

Benefits of Team-Teaching for Doctoral Students Preparing for Academic Careers

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Abstract

Doctoral candidates preparing for an academic career face new challenges in light of a changing academic world. As a result, having the capacity and desire to become a good educator is an important factor in deciding whether to pursue an academic career. However, most research universities typically do not provide significant teaching experience for their doctoral students. In this paper, we present an exciting approach for doctoral candidates interested in academic careers. Specifically, we present our efforts and recommendations on team-teaching an undergraduate class along with a faculty member. Team-teaching is different than a standard teaching assistant appointment or a faculty mentoring program. The duties involve preparing and delivering lectures, preparing homework and exam materials, and interacting with students as peers with a faculty member, while being directly compared to the faculty member. Our experiences range from implementing new tools to enhance learning, to dealing with undergraduates to enhance the ability to supervise students. We believe that such an experience provides doctoral candidates with an opportunity to experience the full spectrum of activities and responsibilities involved with teaching a class. We also believe that team-teaching provides a means of personalized mentoring and critique by experienced faculty, hence preparing the future faculty for the challenging task of teaching and research.

1.0 Introduction

As doctoral students near the end of their studies and face the decision of whether to transition to a faculty status, questions and doubts arise about the difficulties of an academic career. Specifically, the question of what is involved in teaching is never really addressed while conducting research as a graduate student. The increasing competitiveness in academia and the shortage of sufficient academic positions are gradually forcing the importance of the education component to change even in traditionally research-oriented universities. Hence, as doctoral candidates preparing for academic careers, we must be prepared for the challenges of teaching even more than before. Yet, while we learn many important aspects of conducting competitive research as graduate research assistants, preparing doctoral students to become educators is still not a regular component of our doctoral studies. Even if some graduate students get teaching experience as Teaching Assistants, this does not provide a full picture of the teaching aspects of academia.

In this paper, we present a promising approach to preparing future engineering faculty for the difficult task of teaching while conducting research. Specifically, we propose that doctoral students team-teach a course with a faculty member as part of the preparation necessary for an

academic position. In this light, we discuss our personal experiences with team-teaching at The University of Texas at Austin, with two different case studies. Our main purpose is to answer crucial questions for doctoral students preparing to become engineering professors, and to encourage such students, as well as faculty members, to make team-teaching an essential component of the faculty preparation process. We believe that such an experience will not only help doctoral candidates be prepared for teaching as junior faculty while submitting numerous proposals and supervising research, but also help them with their decision on whether to embark on such a challenging career.

1.1 Team-Teaching with a Faculty Member

Team-teaching a course requires a commitment from the faculty member, the academia-track doctoral student, and the department. The idea is to experience the full spectrum of tasks and issues involved in teaching a course. Unlike the typical Teaching Assistantship, the doctoral student is responsible in all aspects of a class, including deciding on course material, lecturing, and preparing and grading homework and exams. There are a few examples of faculty mentoring programs where a graduate student teaches an entire course, with the supervision of a mentor, who provides guidance and critique to the doctoral students^{1,9}. These programs, while rare, are starting to attract a lot of attention among academia-track students and concerned faculty.

The idea of team-teaching is slightly different than faculty mentoring. Specifically, in team-teaching a course, the doctoral students get an opportunity to work along with the faculty member in addressing all aspects of the course, hence being treated as a peer, instead of having a mentor-student relationship. The main advantage of team-teaching is that both the student and the faculty get to lecture as equals, thereby achieving two goals: (1) providing the undergraduate students with two different views on the lecture topics; and, (2) enabling a direct comparison in teaching style and abilities between the faculty and the doctoral student. The first goal allows the undergraduate students to be exposed to two different sets of views and ideas, therefore giving them a different perspective on the topics. The second goal forces the doctoral student (AND the faculty member) to do an even better job, since the students will be comparing the two styles directly.

1.2 Crucial Questions to Answer

Our main goal in this team-teaching experience is to answer questions that we, as academic-track doctoral students, have about teaching in general. Clearly, juggling both quality teaching and quality research is a difficult task. The question remains as to whether it is possible to be a good educator and to conduct competitive research at the same time, especially at primarily research-oriented institutions. Does one have to sacrifice quality in either research or teaching and focus on one aspect or the other as an academician (e.g., work at teaching-only institutions)? What if both aspects were equally attractive?

In this light, we address the following questions that we believe are crucial factors in deciding on an academic career:

- 1) What is involved in teaching a course?
- 2) Are we good at teaching?
- 3) How do we balance teaching and research?
- 4) Is Academia really the career we want?

1.3 Outline of the Paper

In the following sections, we will answer these four questions by sharing our experiences in team-teaching. The first case study is in team-teaching an Introduction to Mechanical Engineering course, a required course for every incoming freshman. The second case study is in team-teaching a junior-level Mass Transfer Operations course in Chemical Engineering. This course is a requirement for all students in the department, and is an essential component of their curriculum. The subsections for each case will follow the set of questions posed above. To address each question, we will each present our views and experiences, and the results of our efforts.

2.0 Team-Teaching a Freshman-Level Introduction to Mechanical Engineering Course

The first case study is a freshmen-level introductory mechanical engineering course taught by Irem Y. Tumer, a doctoral student in Mechanical Engineering, along with faculty member Dr. Kristin L. Wood. A second section of this course was taught by Dr. Philip S. Schmidt, who has been responsible for this course for the past several years. The typical enrollment in this course is around 170 every semester. Due to the lack of a second large room, we broke the course into two sections, and Dr. Wood and I took a class of 40, as opposed to a class of 130 students in Dr. Schmidt's section.

The course involves teaching the basic concepts of mechanical engineering to first-year engineering students, such as design, modeling, reverse engineering, manufacturing, as well as teaching planning and team-work. The students commonly use this course to decide whether Mechanical Engineering is the major they want to declare. It is a two-credit course, and most freshmen take this course in addition to their first-year calculus, physics, and chemistry courses. As a result, a main concern in this class is to make it a fun experience for the students, while making sure that the students get a full flavor for what to expect in Mechanical Engineering.

2.1 Question #1: Am I ready for what is involved in teaching?

This first question addresses aspects of teaching that we are never exposed to as doctoral students. The following discussion addresses my experiences in issues such as preparing the course structure, preparing and delivering the lectures, assigning homework, and interacting with students.

2.1.1 Preparing the Course Structure and Topics

Preparing the course structure and lecture topics was one of the most rewarding aspects of teaching for me. The Introduction to Mechanical Engineering course has been traditionally taught as an overview of the topics covered in mechanical engineering. When I decided to teach this course, along with Dr. Wood, we met with Dr. Schmidt and borrowed his notes to examine the topics covered during the semester. The first thing I noticed was the lack of hands-on lectures. I am a strong believer in making the course entertaining so that the students will be captivated by the material, instead of the traditional lecturing styles^{3,6}. In particular, I believe that it is important to introduce alternative teaching styles in order to accommodate different learning styles^{5,7}. These teaching styles include the introduction of hands-on examples, tools, and activities during the lectures, and getting students to interact with the instructors. When I

mentioned this concern to Dr. Schmidt, his response was very positive and encouraging: not only did he give me the freedom to change the course structure as I wished, but he also expressed his desire to teach whatever changes I implemented.

Taking on the responsibility to reshape the course in the way I would have wanted it to be taught was very exciting. To implement the techniques addressing alternative teaching and learning styles, I included either a hands-on example, a team-activity, or an interactive question-answer session in every lecture. For example, I changed the course structure so that one of the first lectures would be a hands-on activity involving the mechanical dissection of a toy. The purpose of this lecture was two-fold: (1) to start the course with a "fun" mechanical example so that the students are excited about coming to the upcoming lectures; and, (2) to prepare the students for their long-term project in the course, both in terms of working in teams, and in terms of conducting and presenting a systematic study. Another example is the introduction of an in-class simulation of a toy rocket flight, after having developed a simple model of its trajectory. The students were asked to interpret the different responses of the model using the simulation tool and explain the outcomes. The list and content of the lectures can be found at my web site at <http://shimano.me.utexas.edu/~irem>.

The biggest reward of this experience was observing the students' response to the new lecture components I implemented. The introduction of hands-on activities and examples, as well as the interactive sessions during the lectures were met with great enthusiasm in our class of 40 students. The interaction level of the students gradually increased as they got more comfortable with expressing their opinions. The hands-on activities and examples were a great success in getting the students to think about questions they would have never considered otherwise. However, the implementation of such techniques in the larger classroom of 130 students was not as successful. This was my first exposure to considering the problems with large classrooms. As an undergraduate, I had often wondered by there weren't more interaction during such large lectures. The big lesson I learned is that it is crucial to break such a large class into different sections, especially when we are attempting to get the students excited about Mechanical Engineering. However, I do believe that there are ways to implement similar tools in larger classroom as well, and that more emphasis can be put on interactive sessions⁴.

2.1.2 Preparing and Delivering the Lectures

Preparing the lectures was a great experience for me in terms of deciding how much to present and where to break the course to include hands-on activities and interactive sessions. Each lecture was to be delivered by myself and Dr. Wood. In addition, Dr. Schmidt was to present the exact same lecture to his section. As a result, after preparation, I discussed each lecture with both faculty, so that they would be comfortable presenting the material. This was a very helpful exercise for me both in terms of understanding what is reasonable to present in a 50-minute lecture, and in terms of talking through my lectures before delivering them.

In our section, the lectures were delivered both by myself and Dr. Wood. This put a tremendous pressure on me, since the students got to compare my style to Dr. Wood's style directly. However, the team-style was also very valuable in terms watching the students respond to Dr. Wood's lecture. I benefited tremendously from the tactics he used to get the students to think during the lectures and interact with him, instead of letting them take notes. The pressure also helped me focus on becoming a better lecturer, both in terms of delivery and in terms of paying

attention to student response. Another advantage of the team-style was that it helped to break the lecture into two separate portions, therefore getting the students to break the monotony of the lecture, and pay more attention to the content⁷.

2.1.3 Preparing Homework Assignments

Assigning homework problems and projects was one of the most difficult aspects of teaching for me. As a graduate student who had never taught undergraduate students, I found that my expectations and standards were really high. As a result, I started the semester with assignments that I found very exciting, but was soon faced with the problem that I believe most first-year faculty must face: I overestimated how much work the students can handle. I learned that it is important to assess the expected difficulty level of a course and put it in perspective. The student expectations from a two-credit course were very different than mine were. As the semester advanced, I modified the original homework assignments so that most of the questions could be answered quickly, based on the lecture notes. This approach also helped in getting students to review the lecture notes, since they were told that the answers were in the notes.

2.1.4 Interacting with Students

Interacting with students in and out of the classroom was a very interesting experience, as well as one of the most important lessons that I learned from my semester of teaching. It was at first very difficult for me not to give in to the temptation to favor students who ask a lot of questions and show more interest than others. I soon realized that, being vocal in lectures was more an indication of personality, rather than ability. The other valuable lesson I learned was to refrain myself from expecting a certain performance level on homework and projects, based on my in-class assessment of certain students. I think it is a very easy trap to fall into, and I learned very quickly that students know this very well and they can sense when the instructor is impressed with them.

Establishing authority as an instructor was another interesting experience. My main concern was that students would look at me as their friend rather than their professor. I had to make a conscious effort to make them understand that I was the one preparing their lectures, assignments, and deciding on their grades. I had many useful discussions with Dr. Wood and Dr. Schmidt on how to establish respect and authority. I believe that this aspect of teaching was a crucial experience to go through at least once before being faced with it as a first-year faculty.

Answering complaints from students about their fellow students, especially when working in team projects, was another very challenging experience. Mechanical engineering has many courses where students are forced to work in teams. Unfortunately, the efforts to get each team member to take equal responsibility about their own part of the work only meet with limited success. I found that it was not easy for me to sympathize with the reasons students had for team conflicts. As a result, at first, I asked Dr. Wood to handle team problems, as I watched him deal with the teams. I learned a lot from this exercise, and towards the end of the semester, started practicing similar tactics in getting teams to work more effectively together.

2.2 Question #2: Am I any good at teaching?

One of the main reasons I wanted to go through this teaching experience was to prove to myself that I would be good at it, before deciding to become an educator. I knew that teaching and

research were the two things that I had a passion for as a career, but I still had self-doubts about my abilities to handle the teaching task effectively.

2.2.1 Lectures vs. Research Talks

One of the first doubts I had was in facing an audience of students as opposed to a typical technical audience that I face during my research talks. The experience was completely different, and in many ways, more difficult and challenging than delivering technical talks. I discovered that teaching involved thinking about every sentence and word you utter before your audience, since the students take every word as the absolute truth. In technical talks, you unknowingly rely on the fact that, if you say something incorrect or unclear, it will be brought to your attention and discussed on an equal basis. Students, however, believe every word the professor says, which is a great responsibility that I found myself enjoying tremendously. I found that I was very willing to make this important change in my talks and become a lecturer as opposed to a researcher.

2.2.2 Review and Feedback

The other doubt I had was the ability to convey the material in an effective manner to the students. To answer this doubt, I relied on Dr. Wood's assessment of my teaching style and quality. Dr. Wood and I discussed the good points vs. bad points of my performance after each lecture, which was very beneficial. In addition, we decided to get constant feedback from our students. Throughout the semester, we asked the students about the class and how it is advancing, and whether they see any problems, on an individual basis. In addition, we also conducted a mid-semester review of the course to get feedback from the students about the course and our performances. Unlike most of the end-of-semester reviews, the feedback from the students was very informative. I modified some key points about my teaching based on Dr. Wood's and the students' feedback. I recommend such reviews to be done periodically during the semester, since they achieve several goals: (1) pinpoint the problem areas in the lectures; (2) show the students that their opinion really matters; and, (3) help instructors get feedback on their personal teaching styles. The feedback I got from the students during the semester, as well as at the end of the semester, in addition to the feedback from Dr. Wood, helped me decide that I will in fact be a very effective educator.

2.3 Question #3: Can I balance teaching and research?

Another crucial question for me was whether quality teaching and research can co-exist. The decisions you make as a doctoral student in the interviewing stage are crucial, since they define the rest of your career. Specifically, academia-track graduate students have the choice between primarily-research and primarily-teaching universities. My goal is to work at a research institution where education is as important as research. I believe that this depends greatly upon your personal abilities and passions for both aspects of academia.

As a result, one of the issues I wanted to face, before deciding on an institution, was my effectiveness in teaching while conducting research. I could not afford to lack behind in my doctoral research while teaching this course. What I discovered throughout the semester is that it takes a lot of organization, planning, and self-discipline to carry out both tasks effectively. At the beginning of my teaching semester, I had a difficult time organizing my thoughts on research, since there were so many new things I wanted to implement in my lectures. I found myself constantly thinking about the course and how it can be improved. I quickly realized that, by

organizing my time better and allocating specific days of the week to teaching, and other days to research, I could focus on both teaching and research. As a junior faculty, I know I will have many more duties, such as proposal writing and supervising graduate research, in addition to teaching and conducting my own research. Consequently, I believe that it is crucial to face a lighter version of this problem before deciding on such a career.

2.4 Question #4: Is Academia Really the Career I Want?

Overall, the outcome of my teaching experience was very positive. I managed to answer all my questions and doubts about the career I have decided to pursue. I believe that teaching this course prepared me for the challenges that I will face as a junior faculty. The experience made me confident that I can handle teaching and research at the same time. As a result, I now strongly believe that team-teaching a course before graduating should be a requirement for those considering a career in academia.

3.0 Team-Teaching a Junior-Level Mass Transfer Operations Course in Chemical Engineering

The second case study was a junior-level chemical engineering course in mass transfer operations taught by Lia F. Arthur, a doctoral student in Chemical Engineering, along with faculty member Dr. R. Bruce Eldridge. This course is a required part of the curriculum and is normally taken during the end of the student's junior year. It deals primarily with mass transfer operations, including separation principles and column design. The course is also used as the student's introduction to computer process simulation which will be used extensively in the senior design course.

In contrast to Ms. Tumer's experience of team-teaching every lecture, Dr. Eldridge and I divided the semester into clear topic modules. We then decided on which modules I would be primarily responsible for. This arrangement was more to the liking of our department, which was concerned about a graduate student teaching an upper level required course. For the remainder of the course, I served as teaching assistant, and was therefore an integral part of the entire semester.

3.1 Question #1: Am I ready for what is involved in teaching?

My main motivation for team-teaching a course was to gain experience in teaching from the professors' point of view. I had already served as teaching assistant for quite a few classes, and therefore had experience in teaching and tutoring students in one-on-one and small group settings. Areas that I lacked experience in included overall course structure, preparing and delivering lectures, and homework and exam writing.

3.1.1 Developing Course Structure

As an integral part of the chemical engineering curriculum, the expected main topics of this course are well defined. Once Dr. Eldridge and I had divided the topics between ourselves, our main concern was deciding what information and which concepts would be covered under each topic. There are several concepts throughout the course, particularly concerning column design, that could just as well be covered under several different main topics. Together, we decided when each concept should be introduced, and what specific information and details would be

covered. Therefore, even though I was only officially responsible for a portion of the course, Dr. Eldridge included me in the overall course decisions.

3.1.2 Preparing and Delivering Lectures

Preparing and delivering lectures was an invaluable experience for me. I had my personal notes from taking equivalent classes as both an undergraduate and graduate student. I had also served as teaching assistant for this course for two prior semesters, and since I make it a practice to attend the lectures of classes that I'm assisting with, there were class notes from those semesters as well. In addition, Dr. Eldridge provided me with his personal lecture notes. Yet, even with essentially five sets of notes, preparing my lectures was a non-trivial task. I achieved a new level of understanding of material that had been seen for four previous semesters as I worked through the lectures for my topics.

Being responsible for individual topics allowed me the freedom to introduce the topic and present the information in whatever order and manner I chose. Every effort was made to organize my sections into clear and logical progressions and tie them into the flow of the other topics of the class. Dr. Eldridge was an invaluable guide while preparing my lectures, both in the "how to" as well as the "how much."

I wanted to make a special effort to help the students visualize the concepts we were presenting and understand them on a qualitative, as well as quantitative, basis. Dr. Eldridge has a reputation for excellent props to assist the students in visualizing concepts. I wanted to continue this tradition as well as incorporate some of my own ideas. Throughout the semester, we used the same props from module to module, reinforcing to the students that these processes are similar in many basic ways. These props ranged from simple two phase equilibrium examples to real-life column internals. I also tried to provide simplified visual aids to help in the qualitative understanding of the processes. For example, using colored marbles in several clear glass tubes showed qualitatively the process of fixed bed adsorption with or without mass transfer limitations.

I also wanted to explore some other innovative teaching techniques. For one of my topics, Instructional Objectives were handed out outlining exactly what information and details the students were expected to master during that module. The students responded positively by telling me that it was nice to know what key points they should be concentrating on^{8,10}. I also made an attempt to increase cooperative learning within the classroom, by having the students do small group work⁵. This was somewhat unsuccessful for several reasons. As I was new at implementing this technique, I had a difficult time finding activities that were hard enough to require groups, yet simple enough to do in a short amount of time. Also, the students had a difficult time accepting that I wanted them to actually interact in class. I think that if we had consistently asked them to interact in this manner throughout the semester, they would have gradually grown accustomed to the expectation, and my ability at choosing tasks would have improved.

The experience of delivering lectures is unlike any other. Dr. Eldridge was present in most of my lectures, though not all. At times I found it difficult to answer questions myself instead of referring them to Dr. Eldridge. However, I knew that it was necessary for me to attempt my best answer in order to maintain my position as the lecturer. This point was actually helped by Dr. Eldridge's absence from some of my lectures, as it was clear that I was, indeed, the current

instructor and not simply the teacher's assistant. Another difficult situation, as previously mentioned by Ms. Tumer, is the attention students pay to each and every word uttered by the teacher. I was not used to selecting my words quite so carefully and under the critical eyes of students. My "trial-by-fire" came when I failed to follow my carefully prepared notes during the development of an equation. The students quickly knew that what I had written was incorrect, and it was up to me to find the error before my credibility was lost. Dr. Eldridge, though in the classroom, allowed me to recover the situation myself. Though not enjoyable at the time, this was a worthwhile experience that proved to myself my ability to maintain composure in a dynamic classroom.

3.1.3 Homework and Exams

The preparation of homework and exams was also a new experience for me. Though accustomed to checking other professors problems for errors, and grading students completed work, I found out just how difficult it is to develop new problems. As with lecture notes, there were available many previous semesters worth of problem sets and exams. However, I very much wanted to develop new and exciting problems with realistic numbers and real world applications. What I discovered was that a large amount of time could be spent finding realistic problems that were still within the limits of what could be expected of the students. Another difficult task was creating exam problems that could be completed within exam time limits, yet would test the depth of the students' understanding. We wanted the exams to cover not only the students ability to apply the information they had learned, but their ability to analyze and extrapolate². Dr. Eldridge's tutelage in this matter was very much appreciated by both me and the students. I think it was also important that I graded both the homework and the exam problems that I was responsible for. This was vital feedback as to how well the problems were formulated and presented.

3.2 Question #2: Am I any good at teaching?

As I prepared for a possible academic career, it was important to me to gain at least some experience teaching. This would be an integral part of my new job description, as well as an activity that I consider with the highest regard. Would I be able to teach? Would I be able to deliver information in such a manner that student's learn? Would I be able to motivate? The feedback received from Dr. Eldridge and the students, both through formal evaluations and informal meetings, encourages me that I would succeed as a teacher.

3.2.1 Professor Feedback

As previously mentioned, Dr. Eldridge attended most of my lectures. He gave me instantaneous feedback on my presentation skills as well as how I presented the material and handled questions. This quick response allowed me to adjust my actions before the next lecture. Also, if there were any particular difficulties with students, it was encouraging to know when he shared them and have his suggestions on how to handle them.

3.2.2 Student Feedback

I received student feedback through formal written evaluations and talking to the students on an informal basis. The students appreciated the hands-on props and the effort expended to explain concepts qualitatively, as well as being given copies of the instructional objectives. Likewise, they also told me when I was covering information too quickly and were not hesitant to let me

know that they didn't understand something. Since I was also the teaching assistant for the course, I had frequent interaction with most of the students. I believe that the students' willingness to provide informal feedback was due to this somewhat casual relationship outside of class. They did not seem to mind that I was also in a position of partial authority concerning the class, homework, exams, and grades. The responses from written student evaluations at the end of the course were similar to the informal comments received during the semester.

3.3 Question #3: Can I balance teaching and research?

Balancing the time commitment between teaching and research is a clear concern for me. Unfortunately, by dividing the course into individual topic modules, I don't believe that I was able to experience a comparable situation to that of a faculty member. I clearly spent a substantial amount of time on the course during the weeks when I was the principal instructor. However during the remaining weeks, my research continued without too much distraction. I believe that Ms. Tumer's experience of team-teaching each lecture gives a better taste for the academic's perspective on this issue.

3.4 Question #4: Is Academia Really the Career I Want?

Beyond the questions dealing with my abilities to succeed in a teaching environment, I am also questioning whether or not to pursue a career in academia. My experiences as teaching assistant and this particular experience in team-teaching enforced my excitement and enjoyment in teaching. I'm convinced that whether I pursue a career in academia or industry, I will find opportunities to teach in a college setting. I do believe that team-teaching provided me with a much more realistic perspective than normally obtained in graduate school.

4.0 Conclusions

This paper summarizes the efforts of two academia-track doctoral students in addressing their questions about teaching a course as a first-year faculty member, while conducting research. Specifically, both students share their experiences in team-teaching a course with a faculty member. We believe that team-teaching is an invaluable and necessary experience before embarking on the challenging career of educating the engineers of the future, both through classes and through research. Furthermore, we believe that the questions addressed in this paper can be used as guidelines by doctoral students preparing for an academic career. Based on our experiences, we strongly recommend experiencing the teaching side of an otherwise research-oriented career. Aside from removing the element of surprise as a first-year faculty for those who have not taught before, we also think that the teaching experience will be very beneficial in securing the competitive tenure-track positions.

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