IMPROVING CAPACITY AND QUALITY OF UNDERGRADUATE STATISTICS INSTRUCTION THROUGH RESEARCH-BASED TA TRAINING EXPERIENCES

Jennifer J. Kaplan[1] and Kristen E. Roland[2]
Department of Statistics[1], Department of Mathematics Education[2]
University of Georgia, Athens, GA, USA
jkaplan@uga.edu

Statistics has one of the fastest growing course enrollments of the undergraduate STEM disciplines in the U.S., with many introductory courses taught by Teaching Assistants (TAs). Since many TAs will go on to be faculty members in statistics, improved training of TAs should lead to improved teaching and more capacity to meet the discipline's growing needs. This paper describes a two-year study in which a cyclic design was used to create and refine TA training materials. With these materials, TAs increased opportunities for their students to engage in active learning and develop enhanced conceptual understanding. We will share data collected from both the training sessions and the TAs' activity implementations and discuss lessons learned about TA training and solutions explored and implemented to improve the training.

BACKGROUND

In the last two decades, enrollment in introductory statistics courses has grown at a large rate (Blair, Kirkman & Maxwell, 2013). At the same time, there has been extraordinary growth in research on how students learn statistics and how instructors can be more effective in teaching statistics (ibid). One recommendation to promote student learning is to foster active learning in the classroom (GAISE Revision Committee, 2016). To implement this recommendation some U.S. institutions augment the large lecture format with a lab section, in which active learning is implemented. These lab sections tend to be facilitated by Graduate Teaching Assistants (TAs). Little is known, however, about the needs of TAs to facilitate such experiences due to both sparse literature and lack of training programs for TAs in statistics (Green, 2010; Noll, 2011; for exceptions see American Statistical Association (2005). There is evidence, however, that TAs themselves want training to improve their teaching skills in order to have more impact on their students' learning (Green, 2010). In addition, TAs want clear guidelines about the content they will be teaching in order to have the confidence to do well in the classroom and TAs value collaboration in planning and teaching multiple section courses (ibid). Green (2010) and Noll (2011) agree that more work is needed in this field. In addition, they and researchers on TA preparation in mathematics, agree that this research should be situated in actual classroom practice (Green, 2010; Noll, 2011; Wagner, Speer & Rossa, 2007).

Within the general literature on professional development (PD) for university instructors, successful PD models tend to be focused and coordinated efforts that last for an extended period of time and use evaluation and feedback to the instructors (Henderson, Beach & Finkelstein, 2011). In statistics education, Green (2010) corroborates the needs of statistics TAs for PD that extends over time. In addition to the use of a collective community to share instructional approaches (D'Avanzo, 2013; Henderson et al., 2011; Lynd-Balta, Erklenz-Watts, Freeman & Westbay, 2006), successful PD models provide feedback to instructors and the encouragement to reflect on the instructional changes. Finally, the literature suggests that the effectiveness of change strategies would benefit from the incorporation of research on changes in student learning as a result of the instructional change (D'Avanzo, 2013; Lynd-Balta et al., 2006).

This paper provides an overview of the results of two year-long cycles of a design-based research project (Wang & Hannafin, 2005) with the aim of learning about the needs of TAs in statistics to implement activities designed to foster active learning and conceptual understanding.

METHODOLOGY

Following the process of design-based research, initial design of the PD was based on the available literature and then the PD design was modified prior to each new cycle based on data collected during the prior cycle (Figure 1). TAs attended weekly training sessions in which they learned to facilitate the activity for that week. These training sessions were observed by a Graduate Research Assistant (GRA**)** associated with the project. Each week the GRA observed 6 TA

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implementing activities using the Classroom Observation Protocol for Undergraduate STEM (COPUS) (Smith, Johnes, Gilbert & Wieman, 2013). These observations were discussed at the weekly meetings of the project team comprised of the Project PI, the Course Coordinator (**CC**), the GRA, and a TA assigned half time to the project. Notes taken during these meetings, along with the observation notes, form a portion of the corpus of data that contributed to the revision of the training sessions.

In addition, feedback was solicited directly from the TAs through weekly surveys administered the day after the activities were implemented and focus groups held twice during the semester. The weekly surveys included questions about strengths and weaknesses of the training session for the activities. The focus groups were led by a faculty member trained in qualitative methods and not associated with the training program. One of the themes of the focus group prompts was how well prepared the TAs felt they were to lead the activities. Finally, the TAs completed a survey about their pedagogical knowledge and background at the beginning of their first semester in the project and at the end of every semester they participated in the project to document change in pedagogical knowledge.

Across the two years of the project, a total of 27 unique TAs participated in the research, 10 to 12 in each of the four semesters. Seventeen (63%) were male, 11 (41%) had English as a first language and a different 11 (41%) were in their first year in the department when first assigned to the project. Using self-reported data, 19 of 25 (76%) of the TAs had an undergraduate major or minor in mathematics or statistics and 6 of 24 (25%) had no prior instructional experience.

RESULTS

The initial design of the training sessions was to begin the session with a role-playing activity with the CC playing the part of the TA and the TAs playing the part of UG students. The demonstration would be followed by a discussion of the pedagogical considerations and statistical content associated with the activity. The most frequent positive comments made by the TAs about the weekly training sessions in the first fall semester concerned their perceived value of the time spent reviewing the statistical content and doing the activities as though they were students. In fact, there were a number of requests to discuss the content in more depth. Through the classroom observations, we found that the TAs had difficulty in providing closure for the activities and struggled to confront the misconceptions UG students develop, particularly about inferential procedures.

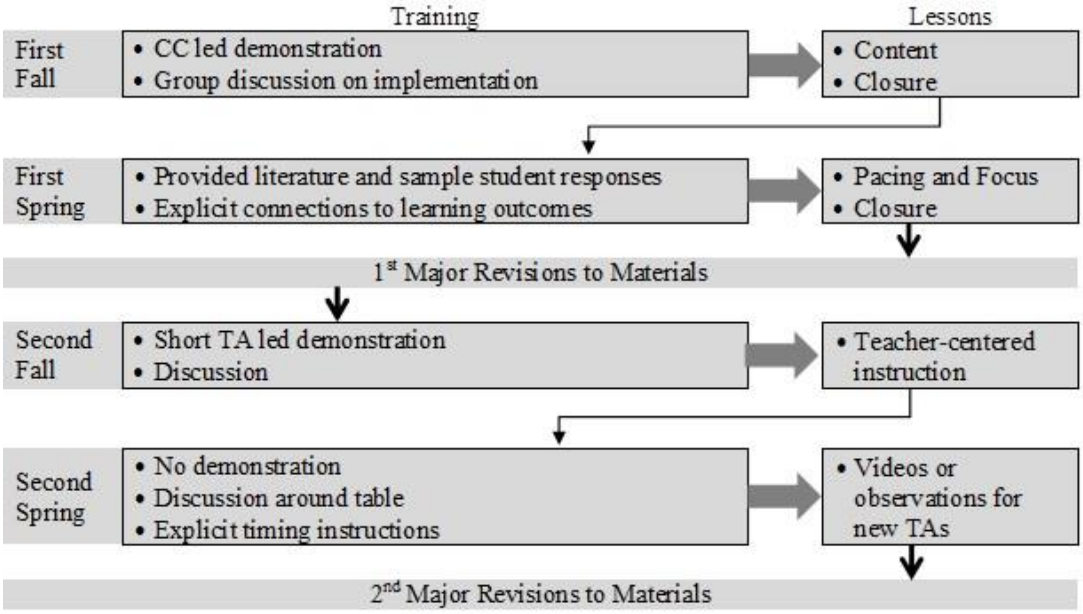

Figure 1: Professional Development Design and Lesson Learned

The demonstrations were retained in the first spring semester, but the training sessions were lengthened to include more discussion of potential student difficulties. TAs were provided readings of literature on student misconceptions as well as student responses to the activity questions in the

prior semester. Data collected during the semester indicated that pedagogically, the TAs wanted advice on pacing the class sessions, in particular when the activity was too long for the period. Observations showed that TAs still struggled with closure. In addition, the CC was finding it difficult to manage the dual role of demonstration and identifying pedagogy and often broke role to provide comments about pedagogy and content during the demonstration.

Several changes were made to the training protocol in Year 2 of the project to address the issues noted in Year 1. The role-playing was changed to have a Senior TA acted as a TA while the other TAs acted as students. The CC would interrupt the demonstration with meta-comments to focus the TAs' attention on important aspects of the facilitation of the lesson. After this the group would discuss the content and enactment of the session in general. In addition, the student materials were revised to include fill-in-the-blank important points for the activity to be used by TAs to provide closure to the sessions.

The weekly TA surveys from the second fall semester indicated that most TAs still valued going through the activities as students. In addition, more comments about the value of discussing potential student responses, exemplary student responses, and potential pitfalls for students began appearing in the survey responses. Observations of the second fall semester classes indicated that most TAs were providing a very similar experience to that done in the training. While this supplied consistent experiences for undergraduate students across TAs, an unintended negative consequence was that some TAs facilitated the activity with the same focus as had been done in training. The time constraints on training necessitated an abbreviated walk through the activity without time for group work and focused on the procedure of implementing the activity rather than developing the active learning aspect of the activity. TAs who matched the focus of training ended up leading a teacher-centered activity rather than the intended student-centered nature of the activities.

To address the issues raised in the second fall semester, the training team revised the training sessions and eliminated the demonstration of the activities. Instead, training sessions were dedicated to discussions of the statistical concepts, student learning, and the specific timing of the activities with particular focus on the amount of time that should be given to letting students work in groups. In addition, the training team redoubled its efforts to communicate the purpose of the activities and the role of the TAs within the structure of the course. As a result of these changes, the TAs were observed to allow more student-centered activity within the class. The responses to the weekly TA surveys indicated that the TAs found the discussions of expected student responses and potential pitfalls to be quite useful. Since demonstrating the activity had been removed, the new TAs (3 of 10) discussed the difficulties of understanding the flow of the activity having never done them as students. One solution to address this issue that worked reasonably well was to have new TAs attend classes of experienced TAs prior to their own first class session. To attend to this issue in the future, the project team began video-recording class sessions to create training videos that TAs can watch prior to training as a way to blend the concerns of the new TAs with the benefits of the group discussions on content and pedagogy.

The responses of the TAs to surveys on their pedagogical knowledge at the time they entered the PD program and at the end of their last semester in the PD program have been analyzed descriptively investigating the TAs perceived changes in pedagogical knowledge. Initial results indicate that the TAs tended to feel more prepared to incorporate recommendations of the GAISE Committee Report (2016) in an introductory statistics course. These self-assessed gains in preparedness did not extend to courses other than introductory statistics. Finally, the TAs indicated more familiarity with research on student learning, common non-normative reasoning, the use of technology, and methods for helping students work in groups in statistics.

LIMITATIONS AND CONCLUSION

While the PD model we used largely followed the best practices from the literature, there were two suggestions that were difficult to implement in our setting: instructor empowerment and feedback on student learning outcomes. The initial TAs in our study, who had worked under a different model, were resistant to the advent of the new activities and their philosophy. While this resistance diminished as new TAs joined the program, we were never able to integrate the TAs fully in the program. Also specific to our situation, the TAs do not have any grading responsibilities so providing evidence of student learning is not a facet of our system. We created activities to be used

in training session that provide actual student responses to questions in the activities highlighting the common correct and incorrect responses, but we hypothesize that having TAs grade their students' responses would be beneficial to the attention TAs would pay to the training sessions. We suggest that new TAs be assigned to grade as part of their initial duties in order to address the suggestions for best practices in the PD literature.

The main pedagogical issues observed in the TAs in this study were problems with timing and closure. TAs also seemed reluctant to let students work through difficult portions of the activity. Instead of working with small groups individually, asking guiding questions, TAs tended to call the class together and present a mini-lesson on the difficult aspects of the activity. We remedied this issue by providing detailed timing instructions for each activity, in both written and verbal form, including the amount of time that should be devoted to small group work and whole class discussion. Furthermore, we have created training videos that include captions specifying the timing of the activities. To address the issues with closure and a related issue that TAs were sometimes unsure of the main points of the activities, we included a fill-in-the-blank section to the activity manual that TAs could use to close the activity. This was effective in our setting, but we encourage those who work with more senior TAs or graduate students who are instructors of record to attend to the importance of closure and to provide opportunities for TAs to develop their skill in closing lessons. Finally, at the intersection of these issues, TAs were reluctant to skip portions of the activity, even when the directions specified the portion that could be skipped. We were never able to completely resolve this issue and we encourage other researchers and TA trainers to attend to this issue in case it generalizes beyond our setting.

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