaluation consisted of weekly reflection responses, a pre- and postsurvey of instructional methods they consider to facilitate inquiry, pre–post definitions of inquiry-based instruction, and end-of-semester evaluations of the learning community experiences. This article outlines the development of the TALC and findings from the various forms of evaluation.

More and more research focused on the implementation and effectiveness of inquirybased instruction that incorporates research experiences is making its way into the educational and scientific literature (Lindsay & McIntosh, 2000; Newton, Tracy, & Prudente, 2006; Russell & Weaver, 2011; Samarapungaven, Westby, & Bodner, 2006; Weaver, Russell, & Wink, 2008). These studies often describe the specific research project conducted, acceptance of the project by students as a viable learning experience, and a lengthy list of project pitfalls and recommendations for improvement. Course-based research experiences (CBREs) in the instructional laboratory (i.e., pseudo-research experiences) as teaching tools are still in their infancy as viable and easily implementable instructional practices. One area that has had little study is the pedagogical development of graduate student teaching assistants (TAs) tasked with implementing these CBREs. Because graduate student TAs are commonly the primary resource for undergraduates in laboratory courses at large universities, their ability to implement the CBRE is paramount to the labs' success. Although several studies have discussed general training for TAs (Addy & Blanchard, 2010; Baumgartner, 2007; Marbach-Ad et al., 2012; Petrinjak, 2010), there is little research to describe how to prepare TAs for the unique environment inherent to courses with embedded CBREs. This manuscript addresses the formation, implementation, and evaluation of a two-semester learning community designed to give TAs the opportunity to develop the necessary skills to teach in CBRE learning environments. It also addresses the concerns of those TAs currently attempting to implement CBREs.

Formation and implementation

In the context of a university-wide initiative at Iowa State University aimed at implementing inquirybased laboratory experiences into the undergraduate curriculum, TAs and postdoctoral research associates from a broad array of science, technology, engineering, and mathematics (STEM) disciplines (i.e., biology, chemistry, geosciences, and psychology) were brought together into a learning community. Support for this initiative was provided through a Howard Hughes Medical Institute (HHMI) grant. The focus of the learning community was to address the concerns of TAs tasked with implementing CBREs in their respective laboratory courses. The degree to which CBREs were implemented in the courses ranged. Many courses in chemistry consisted of traditional "cookbook" experiments for the first 8 weeks and then began the CBRE module. Biology courses had traditional experiments but required students to think of a researchable question based on the topic of the traditional lab, and at the end of the semester the students had 2–3 weeks to answer one of the questions. The geoscience courses used inquiry-based experiments throughout with a CBRE at the end of the semester. Therefore, the amount of inquiry training and experience the TAs came to the learning community with and used throughout the semester varied greatly. The biology TAs had much more latitude in regard to how they went about teaching the material in the laboratory, whereas the geoscience and chemistry TAs had a much more scripted role in their teaching.

The purpose of the interdisciplinary participant mix was to leverage the idea that despite content differences, the experiences of TAs in these instructional settings are similar. TAs from courses implementing CBREs in the instructional laboratory self selected to participate in the learning community. TAs received a stipend for participating in the amount of their semester student fees and were encouraged to list their participation in the

learning community on their curriculum vitae; stipends were distributed at the conclusion of each semester. Participation in the learning community was limited to two semesters.

Sixteen TAs participated in the first semester; four of the authors of this manuscript facilitated the learning community. Due to various conflicts (such as graduation, time commitments, and scheduling), five TAs were unable to participate for a second semester. However, three new TAs were able to join, so 14 TAs participated in the second semester. Five of the authors of this manuscript facilitated the second-semester community. For consistency in comparison, only the 11 TAs participating throughout both semesters will be considered in the analysis. Six TAs were female; 10 were doctoral students, and one was a master's degree student. There was an even distribution of disciplines: two TAs were from psychology, and three each were from biology, chemistry, and geosciences, respectively. Six TAs were set on future careers in academia, one wanted to continue research in bioinformatics and work closely with the education community, and the remaining TAs were unsure as to the degree teaching would be incorporated into their future career plans.

The TALC met biweekly in 1-hour sessions for the first semester. Because of a majority request to increase the amount of discussion time, the second semester community met for 1.5-hour sessions. Meetings included a mix of individual reflections, small group activities and discussions, and whole community discussions. Between sessions, TAs responded to reflection questions; the facilitators used these reflections in evaluating and planning future sessions. TAs read two to three journal articles and web pages in preparation for each session, which are included in Table 1.

Biweekly discussion topics

A key feature of the learning community was that biweekly discussion topics emerged from self-reported concerns of the participating TAs (Darling-Hammond & McLaughlin, 1995). These concerns were gathered via a survey conducted during the first session of the learning community and from the first semester evaluation. The topics listed in Table 1 were the concerns the TAs mentioned most often when asked about their teaching in an inquiry-based course. A more detailed explanation of each session can be found in the supplementary material.

An additional key feature of the community was how the community was facilitated. To promote open discussion and build the community environment, course instructors were not directly involved with the learning community. Postdoctoral research associates either involved with the inquiry laboratory development or with extensive training in inquiry instruction selected the readings, developed the activities, and led the discussions. We believe that this is a key component—and what set this group apart from other more traditional groups for formal TA training. This independence from faculty was commonly listed as a strength of the group in evaluations.

Because the focus of the community was to develop TAs' inquiry based teaching abilities, the second semester TAs were encouraged to cofacilitate a session under the guidance of the postdoctoral research associates. Groups of two to three TAs chose reflection questions, selected readings, developed activities, and led discussions during each session; the planning and leading of these TA-led sessions were done in consultation with a postdoctoral research associate.

Evaluation of the learning community

During the first session of the first semester, the TAs completed a survey including which concerns they had in teaching inquiry-based labs, how they defined "inquiry-based instruction," and their experience with the 31 teaching methods shown in Table 2. They were asked about their experience with these methods both as an undergraduate student and as a TA, as well as what they perceived the importance of these techniques was in relation to inquiry-based teaching. Data from this survey was used as a baseline for assessing the TAs' familiarity with inquiry-based teaching.

Subsequent surveys were administered at the end of each semester to evaluate the TAs' perception of the effectiveness of the different instructional methods used in the community, the strengths of the community, any improvements that could be made, the TAs' familiarity with inquiry-based instruction, and how this experience had impacted their teaching. All data collected for assessment purposes was obtained with consent from the TAs and approval from Iowa State University Institutional Review Board.

Only the data from the Instructional Methods Survey and end-of-semester surveys will be discussed herein. Nonparametric statistics were used to determine significant differences in how the TAs responded to the Methods Survey. The short-answer responses from the end-of-semester surveys were coded using the constant comparative method (Lincoln & Guba, 1985), which determined common themes in the data. Responses were then tabulated to provide a graphical depiction of the number and range of responses. For brevity, only responses mentioned by more than two TAs are presented.

Results and discussion

Familiarity with classroom instructional methods

The first administration of the Instructional Methods Survey provided insight into the TAs' prior experiences and prior knowledge of inquiry instruction. For this survey, the TAs ranked how often these methods were used during their undergraduate instruction and during their current teaching practices. Responses were given on a scale from 1 to 5, with 1 being never to 5 being used ~75%– 100% of the time. The instructional methods were also ranked 1 to 5 in terms of their importance to inquiry, with 1 being not important and 5 being essential. For the purposes of the inquiry experiments the TAs were facilitating, Instructional Methods 11–31 would be considered inquiry. However, because of the structure of some of the laboratories having traditional "cookbook" labs and then transitioning to a CBRE midsemester, some TAs used the inquiry methods more than others.

On first inspection of Figure 1, it can be seen that the TAs' own undergraduate learning experiences (blue) were not consistent with what they deemed most important to inquiry instruction (green). For instance, the TAs more often experienced "2: Listening to the instructor lecture," "6: Engaging in experiments with predetermined, written procedures," and "8: Writing lab reports for experiments with preset procedures and results" during their undergraduate instruction, while only rating these methods as moderately important to inquiry instruction. The converse is also seen in Figure 1. TAs infrequently experienced "21: Searching outside primary literature sources to learn what is already known," "22: Designing and implementing new procedures or models," and "23: Exploring alternative methods for solving problems" even though they rated these methods as being essential for inquiry instruction.

This inverse trend is also seen in comparing the TAs' current use of instructional methods (red) to those they deem most important for inquiry instruction, although to a lesser extent. The TAs are still using methods including "2: Listening to the instructor lecture," "6: Engaging in experiments with predetermined, written procedures," and "8: Writing lab reports for experiments with preset procedures and results" ~50%–75% of the time even though they are teaching a laboratory with research-like experiences. However, they are also to the same degree using methods they initially deemed essential to inquiry instruction such as: "14: Participating in an in-class simulation or group exercise," "15: Participating in a class discussion," "17: Making predictions based on prior knowledge," and "31: Explaining data from experiments without a predicted outcome, or using other evidence to make and defend conclusions."

A Spearman's Rho (?) ranked correlation was conducted for each teaching method among all three variables. Because of the small sample size and the Likert-scale rakings for each variable, Spearman's Rho ranked correlation was chosen over a Pearson correlation. A significant correlation ($p < .05$) was seen between the TAs' prior experience with the method and their current use of it for methods 7 (? = 0.704), 10 (? = 0.763), 14 (? = 0.900), 20 (? = 0.742), 23 (? = 0.722), 28 (? = 0.640), and 31 (? = 0.683). This strong significant correlations between the methods used to teach the TAs and the degree to which they use those methods now is consistent with prior research that concludes that we teach how we were taught. This is also consistent with the fact that this was a survey measuring the TAs' experience with these methods prior to implementing the CBREs for the first time.

Instructional methods 7 (? = 0.688) and 10 (? = 0.860) were the only two instructional methods that were significantly correlated between the TAs' undergraduate experience and the importance of the method for inquiry based instruction. In correlating the instructional methods the TAs currently use with what the importance of the methods for inquiry methods 2 (? = 0.748), 4 (? = 0.699), 7 (? = 0.699), 10 (? = 0.889), 12 (? = 0.671), and 27 (? = 0.704) show significant correlations ($p < .05$). Although methods 2, 4, 7, and 10 would not traditionally be considered important for inquiry by experts, in discussion with the TAs, they thought that these methods were needed to ensure proper safety procedures in lab.

In order to determine how their views of inquiry instruction changed over the duration of the TALC, the "importance to inquiry" portion of the Instructional Methods Survey was also administered at the end of both semesters of the TALC as part of its evaluation (Figure 2). The methods that were deemed essential across all 3 administrations were "13: Asking clarification questions during or after class," "23: Exploring alternative methods for solving problems," "29: Asking new questions based on data analysis from a previous experiment," and "30: Reflecting on one's own work or learning." In discussions with the TAs, it was revealed that the consistency in "2: Listening to the instructor lecture" and "9: Receiving factual information from the teacher" resulted from the need for dissemination of prelaboratory safety information, even in more open-ended inquiry teaching
settings.

To determine if any of the changes in importance was significant across time, a Friedman's test was conducted for each method. The Friedman's test is the nonparametric equivalent to a one-way repeated measures analysis of variance and was chosen because of the small sample size and ordinal data. For this sample, Friedman's chisquare values ranged from 0.15 to 3.65 with p-values all above 0.5. Hence, although there is some movement in scores noted previously, the movement across participation in the TALC is not statstically significant as a whole for each method. This is most likely because of the lack of differentiation in the 5-point Likert scale and a ceiling effect, resulting in there being little room to improve from the beginning.

Evaluation of the TALC

As part of the end-of-semester evaluation, the TAs ranked their level of understanding of the various topics discussed during the TALC sessions prior to and after the completion of the TALC on a scale from 1 to 5 with 1 being never heard of before and 5 very familiar and have experience (Figure 3). The greatest increase in level of knowledge from prior to post- TALC occured in the areas of understanding "inquiry-based instruction" and "Bloom's taxonomy." The improved understanding of these two areas are not surprising, as the focus of the TALC was to develop methods of implementing inquiry-based instruction. Likewise, the discussions of assessment and asking and fostering better questions revolved around the introduction and understanding of Bloom's taxonomy. It should be noted that there was an overall selfreported increase in understanding across all of the topics covered during the TALC; however, Friedman's test indicated significant differences in understanding over time participating in the learning community for only five of the eight topics: inquiry-based instruction (15.59, $p < .001$), effective questioning (9.95, $p < .01$), Bloom's taxonomy (7.09, $p < .05$), rubric development (7.09, $p < .05$), and rubric use (9.86, $p < .01$).

The TAs were also asked to list three strengths of the TALC (Figure 4) and three improvements that could be made to the TALC (Figure 5) on both of the end-of-semester evaluations. For both semesters, the greatest strengths mentioned were the discussions and the interdisciplinary nature of the TALC. For instance, one student mentioned that the combination of these two aspects "allowed for learning of new techniques." Other aspects that were mentioned by several TAs were the sense of community and the ability to speak freely in a safe environment. An example of this would be "I felt supported in the group to talk about ideas and concepts that may get you reprimanded if you talked about [them] with your advisor or instructor (boss)." This is why emphasis has been placed on the facilitators being postdoctoral researchers not assigned to being "incharge" of any of the teaching labs. It allowed for open discussion among the group without there being a right or wrong answer.

The decrease in facilitator strength and appearance of activities as a strength during the second semester can be explained by the difference in facilitation format between the two academic terms. The facilitators (i.e., the postdoctoral researchers) were mentioned as strengths often after the first semester because they were the ones leading the discussions. This changed during the second semester as the TAs increased their roles in the learning community, both in leading discussions and incorporating more activities, which is noted in Figure 4.

Compared with the perceived strengths of the TALC, the improvements that the TAs mentioned varied between the first and second semester (Figure 5). For the first semester, the TAs wanted a longer meeting that was not held Friday mornings at 8 a.m. Following both semesters, TAs thought more TAs could benefit from the TALC and wanted more diversity by "incorporating more 'soft' science disciplines," TAs from other courses, and TAs not facilitating a CBRE laboratory. It was also suggested during both semesters that there should be more interaction with faculty by having "guest speakers that teach classes [that are] inquiry based"

or getting “feedback from faculty about TAs in TALC” regarding their teaching. In addition, the TAs wanted more practice applying inquiry either by “making a cookbook lab into an inquiry lab” or “practicing in a real environment what we learn.”

There were some aspects of the TALC that the TAs saw as strengths but still needed some improvement (Figures 4 and 5). The majority of TAs felt the group discussions were beneficial. To account for this, the length of the TALC meetings were lengthened second semester to 1.5 hours with the goal of allowing more time for discussion of the readings. However, this goal was not necessarily achieved. According to the TAs, the discussions needed to be more focused and structured, because they still felt that there was not enough time to discuss the readings. This issue is potentially a result of having the TAs lead the discussions, and their relative lack of experience leading a more discussion-oriented “class” of this kind, which is far different from a typical laboratory session. The TAs also felt that developing their pedagogical knowledge was a strength of the TALC but at the same time they wanted more emphasis placed in this area by “providing a list of strategies for presenting information,” or “including not only the labs but also teaching in general.” Because the focus of the TALC was on facilitating inquiry labs, efforts were made to provide additional information about the “Preparing Future Faculty” program on campus for more comprehensive pedagogical development.

Finally, one of the most important questions we asked the TAs at the end of each semester was how the learning community had influenced them as an educator. Perhaps most interesting in Figure 6 is the number of TAs who mentioned that the TALC helped them become more reflective in their teaching. This sentiment is exemplified by these two quotes: “[teaching] can always be improved, and that constant self-evaluation is necessary to continue getting better at it,” and “It has encouraged me to take chances, get messy and make mistakes! I can go for it!” The TAs have gained confidence in their ability to teach using this style of instruction, especially in the areas of how to ask effective questions and keeping students motivated throughout a research project. After the first semester, all of the TAs said their experience had been so fulfilling and they learned so much that they would continue for a second semester of the TALC. In fact, the TALC was so influential for one of the TAs that she stated the following, “Before I started TALC, I was pretty sure I wanted to get into industry after getting my PhD. I am [now] actually seriously considering teaching at a 4 yr college too! That is how much it helped.”

Conclusion

For institutions implementing CBREs in their instructional laboratories, we recommend training graduate student TAs in pedagogy associated with facilitating inquirybased learning. Although the findings discussed are based on TAs’ self-reported data, many important recommendations can still be made on the basis of the development and assessment of the interdisciplinary graduate TALC at Iowa State University. First, there must be a great emphasis placed on training TAs in an environment where they feel safe to voice their concerns about the class and give advice to other TAs. This could be accomplished by having a senior TA, postdoctoral assistant, or a faculty not associated with the laboratory facilitating the training so the TAs do not fear repercussions of speaking openly. Second, there are TAs that seek greater pedagogical content knowledge, and this is the perfect opportunity to develop effective educators and improve undergraduate instruction simultaneously. Third, there is strength in the interdisciplinary nature of the TALC—the “me too” effect. The TAs took solace in the fact that other TAs were having the same issues in other disciplines, and they were able to get ideas for different strategies to help overcome some of the common issues they faced. The interdisciplinary nature was so important to them that the TAs wanted more diversity within the group by adding additional “soft” science assistants because of the perspective they brought to the group.

The results of the first year of the TALC were so overwhelmingly positive, based on the feedback from the TAs, that a second cohort of TAs of a pseudo-research experience has begun and the TALC model has expanded to include cohorts for TAs of large introductory physics courses (which were recently made more openended), as well as chemistry courses using the Science Writing Heuristic (Burke & Greenbowe, 2006), TAs of a large introductory biology laboratory implementing inquiry techniques, and TAs for a large introductory biology lecture implementing active learning strategies. Additional studies are currently underway to determine to what degree the instructional strategies used in the laboratories influence students’ understandings of the nature of science and their retention in STEM disciplines.

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