AC 2010-532: WORKING WITH AND MENTORING GRADUATE STUDENT INSTRUCTORS IN FIRST-YEAR ENGINEERING COURSES

Melissa Roberts, Michigan Technological University

Amber Kemppainen, Michigan Technological University

Gretchen Hein, Michigan Technological University

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Abstract

Michigan Tech University has a history of teaching first-year engineering courses. Annually, approximately 900 first-year engineering students learn basic engineering skills and concepts in the first-year engineering program. The program offers a two course sequence (ENG1101, Engineering Analysis and Problem Solving, followed by ENG1102, Engineering Modeling and Design) for students who are ready to take Calculus. For students taking Pre-Calculus, a three course sequence has been implemented (ENG1001, Engineering Problem Solving, ENG1100, Engineering Analysis, followed by ENG1102).

Each fall, approximately 13 sections of ENG1101, 5 sections of ENG1001 and 5 sections of ENG1102 are taught in addition to several service courses. With this quantity of courses and sections, the department occasionally seeks part-time faculty to fill the instructional load. While some of the positions are filled with engineers within the community who have advanced engineering degrees, others are filled by graduate students interested in teaching college-level courses. This paper will focus on the latter case where graduate students are mentored by departmental faculty to learn teaching skills and to implement change within the department.

The mentoring program at our university is informal and involves pairing a graduate student with a faculty member who is teaching the same course. The faculty and graduate student work closely together to develop learning materials, design exercises, and exams. Typically, the graduate student offers new ideas and learning exercises for the classroom that add new energy to the course. The faculty member provides guidance regarding the design of exam materials and what works well in the classroom.

Introduction

Michigan Tech University's first-year engineering program began in the fall of 2000. Within this program, entering students learn basic engineering and technical skills that are applicable to their engineering and professional careers. Through the completion of the first-year engineering courses, students gain, develop and improve their skills in:

- Teamwork
- Written and oral technical communication
- Problem solving
- Engineering design
- Engineering modeling (numerical, graphical, 3-D)
- Engineering analysis (data collection, analysis, description)
- Computer software
- Interpersonal communication
- Basic university skills

The path students take to complete the first-year engineering program is dependent upon their math readiness. The majority of the first-year engineering students are calculus-ready. Approximately 25% of the entering class are enrolled in pre-calculus with a few students who are enrolled in preparatory math. Students who are calculus-ready take the traditional track for first-year engineering students (ENG1101 followed by ENG1102). Students who are in Pre-Calculus are on an alternate path (ENG1001, ENG1100 and ENG1102). This path was implemented so that students can take an engineering course while they are in Pre-Calculus. This structure has improved retention of students who are not ready for Calculus.¹ Students who start in Pre-Calculus take three semesters to complete the first-year engineering program, while students on the calculus-ready path are done in two semesters.

Each year, there are multiple sections of all courses within the first-year engineering program. Table 1 shows the typical annual course load for the department which has 8 full-time lecturers. Faculty teach an introductory spatial visualization course for students lacking these skills (ENG1002), and service courses in AutoCAD (ENG1003), Thermodynamics/Fluid Mechanics (ENG3200/3507) and Statics/Mechanics of Materials (ENG2120). Furthermore, departmental faculty advise Enterprises (student teams that operate like a company to solve real-world problems) and are working on engineering educational research and program development. With these responsibilities, the faculty cannot meet the teaching load requirements.

Table 1. Michigan Tech's First-Year Engineering and Service Course Distribution

First-Year Program Core Courses				
Course	Fall	Spring	Summer	Credits
ENG1001	5	0	0	2
ENG1002	4	1	0	1
ENG1101	13	1	1	3
ENG1100	0	3	0	2
ENG1102	5	12	1	3
Service Courses				
ENG1003	0	1	0	1
ENG2120	1	2	1	4
ENG3200	1	2	0	4
ENG3507	0	1	0	2
<u>Enterprise Advising/Instruction</u> : Robotics, SAE Baja, Automotive Systems				

To meet the instructional load, part-time faculty are sought. Some of the positions are filled by engineers within the community who have advanced engineering degrees, while others are filled with graduate students who are interested in teaching at the college level. This paper will focus on the latter case where graduate students are mentored by departmental faculty to learn teaching skills and to implement change within the department.

Why Mentor Graduate Student Instructors?

Many graduate students in STEM fields (Science, Technology, Engineering, and Math) are interested in developing their teaching skills as well as their skills in research. At this point in

their career path, they may be interested in or curious about remaining in academia. For many graduate students, the prospect of fulfilling the teaching requirements of professors could be daunting and may even discourage them from remaining in a university setting. To determine if teaching truly interests them, the students may elect to be a graduate teaching assistant (GTA) or, like in the Department of Engineering Fundamentals (EF), they may teach a section of a first-year engineering course. The practice of the Engineering Fundamentals department is to pair a graduate student with a faculty mentor to assist them with things such as lesson planning, student ethics, and grading policies. Recently, this program has been evaluated in order to better understand the impact and future directions of EF graduate student mentoring. Additionally, the approach of the EF mentoring program has been compared to its contemporaries at other universities.

Some universities have graduate courses specifically aimed at teaching techniques in higher education for STEM fields. The University of Washington has developed a 2 credit graduate level course where students study active learning techniques and how to integrate them with traditional teaching methods. Graduate students taking this course either had some teaching experience as lecturers or GTAs.²

At the University of Cincinnati, doctoral students receive mentoring and teaching instruction as part of a multi-course sequence. Students teach part or all of a course under the guidance of a mentor. The purpose of this program is to give graduate students an idea of what teaching and research responsibilities they can expect along with a basic set of teaching skills they can apply to their individual careers.³ This program is similar to the approach used at the University of Michigan where courses are team-taught by a faculty member and a graduate student.⁴

Since 1998, Michigan State University has offered a College Teaching Certificate for engineering graduate students. The program introduces future faculty to the theory and practice of educational methods. Graduate students also work with a mentor to develop teaching materials for a specific course that they then teach. The mentor evaluates the students' teaching delivery and materials throughout the course. The student gains insight into what methods work in a given course and what does not. This in turn allows the student to learn what materials and methods would be transferable to other courses.⁵

Another avenue for aspiring teachers is the National Science Foundation (NSF) funded project called the Engineering Teaching Portfolio Program (ETPP) which has been implemented at six universities across the nation. The program is set up as a multipart workshop in which participants will complete a draft teaching portfolio, draft teaching materials, and a teaching philosophy. Other activities of the ETPP include a forum to discuss teaching issues as well as a developed peer network.⁶

Previously mentioned graduate level programs have been formal course offerings or workshops, often with an audience that were self-selected and highly interested in higher education.⁷ This, however, is not the only scenario for graduate students interested in pursuing a professorship in STEM fields. The opportunity for graduate students to develop teaching philosophy and pedagogy outside of coursework is much less available. Furthermore, experience in engineering education is often not a requirement for employment of professors in STEM fields because of the

emphasis on research and publication success. A survey by the National Academies Press indicates that many faculty members “receive little preparation for their teaching roles”.^{6,8} As a result, new faculty enter the university teaching environment lacking experience. To counter this, a larger prospective teaching audience needs to be reached within the graduate student population. This could be accomplished by adopting the approach described below in all departments utilizing graduate students as teaching assistants and lecturers.

EF Mentoring Overview

Unlike those mentioned previously, the EF program is more of an informal approach centered on the pairing of an experienced faculty member and a graduate student with a desire to teach. The program’s genesis was an evolution based byproduct of the department’s need for temporary engineering instructors. Other differences between the EF program and others previously described are:

- All graduates are actively teaching and developing course materials that will be directly disseminated to the students
- Graduates have autonomy over their classroom (not team-teaching their class with an advisor)
- Graduates do not receive course credit for participation in the program
- Graduates do receive compensation commensurate with their teaching commitments

The program is described in detail below, as well as a dialog with a previous mentee/mentor pair.

EF Mentoring Structure

The mentoring program within Engineering Fundamentals has two possible structures: 1) Masters students who typically teach for one or two semesters and 2) Doctoral students who teach for multiple semesters throughout their course of study. Typically, the Masters students, as expected, receive more guidance than the Doctoral students and have less responsibility. Prior to teaching in the department, the graduate students are paired with a mentor who has the primary responsibility for the basic course material, class projects, exam creation and course logistics. In past years there has been several graduate students working in the department. Due to the success of past participants and the increased need for lecturers, this number increased for the 2009-2010 school year. For the student instructors, the mentoring activities were similar and included:

- Meetings (weekly or varying frequency depending on mentor)
- Overview of departmental policies
- Review of course material
- Review and assessment of skills on applicable software (NX, Excel, VBA, MATLAB)
- Development of solution manuals and grading rubrics for the design project and homework prior to assigning them in class
- Development and coordination of Lab Practicals for different software applications
- Development of exam questions under the guidance of the mentor

The weekly meetings are important for developing the mentor-mentee relationship and a productive way to disseminate course material. At the first meeting, the mentor explains the

departmental policies regarding exams, homework assignments, academic integrity and other common issues.

Prior to the weekly meetings, the mentor and mentee review the material for the following week. It is very important, for the mentees especially, to review the material beforehand so any questions or concerns can be identified. Interestingly, many of the questions the graduate instructors had would be similar to problems students encounter in class. Since the mentee is a fresh pair of eyes, they could identify when course materials were confusing or when instructions were omitted. Also, these new instructors often fall prey to easily made mistakes. For example, in preparation for her first lecture with VBA in excel, a new instructor discovered that she could not get her VBA code to run. Frustrated, and a little embarrassed, she met with her mentor who knew exactly what the problem was and showed her how to fix it. The mentee, now prepared, was not surprised when many of her students made the same mistake and she was able to impart the same advice she was given by her mentor.

Another important component of the weekly meetings is the development of grading rubrics for the homework and projects. This helps maintain continuity between sections as well as teaches the mentee how to develop effective and consistent grading policies. The mentee response to these mentoring activities will be discussed in the following dialog.

Dialog with Mentee, Ms. Melissa Roberts

Ms. Roberts is a PhD Candidate in Biomedical Engineering who started teaching in the EF department in Fall 2006. Her tenure with the department has spanned four years (much longer than the average graduate student) and she was the first graduate mentee. Therefore, her insights on the mentoring program are significant to its evolution and continued improvement. The following is a conversation with Ms. Roberts on the mentoring she received.

Question: What benefits did you receive from the mentor/ mentee relationship?

Confidence in the classroom was a key benefit of the mentorship. At first, the thought of teaching an engineering course for 30-60 first-year students was nerve wracking. The weekly meetings helped counter the nerves because we were able to go through each lecture with a fine-tooth comb. My mentor would point out which topics students often had problems comprehending as well as the common questions students had about the particular topic. This helped to keep the class on track because I could provide a concise answer and move on instead of faltering and telling the class I would get back to them.

Another benefit was the learning tools my mentor used in the classroom. I mimicked her approach when teaching mathematical formulas and calculations by allowing class time for students to practice calculations individually and in groups. I also followed her advice and walked around the room to check student answers. At first I assumed that if I gave students class time to work on something they would do it, but soon found out that some students would get distracted or give up completely. Checking the students work increased student diligence and

allowed me to give some personal attention to those that were having trouble with the subject matter. This approach helped increase student success on homework and helped me understand my student's cognitive process.

Question: Did you encounter any problems in the classroom and if so, did your mentor help you remedy these problems?

The biggest classroom problem I faced was how to deal with student behavior in and out of the classroom. My mentor always had good insight into stressful situations like poor grades, prolonged student illness or tragedy, academic integrity violations, etc. I would have not known how to tackle these things without advice from my mentor. What do you do if your student has not come to class in two weeks? My first instinct was to do nothing; after all, this is college! But my mentor reminded me that these were first-year students and student success was our top priority and she suggested emailing the student and trying to arrange a meeting to figure out the problem.

Another big student issue was dealing with student's interpersonal problems. This course relies heavily on teamwork which can be tumultuous if students are having trouble communicating with each other. My mentor stressed that it is important not to allow a confrontational environment and she helped me develop a dialog that would help students move past the blame game. I would organize team meetings outside of class where we identified the problems the students were having with each other, how we could solve these problems, and then we would develop a plan to move forward.

Question: Which parts of the mentoring program would you preserve in future iterations of the program?

I felt that the weekly meetings were essential for the first semester I taught in the department and meetings in subsequent semesters should stay on an as needed basis. I also appreciated that course material was created in collaborative efforts and my suggestions were always welcome. This type of positive reinforcement helped me gain confidence in my teaching methods and future ability to create course curricula.

Question: Which parts of the program would you change in future iterations of the program?

I think the program would benefit from some qualitative and quantitative analysis. The current student evaluations that are used at the university do not give enough feedback on the teaching methods used in the course. An additional survey that targets this area would help graduate students improve and perhaps be a measure of the usefulness of the mentoring. Mentees should also have an exit interview to discuss the strengths and drawbacks not only of the mentoring program but of the course instruction itself.

Dialog with Mentor, Dr. Gretchen Hein

Dr. Hein is a Senior Lecturer in the EF Department and has served as the primary mentor for several of the graduate student instructors. The following is a conversation with Dr. Hein on serving as a mentor:

Question: What benefits did the graduate mentees bring to the EF department?

From a personal standpoint, it was a great experience working with the next generation of scientists and scholars. Being able to provide them with teaching insights very rewarding and I am excited to see them establish their careers in academia.

From a professional standpoint, the graduate students' feedback on the EF courses has led to global course improvements. Much of it owes to the unique perspective the graduate mentees have as both a teacher and student. For example, one of the graduates noticed that ESL (English as a second language) students sometimes performed poorly on specific exam questions. The student suggested modifying exam questions to allow for ESL students to be as successful as their counterparts by minimizing confusing English terminology, words that have dual meanings, and popular American expressions. Now this has become common practice among all Engineering Fundamentals courses.

Graduate mentees have also helped develop course projects. After seeing a disappointing research poster forum, a graduate student helped develop a project to cap off the section on ethics in engineering. We continue to do this project and have outside judges (professors from other departments) come in to judge the posters in a mini poster competition. The purpose of this assignment was two-fold: 1) have the students become familiar with engineering ethics case studies by outlining an ethical engineering failure in poster format and 2) allow the students to be introduced to the concept of communicating through poster design since it is a requirement of their senior design project.

Another benefit of working with graduate students is that they are conducting novel engineering research and are excited to incorporate that into their course. While students were learning about computer modeling using MATLAB, one of our graduate mentees invited a guest speaker to demonstrate a MATLAB program estimated the electrical conductivity in layers of the skin. This helped the students understand the practical applications of using a mathematical model.

The students have also directly benefited from the graduate mentees knowledge of research opportunities on campus. One graduate mentee allowed the EF students to tour some of the research laboratories in her department. She also introduced her EF students to undergraduates who have performed cutting edge research, publish journal articles, and present at conferences around the nation. This

demonstrated that even young students can contribute to the scientific community in astounding ways. One of the EF students went on to join a lab and is currently conducting human clinical trials and will have two publications by the time she graduates.

Question: What are some of the greatest challenges of mentoring graduate student instructors?

Most graduate students are not only teaching, but taking courses *and* conducting research. This creates challenges in scheduling meetings and course activities that have to occur outside of class time, and may also interfere with timely completion of common course materials. Graduate students have an enormous amount of energy and truly enjoy teaching and working with students, however, they have a tendency to over commit themselves. For example, over the course of working with approximately 10 different graduate students, each has stated that he/she can complete something only to realize that they have also committed to doing another activity related to their graduate work. When this occurred, the student and I would step back and either change the deadline, exchange duties, or I would complete the task.

Most of the graduate students teach in EF for one semester. There are very few who are like the author and teach for multiple semesters. This translates to working with and advising new instructors every semester a course is taught. For anyone who has taught courses, the first semester is the most difficult, especially if, like these graduate students, the department is new for him/her too. The students need assistance not only with course material (creating homework assignments, exams and class materials) but with working with their teaching assistant, and learning and adhering to departmental policies. For the faculty mentor, this assistance requires a substantial time commitment. On the plus side, helping graduate students learn about departmental policies has changed how EF does some things by introducing measures in course consistency. For the first-year courses, common exams are used in multiple sections of a given course. Many of the homework assignments are common between sections, along with lab practicals where students demonstrate their competency with different software packages.

When comparing the benefits and challenges of working with graduate student instructors, the benefits have greatly outweighed the challenges. These motivated and active individuals have had the opportunity to investigate their interest in university teaching. Some have found it rewarding and have continued to teach as graduate students and later as faculty members. Others have decided to pursue other interests. As a faculty member, it is the exploration and the realization the graduate students come to that is the important part of the experience, not the challenges the mentor encountered.

Continued Professional Development for Mentee

Just as with undergraduate education, the opportunities outside the classroom offer breadth to the academic experience. Because a career in academia often comprises more than student instruction, graduate student mentees are encouraged to look for opportunities for professional

development: working on publications, educational research and grants, etc. These avenues continue to offer opportunities to expand the mentor/mentee relationship.

In the summer of 2009, one of the graduate mentees (Ms. Melissa Roberts) was asked to help develop a biomechanics module as part of an NSF CCLI Phase I grant submitted by faculty Amber Kemppainen and Dr. Gretchen Hein (DUE-0836861).⁹ The biomechanics module is one of three design modules being developed as part of this grant. All projects have engineering activities that include a MATLAB Mathematical Model, design/model/build sequence, spreadsheet analyses and technical communication of their activities. In this module, students develop a prosthetic limb over the course of the semester. They use virtual analysis techniques as well as physically build the prosthetic and test it with a force plate.

With her familiarity with the EF Department curriculum, and her background in biomedical engineering, Ms. Roberts was an ideal candidate for this endeavor. Since she had three years of teaching experience, it was important for her to have autonomy on the project instead of being micromanaged. Her mentors encouraged this autonomy, yet had an open door policy for Ms. Roberts to share ideas and receive guidance when needed. Ms. Roberts was responsible for the development of the lectures, class activities, project description, deliverables and example MATLAB code. During the initial stages, she met with both faculty to determine the goals and scope of the project. Together they developed a timeline with project completion goals throughout the summer. Ms. Roberts teamed up with an interested first-year engineering student to ensure that each project deliverable was successful and within the knowledge base of the target audience. The module was implemented successfully in the Fall of 2010 as a pilot program and will continue to be available for use in EF courses.

Ms. Robert's participation in these opportunities outside traditional instruction helped her gain valuable skills that she can employ in her future career in academia. In addition to her years of teaching, she participated in writing a successful grant, developing a hands-on engineering curriculum, and implementing the curriculum. This knowledge of the fundamentals of academia will ensure that she is prepared to begin her career as a PhD.

Analysis

Since the program developed spontaneously as a need to prepare new graduate instructors for the classroom, little focus was put into a formal analysis of the mentoring process. Therefore, to evaluate this program further, we turned to published literature on the analysis of mentoring programs. While there have been some documented benefits of an informal, spontaneous mentoring program such as the one described here, in general a more organized approach is desirable.¹⁰ One publication lists a series of dimensions suggested for mentoring of new faculty and graduate teaching assistants.¹¹ According to this article, GTAs should meet regularly, show reciprocity in communication, and comply with the mentoring program expectations. All three of these have been accomplished in the EF mentoring program thus far. Furthermore, the article lists dimensions to be achieved by new faculty, many of which this mentoring program accomplishes with its graduate instructors. For example, the article lists "mentee shows interest and competence" which was exhibited by the Ms. Roberts as she expanded her involvement with the EF department by collaborating on grants and publications.

Ms. Roberts also allowed us to compile the student comments from her semester evaluations spanning the past four years. Just like full-time lecturers, students evaluated their graduate instructors at the end of each semester. As is campus policy, if these ratings are low, department chairs are notified. However, this has not happened with any of the graduate instructors in the EF department. Some of the feedback from the write-in questions of the semester evaluations is compiled below.

Question 1: “As I, the instructor, prepare to teach this class again, what aspect(s) of this course should I preserve that effectively furthered learning?”

Sampling of Student Responses:

- “This class has a friendly and open classroom atmosphere [that] helps students relax around the professor and ask necessary questions.”
- “You are always enthusiastic about what you teach, even if it is really boring material. You also make time to help students whenever needed. You are also really easy to talk to and can always offer help when needed.”
- “I thought she was a very good teacher mostly because I wanted to come to class, she made ever day enjoyable and I want to take ENG1102 with her. She was also very helpful and [dealt] with problems very well.”
- “She is easy to approach and good at communication.”
- “It helps a lot when the teacher is excited about the material. Keep it up.”
- “There was a fair amount of homework, and it was all relevant to our class discussion.”
- “The assignments were really helpful.”
- “Interactive teaching and accessible outside of class were positives.”
- “Very enthusiastic, gives good details about info, is always willing to help. Good time management.”

Question 2: “What aspect(s) of this course should I change to improve learning?”

Sampling of Student Responses:

- “Less homework, it’s all busy work.”
- “Make sure you clarify when things are due and remind students when long term things are due as the date approaches.”
- “Spend more time on a few [subjects]. I understand we must cover a lot of material but we had way too much homework!”
- “More time given to complete in class activity.”
- “Go over the lectures a little slower.”
- “Sometimes there are ‘assumed knowledge’ issues wherein instruction is vague or relies on previous knowledge we do not have.”

Some of the critiques are not possible for Ms. Roberts to change (the amount of homework or how many subjects are taught), but she quickly consulted her mentor and other faculty in the department to decide how to handle the other items. After surveying the faculty, she came up with a system of posting homework due dates online which she employed in subsequent semesters. To address the comments about going through things a bit slower, she started pacing

herself by monitoring the students (were they frantically trying to write? Or are their eyes glazed over?). Finally, to aid students whose background knowledge (usually in math) was weak, her mentor suggested supplemental reading and examples from their math textbooks.

Future Directions

From the documentation and subsequent analysis of the previous mentees, the authors include a series of recommendations to improve upon the mentoring program in future years. In general, the mentors agree that a more structured mentoring program needs to be in place for the department if external instructors continue to be required. The overview of the current EF program previously discussed is a good step in this direction, but some suggestions from the current mentors and mentees follow.

Recommendations from the Mentors:

- A weekly mentoring meeting needs to be set-up with the intent that the mentor and mentee meet minimally twice a month or more as the course material dictates.
- There needs to be a commitment on the part of both the mentor and mentee so that each person is completely prepared for this meeting.
- The responsibilities of the course (lectures, exams questions, activities) need to be divided between the mentor and mentee so that each party is accountable for some aspect of the course.
- A survey should be conducted to analyze the interactions between the mentor and mentee. This could be modeled after a faculty peer mentoring program survey published by the Journal of Higher Education in 1991 which included 29 ideal mentoring functions.¹² Some examples of what was included on the survey include intellectual guidance, constructive feedback, and information on formal and informal expectations and advice about people.
- A mentee should be observed during a lecture at the beginning of the semester to evaluate instructor habits and suggest improvements. A second observed lecture at the end of the course could be used to gauge the progress made over the semester.
- A third party should conduct exit interviews with outgoing graduate students to discuss the problems they faced with the implementation of the material as well as suggestions for improving the curriculum.

Recommendations from the Mentees:

- The mentor should assist mentees with future job preparations such as developing their curriculum vitae and portfolio as well as expanding their network.
- The department should include mentees in professional development including departmental activities, campus wide events, or off-campus programs.
- A continuing effort should be made to promote collaboration between the mentor and mentee while allowing the mentee to maintain autonomy in the classroom. This sense of ownership is a strong motivation to excel.
- The department should develop an exit interview or survey for mentees (anonymous if possible) to assess the relationship between the mentee and mentor, as well as the department as a whole.

Conclusions

The Michigan Tech first-year engineering program has developed a mentoring program for graduate student instructors. This informal program helps graduate students determine if they wish to pursue teaching and/or research positions upon graduation. The graduate student instructors fill an important gap in the department. They work with faculty to improve the courses, they ask probing questions about course material and policies to improve the overall program, and they teach sections of the courses to prevent the faculty from having a teaching overload.

This program is evolving from a spontaneous effort into a more structured program. Suggestions from mentors include evaluating the current process and expanding the commitment of mentors to their mentee with regard to weekly meetings. Mentees have responded well to the informal mentoring style and many of them have prolonged relationships with the first-year engineering program. Mentees agree that a structured mentoring environment would be beneficial, but wish to conserve their autonomy in the classroom.

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