Mentoring Graduate Students In Engineering Education Through Team Teaching

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Abstract

The preparation of science and engineering graduate students for careers in academia is of concern due to the lack of formal professional training in teaching required for new science and engineering faculty members. In this paper, a team teaching project resembling a teaching internship is described. An undergraduate electrical engineering course was team taught by a faculty member and graduate student in the goal of preparing the graduate student for a future career in academia. The structure and outcomes of the project are presented as a potential vehicle to expand opportunities for mentoring graduate students in engineering education.

Introduction

Graduate students in science and engineering pursuing doctoral degrees typically have minimal focus on teaching, despite a potential career path in academics. The primary mechanism for graduate students to learn about engineering education is through an appointment as a teaching assistant or graduate student instructor. At many institutions, formal programs are in place to develop teaching skills in graduate students for their role as instructors. However, the duration or scope of teaching assistant assignments are often limited, where students are typically not exposed to key aspects of teaching a course. Graduate students are typically not included in fundamental aspects of teaching such as the development of educational objectives, course planning, addressing learning styles of students, and examination of course material. Formal courses in teaching science and engineering have been introduced at some institutions including Purdue University[1] and The University Of Michigan (Engineering 580 - Teaching Engineering, introduced by Susan Montgomery), where fundamental aspects of teaching are addressed explicitly. Unfortunately, there are very few opportunities provided for graduates students to apply knowledge and skills related to teaching prior to obtaining an academic faculty position. Given this shortcoming, teaching internships for graduate students have been envisioned to provide opportunities for graduate students interested in future careers in teaching. J. Burke has gone as far as to suggest that teaching internships should be required for all doctoral students[2], perhaps modeled after the clinical internship for medical fields. The Georgia Institute of Technology has been a pioneer in this area, where teaching internships in the Woodruff School of Mechanical Engineering have been offered since 1990[3]. In the teaching internship, the graduate student team-teaches one-third to two-thirds of a quarter-long undergraduate course. In this work, the outcomes of a team-teaching "internship" for a semester long undergraduate course in electrical engineering at the University Of Michigan are presented. The perspectives of

the faculty member and feedback from students in the course are described, where perspectives of the graduate student intern will be described separately in these proceedings.

Team-teaching description

In the Fall semester of 2004, the course "EECS 320 – Introduction To Semiconductor Devices" was taught by a team of one faculty member (Jamie Phillips, Assistant Professor of Electrical Engineering and Computer Science) and one graduate student (Timothy Murphy, third year graduate student). The graduate student had previously served as a teaching assistant and had previously completed a graduate course in engineering education. Team teaching in this manner is a rare, if not first of its kind, occurrence for an undergraduate engineering course at The University of Michigan. The course had a student enrollment of approximately 100 students, three hours of class per week in a lecture format and one hour of discussion per week in smaller groups (approximately 30 students) led by two separate graduate student instructors. The course objectives and syllabus were developed by the faculty and graduate student team. The graduate student taught three one-week segments of the class, developing lecture materials, homework assignments, and corresponding exam materials in conjunction with the faculty member. During these segments of the class, the graduate student also held the primary office hours for the course to interface directly with students, though the faculty member was also available as an alternative. During this semester, the graduate student was fully engaged in (and supported by) research, where the role in the project was entirely voluntary. The one-week segments taught by the graduate student were spaced approximately one month apart. This arrangement provides valuable time between teaching segments to obtain feedback from students and the faculty mentor, and to develop the following teaching segment based on this feedback. In this arrangement, the time demands are decreased to allow the graduate student to meet research or other obligations, one of the drawbacks indicated by some students participating in the intern program at Georgia Tech[3].

Faculty perspective

Team teaching with graduate students provides an excellent opportunity for both the participating faculty member and graduate student, provided that the team-teaching experience is approached with an appropriate attitude. The faculty member should have a genuine interest in the mentoring experience with the expectation that time demands will not necessarily be reduced due to team teaching, but rather shifted from pure teaching to mentoring, evaluation, and coordination. The team teaching arrangement offers time-saving advantages to the faculty mentor by reducing the course preparation and implementation load, providing an additional primary contact for the course, and providing some degree of flexibility for travel required by research projects. However, the faculty member should be present for most, if not all, class sessions taught by the graduate student to observe and provide feedback. In order for travel to be accommodated, the segments to be taught by the graduate student should be determined well in advance. Sections where the graduate student is teaching requires no direct time for class and homework preparation on the part of the faculty member, though significant time should be spent working with the graduate student in developing course materials. In this teaching internship, the graduate student and faculty member met to discuss plans for conducting class sessions and developing homework problems at least one week prior to implementation. After discussing and

reviewing notes and homework problem sets, course materials developed by the graduate student were refined based on feedback. From the perspective of the faculty member, this form of mentoring has a natural feel that is similar to working with graduate students to prepare research journal articles and conference presentations.

In addition to the faculty mentor, the research advisor for the teaching intern should be in favor of the teaching internship and realize time demands associated. In this project, the teaching mentor and research advisor were the same person. For this internship, it was not clear whether this is a desirable or undesirable situation. For this internship, interfacing was found to be easier since the student and faculty member had established relations and met on a regular basis to discuss research projects. On a marginally negative note, discussions between the student and faculty mentor regarding teaching had a greater tendency to drift towards discussions on research. If a faculty advisor is to be the same as the research advisor, there should be clear dedication to separate the teaching internship and research project, and to attach appropriate emphasis on both.

Perhaps the largest adjustment required by the faculty member is the need for coordination and timing. It is desirable that the teaching intern know of the subject matter and the dates for teaching well in advance to provide ample time for the described course materials development process. This requires that a relatively strict schedule should be kept, where courses that have plans for significant modifications from past semesters or where the faculty member is not very familiar with the course should be excluded from such teaching internships. For the internship described here, this was the third time that the course was taught by the faculty member, without significant modification. The time required to teach various aspects of the course was well understood, so timing was not an issue for the internship. In addition to the extra effort required in coordination of the course, the faculty member may sense some "loss of control" over the course. Nearly every aspect of planning and conducting the class should be in conjunction with the teaching intern.

Inspiring teaching innovation in the faculty mentor

One overwhelming benefit of the teaching internship to the faculty member is a drastically improved awareness and sensitivity to teaching and student learning. The mentoring process involves teaching "teaching", where similarities may be drawn to technical subject matter where teaching a subject is known to be one of the best methods of learning a subject. The mentoring aspect of the teaching internship forces the faculty member to not only assess the effectiveness of the teaching intern, but also to evaluate the teaching approaches of the faculty member and to evoke thoughts of pedagogy in general. These effects were pronounced in this teaching internship, and are consistent with feedback from the Georgia Tech program[3]. The teaching intern for this project had recently taken a course in teaching and had interest in integrating active learning strategies and evaluating their effect on students with varied learning styles. This sparked interest on the part of the faculty mentor, where interactive classroom participation is encouraged, but has never been given much focus nor has been separately evaluated in previous courses taught by the faculty mentor. To investigate active learning strategies and effects on student learning, the intern and mentor had agreed to incorporate interactive classroom exercises and to make a concerted effort to include homework exercises and exam questions to appeal to

varied learning styles, and to track student performance and relationship to learning styles. As a part of the first homework assignment, students were asked to fill out a questionnaire[4] to get an approximate representation of learning styles according to the Felder and Silverman model[5]. Results of this survey are shown in Figure 1. From this data, the learning styles of students appear to have a relatively broad distribution. However, there appears to be a larger majority of students that have an affinity towards visual learning rather than verbal learning. This persuaded us to include visual aids whenever possible to explain course concepts, though this is not a significant departure from standard practice, where semiconductor device courses are typically reliant on visualization methods.

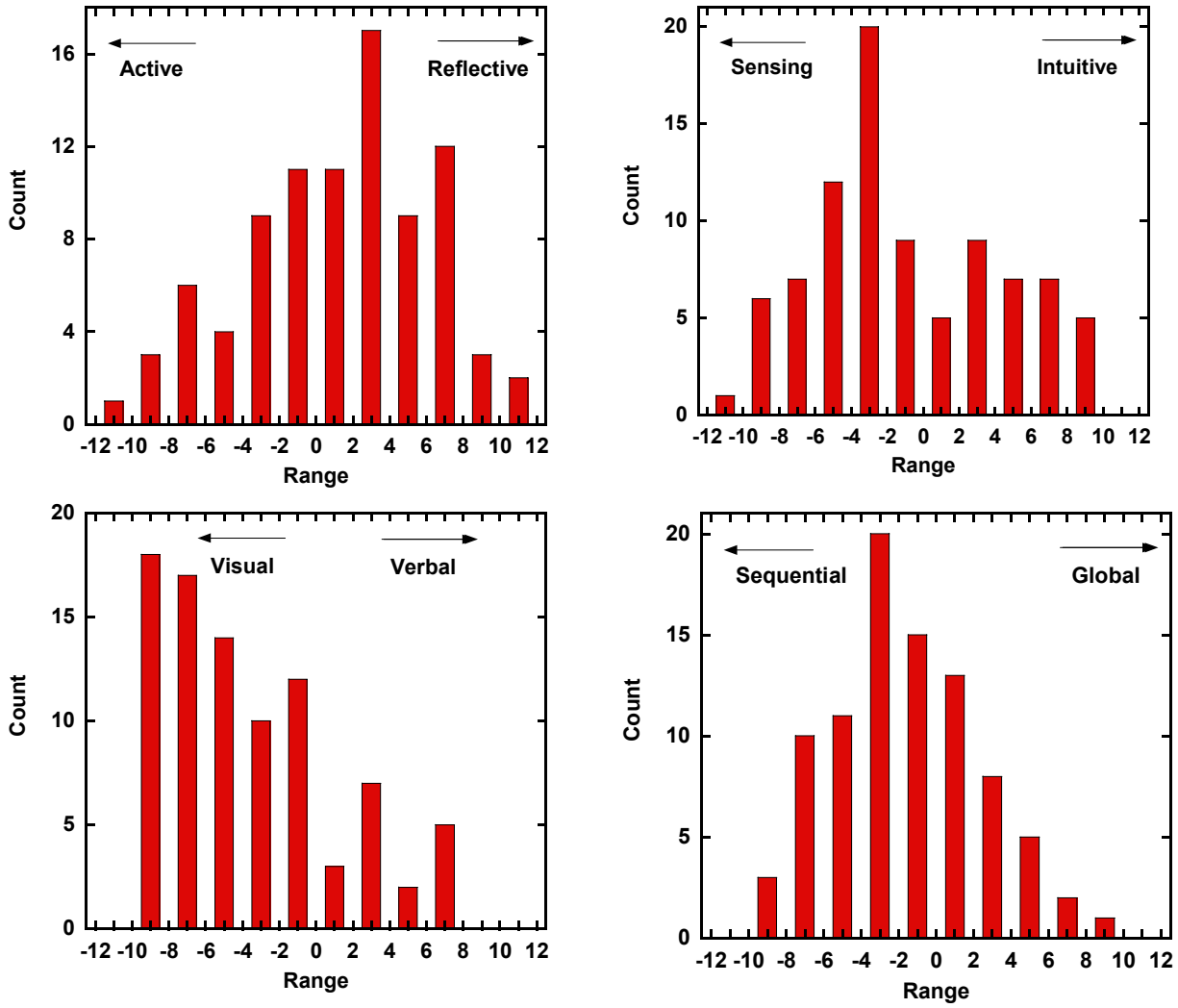

Figure 1: Histograms corresponding to learning styles of students participating in the teaching internship course.

During the course, student performance on exams and homework was tracked according to values obtained on the learning styles questionnaire. The mean score obtained by students on exam questions and homework was plotted for each value in the questionnaire (-11 to +11), for each of the four learning style classifications. In general, no clear correlation was observed between learning style and performance. However, some correlation was observed for active

versus reflective learners, as shown in Figure 2. Reflective learners generally performed better on Exam 1. The material on this exam primarily covered conceptual material on semiconductor physics, which are fairly abstract and may have been easier to grasp by reflective learners. This suggests that future semesters of this course take a direct approach to engaging active learners during class to practice these concepts as they are being presented. There was also a similar, but much weaker, dependence of performance on active versus reflective learners on the other exams. The homework scores showed an inverse (although weak) relationship on learning style, where active learners generally fared better. This dependence would be anticipated, where active learners may excel when given the opportunity to interact with instructors and other students and to practice concepts through in depth problem solving exercises. The teaching internship resulted in a strong overall benefit to the faculty mentor through motivating this form of learning styles assessment, and to encourage a continued focus on teaching methodology.

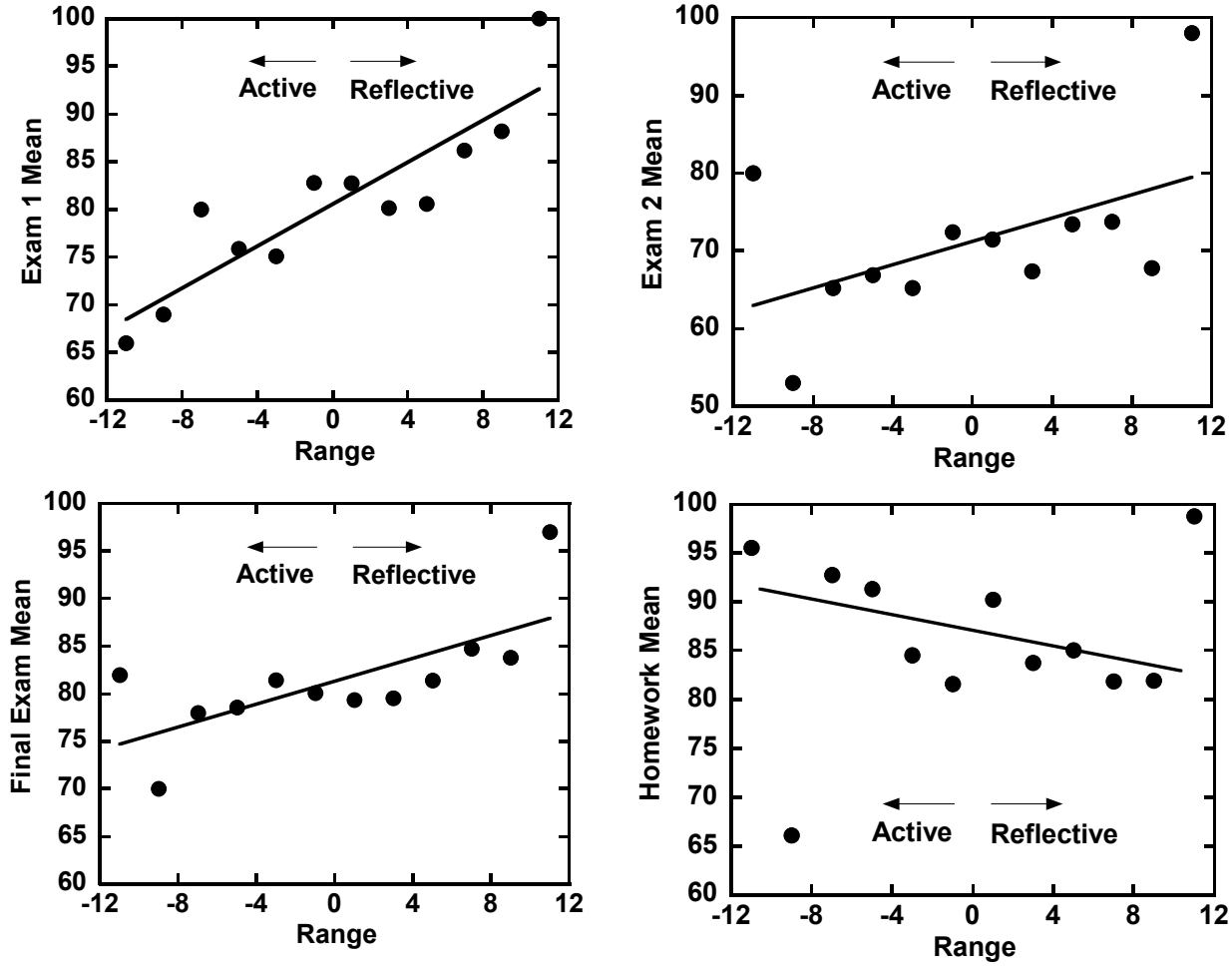

Figure 2: Plots of mean student performance versus values obtained on the Felder and Silverman learning styles assessment questionnaire for course examinations and cumulative homework score.

Perspectives of undergraduate students

The effects of the teaching internship on the students in the course need to be considered, where a high standard of teaching must be assured for the students. In general, the primary concerns from the student perspective are as listed below.

- Quality of teaching of student intern
- Continuity between team teaching segments
- Complexity of course structure due to multiple teachers

To assess student perception of the course and team teaching format, an evaluation was conducted in the middle of the semester using the procedure and evaluation form described in ref. 6. From the midterm student feedback session, the teaching intern gained valuable advice regarding teaching style and effect on the class. Example feedback for the student intern was to speak louder in class and to be more specific on homework problems. The team-teaching format was viewed as a positive experience by a majority of the students (approximately 75%), where consistent course notes and differing teaching styles made the course versatile in more interesting. A few students (about 10%) recommended that either one instructor should be used, or that the schedule should be evenly balanced between the faculty mentor and the teaching intern. In general, a team teaching format is believed to possess advantages including the ability to provide varied perspectives on a given subject to accommodate varied student learning styles, and potential to provide an increased level of expertise depending on the instructors involved. For this teaching internship, the graduate student had previously worked in the silicon microelectronics industry, and was able to share his direct experience in this technology area during the sections that he had taught. The students in the course appeared to have deepened their interest in class dialog where direct industry experiences were discussed. When designing a similar teaching internship, past or present research or work experience should be considered to maximize effectiveness.

At the conclusion of the course, a specialized course evaluation sheet was issued to solicit feedback from students on the team teaching format. Two of the questions/statements are listed in the following, where students were given the choice to respond with a number ranging from 1 (strongly disagree) to 5 (strongly agree).

1. I feel that the Team Teaching environment aided my learning in this class.
2. I feel that the Team Teaching environment was an impediment to my learning in this class.

The responses to statements 1 and 2 were a mean/standard deviation of 3.0/1.0 and 2.7/1.1, respectively. These results suggest that the students felt neutral about the enhancement in learning due to the team teaching format. There was also a slight tendency to disagree that the team teaching format detracted from learning in the class. Overall, these results suggest that students generally did not feel that there was a significant benefit nor a significant downside to the team teaching environment. This is viewed as positive feedback for teaching internships, where the primary goal is to provide opportunity for graduate students considering academic careers, without sacrificing the quality of classroom teaching. One opportunity for improvement is to seek ways of *enhancing* the experience of students through team teaching, where higher and lower values would be predicted for statements 1 and 2, respectively.

Mechanisms for accommodating teaching internships

Perhaps the primary impediment to implementing teaching internships such as described are in providing support for the graduate student and balancing efforts devoted to the teaching internship with demands on the graduate student's research. In general, there are four mechanisms to accommodate teaching internships:

- Support student through a fellowship
- Support student as a teaching assistant
- Support student as a research assistant
- Student receives academic credit for teaching internship (course or directed study)

Perhaps the most desirable mechanism is through a fellowship, where the student has significant freedom to pursue academic interests when supported by a fellowship. However, fellowships typically represent a small fraction of graduate student support. Teaching assistants are also desirable since their objective is to teach. However, most departments/colleges/universities will not have resources available to support additional "non-required" teaching assistants. Graduate students supported by research projects may also participate in a teaching internship, since research assistant positions are often 50% appointments. However, the research project would typically need to receive first priority, where the faculty mentor would have to accommodate any planned or unforeseen research obligations to maintain class continuity and quality. One alternative that may be considered, but to the best of our knowledge does not exist (at least in engineering programs), is the development of a course or directed study based on a teaching internship. Teaching internships are often required for degree programs in education, though are rarely available in science and engineering. Care must be taken to ensure that teaching by students supported by mechanisms other than a formal teaching appointment is allowed at the particular institution. At many institutions, graduate students are represented by a union or other organization that may require that all students in a teaching role be formally supported by a formal teaching appointment.

Conclusion

The faculty experience of a teaching internship in collaboration with a graduate student interested in an academic career is presented. The internship was found to be a valuable experience in providing a mechanism to prepare graduate students for academic careers and to inspire faculty members to improve their approach to teaching. Feedback from students suggest that the teaching internship provided a marginal benefit, though no degradation in the quality of teaching. The positive experience of this teaching internship suggest that such approaches would be beneficial for the faculty mentor, graduate student intern, and students in the course, and should be continued provided resources to support the intern may be allocated.

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