Developing Interactive Teaching Strategies for Electrical Engineering Faculty

Dr. Margret Hjalmarson, George Mason University
Prof. Jill K Nelson, George Mason University

Jill Nelson is an associate professor in the Department of Electrical and Computer Engineering at George Mason University. She earned a BS in Electrical Engineering and a BA in Economics from Rice University in 1998. She attended the University of Illinois at Urbana-Champaign for graduate study, earning an MS and PhD in Electrical Engineering in 2001 and 2005, respectively. Dr. Nelson's research focus is in statistical signal processing, specifically detection and estimation for applications in target tracking and physical layer communications. Her work on target detection and tracking is funded by the Office of Naval Research. Dr. Nelson is a 2010 recipient of the NSF CAREER Award. She is a member of Phi Beta Kappa, Tau Beta Pi, Eta Kappa Nu, and the IEEE Signal Processing, Communications, and Education Societies.

Dr. Lisa G. Huettel, Duke University

Lisa G. Huettel is an Associate Professor of the Practice in the Department of Electrical and Computer Engineering at Duke University, where she also serves as Associate Chair and Director of Undergraduate Studies for the department. She received a BS degree in Engineering Science from Harvard University and earned her MS and Ph.D. degrees in Electrical Engineering from Duke University. Her research interests are focused on engineering education, curriculum and laboratory development, and applications of statistical signal processing.

Dr. Wayne T. Padgett, Rose-Hulman Institute of Technology
Prof. Kathleen E. Wage, George Mason University
Prof. John R. Buck, University of Massachusetts, Dartmouth

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Overview

The goal of this project is to develop a model for faculty collaboration designed to broaden the use of innovative practices in engineering classrooms. A recent recommendation from the *Innovation with Impact* report called for increasing faculty awareness about effective teaching innovations as well increasing engagement in engineering courses (Jamieson & Lohmann, 2012). The focus of this research study is on how small, long-term faculty groups can be used as a model to encourage such innovations and improvements in teaching. In addition to developing a faculty teaching development process, the project also involves the creation of sharable resources for innovative teaching. While there are many general resources for teaching, we seek to create resources specifically for electrical and computer engineering faculty to address the technical considerations and content of their courses. We used a process wherein each member of a faculty development group wrote a two-page memo about a teaching practice they had used. Included in the memo are the challenges, the logistical questions (e.g., time required), and assessment approaches. A group of experienced electrical and computer engineering faculty was formed to pilot the long-term development group model, and the group met monthly throughout the first year of the project. Each group member used an innovative strategy in his/her classroom and developed a two-page memo describing the implementation and his/her experience. We asked that the strategies focus on encouraging interaction in the classroom or engaging students in the content more deeply (i.e., anything that was not a lecture or typical homework). Deliverables from this phase of the project include both a collection of two-page memos describing classroom innovations in the context of signals and systems, as well as characteristics of faculty development groups and the topics instructors found most important to discuss in meetings with the group. Based on data collected in this phase, we provide recommendations about how to structure faculty groups to facilitate discussions about teaching.

Background

The project draws on what we know and understand about accomplishing teacher development at the K-12 level. School-based models that are grounded in teachers' needs, questions, and daily work have shown to be more effective at long-term change than isolated workshops or seminars (e.g., Loucks-Horsley, Stiles, Mundry, Love & Hewson, 2010). One example of school-based professional development for teaching are design-based or product-based processes. Design-based models for professional development of K-12 teachers focus on how teachers design products or tools for their classrooms with the goal of some change or improvement to their teaching and to students' learning (Author, 2004; Zawojewski, Chamberlin, Hjalmarson, & Lewis, 2008). The theory for this kind of professional development is that instructors are developing tools they personally find useful, thereby increasing their buy-in to the process because they understand the need for the tools. A second aspect is that the change process is ongoing and incremental. One reason that attempts to change instruction are unsuccessful is because too much is attempted too soon. A second reason is that one-time workshops or sessions are not generally effective in helping institute long-term change for faculty or K-12 teachers. This is because such one-time interventions do not provide instructors with the support they need to handle the ongoing challenges inherent in more interactive teaching. The final aspect of the professional development model is that the tools developed should be content driven. Hence, the participants are electrical engineering faculty describing the strategies they use to other electrical engineering faculty. One challenge in teaching reform is that general pedagogical "best practices" can be difficult for faculty to translate into their own discipline. Something that may work in a humanities classroom may need to be interpreted differently in an engineering classroom. We have attempted to bridge that gap by specifically asking the participants to write descriptions of their strategies with other engineering faculty in mind as an audience.

We housed the tools under the broad objective of formative assessment because it was a practice many of the participating instructors were attempting already and because it includes a variety of teaching strategies and learning objectives that are relevant to engineering education. Formative assessment, broadly, is any strategy which is intended to both help students learn the material as they are assessed and provide feedback to the instructor that can be used to inform future instruction (either immediately or at a later class session). A second purpose of formative assessment is to create a more engaging and participatory learning environment where students shift from passively listening to lectures and taking notes (or possibly asking questions) to working on problems immediately after the explanation of concepts or reflecting about what they have learned. Formative assessment tools should communicate to students what material or concepts are most important. Often these concepts are also the most difficult for students to grasp or are connected to difficult procedures and processes.

Methods

The participants in the year-one faculty development group were electrical and computer engineering professors with a signals and systems teaching focus. Members were selected based on their experience in implementing interactive teaching practices. Each member focused on a single formative assessment technique that they were using in their classes and wrote a two-page memo describing their chosen assessment technique as if they were explaining it to a colleague who wanted to try it. The memos were designed to be content-driven, i.e., to account for specific considerations for electrical engineering courses. We gave the following list of questions as a template for writing the memo (using writing about in-class problems as an example). As an example, figure 1 shows responses to the first three questions for reading summaries.

- What are conceptual in-class problems?
- Why should I use them? (How are they useful for the students? How are they useful to the instructor?)
- What is an example (or two) of a conceptual in-class problem?
- How do these problems fit into my class? How long will they take?
- For which topics should I assign conceptual in-class problems?
- How should I grade these problems? *Should* I grade these problems?

- What pitfalls do I need to avoid?
- What do I need to explain to my students about this new classroom activity?
- Should I do these problems in groups? How big? Who chooses them?

What are class summaries?
Class summaries are 1-page documents that students prepare after a lecture to summarize the key points. The 1-page summary is a slide (hand-written or computer-generated) suitable for display via a document camera or computer projector. At the next lecture, one student is selected at random to present his/her summary to the class. If the summaries are to be used for a grade, all students will turn in their summary.

Why should I use them?
Summaries encourage students to review material between classes, thereby forcing them to keep up with the class. In addition they encourage students to organize the material and see the big picture. Summaries are useful to the professor because they provide an indication of how well the class absorbed the material from the last lecture and offer an opportunity to solicit and answer questions at the beginning of class.

How do summaries fit into my class? How long will these activities take?
The presentation of a summary by a randomly chosen student at the beginning of class should take 5 minutes or less. The question/answer that follows the summary should take 5-7 minutes. (This may depend somewhat on the length of the class. Classes that meet once per week for 150 mins might require longer for the summary/questions than classes that meet twice per week for 75 mins/class.)

Figure 1: Excerpt of responses to a two-page summary about reading summaries

We held one in-person, daylong workshop with the group, followed by monthly conference calls throughout the semester as the faculty continued to revise their memos. Detailed notes were taken at all meetings (similar to a transcript). Qualitative coding of the results for common themes and considerations was used to describe the memos (Strauss & Corbin, 1998). In year two of the study, the members of the initial faculty development group created teaching-focused groups at their own institutions; the members of the year-two groups included faculty from engineering and the sciences. Data from year two is still under analysis and only preliminary recommendations are given here.

Recommendations from Year One

One of our goals is to understand what types of innovative strategies faculty found attractive and were willing to try in their classrooms, as this helps us determine which strategies are likely to be broadly adopted. In addition, via the two-page memos, we gain a better understanding of why faculty were interested in certain types of strategies and what the challenges and affordances of those strategies were. This information is useful to engineering educators who are interested in facilitating a long-term development group and would like to know what questions and concerns participants might have. The results we present here are two-fold: (1) a summary of the strategies employed and discussed by faculty development team members, and (2) a collection of common concerns and discussion topics across the various strategies considered.

The results based on analysis of the meeting notes and the two-page memos at this stage fall into three categories: teaching goals, forms of assessment, and logistical issues. For teaching goals, when describing why they had chosen a particular strategy, goals and objectives for teaching emerged. These goals explain what the instructor is trying to achieve not only with the particular content, but also with the learning environment and how students learn. For the forms of assessment, we analyzed the various ways in which the instructors incorporate formative assessment into their teaching. Finally, there were logistical challenges such as time that impacted how they met their curricular and teaching objectives.

Teaching Goals

During the discussions that took place during the kickoff meeting and subsequent phone conferences, three teaching goals were discussed at length. The first was the use of formative assessment as a way to engage students with the material during class rather than having the students passively watch the instructor work through a problem. The goal was for students to realize what they did and did not understand about the content sooner (in class) rather than later (when they were working on assigned homework). In addition, the formative assessment, at minimum, was intended to break up the class session and improve the learning environment. The second teaching goal was for students to understand the main points and the overarching structure for the content. Instructors noted that students should understand that if time was taken in class to work on a particular problem type, then the problem and its related content were probably important. Instructors also selected problems that illustrated particular concepts or helped highlight critical aspects of the content in order to reinforce students' learning. The in-class problems, in particular, were intended to help students review the material both during class and at a later time. Finally, instructors also had multiple higher-order thinking or metacognitive goals when implementing formative assessment tasks. They wanted students to analyze their problem-solving strategies and think about what they had learned (or not learned) in order to understand the content more deeply.

One aspect of the teaching goals was balancing conceptual understanding and learning how to carry out procedures. Star (2005) describes a spectrum of both conceptual and procedural understanding ranging from superficial to deep. Deep procedural understanding includes flexibility in using procedures alongside an ability to analyze the steps in a procedure. Deep conceptual understanding includes understanding the related concepts, skills, and knowledge as well as the ability to apply concepts in multiple situations. The participants in the professional development group repeatedly expressed the need for students to be able to flexibly approach problems from a procedural perspective as well as have a deep, conceptual understanding of the content. In particular, some strategies were designed to emphasize the connections between concepts and/or to highlight particular procedural strategies.

Forms of Assessment

The overarching goal of most of the strategies was to have students go beyond passively watching the instructor in the classroom. For example, summaries of assigned outside reading were prepared and presented by students to help them actively engage with the material and learn how to synthesize and summarize material. The assessments required varying in-class and out-of-class time commitments from the instructor. Significant discussion surrounded whether to assign a grade or give points to students for the assessments. If the purpose of the assessment was to document student learning or give students an opportunity to practice a procedure that had just been presented, the instructors often wanted only that students reflect about what they understood and what needed to be reviewed. However, formative assessments were also used as assessments of what students had learned from the previous class or homework. In this case, students might be given a holistic score in order to tell them how they were doing and whether they were understanding the material. The ongoing dilemma in group meetings was whether students understood the value of the formative assessments enough to participate and give an honest attempt to the problems without being given a grade.

In-class problems (from 2 to 15 minutes in length) were designed by multiple instructors to require students to attempt procedures or apply concepts on the spot, allowing the instructor to see their learning in progress. One area for faculty learning was an iterative process of writing and implementing problems over time. Participants acknowledged that there was some risk inherent in putting a problem in front of students during class. For example, students might not finish the problem at the same time, not be able to do the problem, or have a variety of unexpected solutions. Faculty agreed that the risk was outweighed by the benefits of student participation and engagement with the content. Writing formative assessment problems did require experience with teaching the content and the particular level of student. Problem selection also required instructors to think about what misconceptions might arise and how the problem would need to be differentiated.

Logistical Questions

Logistical issues attempted to balance increasing student engagement and participation with how much time was realistically available. Time constraints, both time in class and time for providing feedback outside of class, were challenges encountered across techniques. For example, a few discussions centered on how and if the instructor should review students' responses to in-class problems after class. The issue was giving students feedback in a timely fashion while operating with realistic demands on the instructor's time. In addition, for some instructors who had tried to turn around reviewed work quickly (within an hour or two after class), students often did not pick up their solutions until the next class, so the timeliness objective was not met.

Another prevalent time issue was how much time to spend in class doing a problem and how to judge when it was time to stop small groups working on the problem. The first issue came about because the participants knew that instructors new to interactive teaching would be concerned about covering the content sufficiently (i.e., would there be enough time to lecture?). A few low-risk, low-time strategies were proposed that would not take a lot of time out of class but would still provide some of the benefits of formative assessment. These strategies included muddy point cards, two-minute problems, or simply asking students to provide the next step in a solution. A muddy point card was given to the students at the end of class and simply asked them questions such as "What is still confusing? "What do you understand?" or "Do you have any questions?". A two-minute problem was designed to be short (sometimes multiple choice) problem about a focused topic that might also prompt discussion. For example, "What is the best procedure for doing a particular type of problem?" "Which strategy would you choose?" For longer problems, the concern emerged about when to stop the groups' discussions and go over the problem as a class. This was a differentiation issue since the faculty participants knew that some groups would always finish more quickly than others. It also connected to the logistical issue of balancing the need to pick student groups quickly with the need to form groups with diverse knowledge and experience. In some cases, forming groups quickly was more desirable than assigning groups. This depended on how much time the problem was intended to take in class.

Recommendations for Faculty Teaching Development

In year one of the project, the instructors in the faculty development team met by phone conference approximately once a month. These phone conversations were used to motivate group members' development of the two-page memos by giving each member an opportunity to share their tool and provide feedback to each other about the strategy by asking questions and making comments about it. These conversations were useful for helping to clarify some of the goals faculty had for their strategies as well as for identifying common themes mentioned previously (e.g., grading, time). The phone conference conversations helped group members to improve their two-page memos by integrating answers to questions asked by other group members, as well as addressing concerns raised by the group. In this way, the group served as a proxy for instructors new to formative assessment who might use the memos as a guide to modify their teaching.

In year two, the focus shifted toward faculty from the initial (year-one) development team creating small teaching-focused groups at their own institutions. For these groups, we encouraged the year-one participants to seek faculty from engineering, but not limit recruitment to engineering. Broad recruitment was performed in order to ensure enough participation and because other science and mathematics disciplines may have similar concerns and challenges in transitioning to more interactive teaching. The groups were recruited in some cases with support from university centers for teaching and in some cases via personal connections. Most groups were interdisciplinary in nature but focused on STEM departments and teaching. All year-two group members also had the same assignment as the first-year faculty development group: try a new teaching strategy and report on it using the two-page memo format. In all cases, faculty successfully recruited 3-5 other instructors. Smaller groups were felt to be beneficial in this case so that scheduling would be simpler and to provide a more comfortable environment for discussion. Each group met one to two times each month. In order to support discussion about teaching and learning, some groups also read *How learning works: Seven research-based principles for smart teaching* (Ambrose, Bridges, DiPietro, Lovett, Norman & Mayer, 2010). In some meetings, discussion centered on a particular topic relevant to teaching and formative assessment, e.g. how should homework submissions be assessed? (Should homework be graded in a traditional manner? Instead, should students be assessed based on a quiz on the homework material? When should solutions be provided?) Group members shared their own experiences and learned about approaches that had worked (or not) for other instructors. In other meetings, discussion focused on readings of teaching-related articles of interest or on teaching-related videos such as those from Dr. Sanjoy Mahajan's course "Teaching College-Level Science and Engineering" available via MIT Open Courseware.

As recommendations for starting a small group of faculty to talk about teaching practice, we found the following features helpful. First, keeping the group small helped foster productive discussion about teaching and facilitated scheduling. Second, focusing on one strategy at time made the task of changing teaching more manageable. Many types of strategies (e.g., clickers, problem-based learning) can feel overwhelming to faculty because of the additional time required for set-up, planning and grading. We focused on smaller types of changes that could still be beneficial in increasing students' engagement in the class so as to provide an easier transition into more interactive teaching. Finally, the groups focused on being encouraging to individuals' needs and concerns about their teaching. The small group format made this responsiveness easier and regular meetings provided an open forum for discussing changes to teaching practice.

Conclusions

The results first provide a model for helping instructors share their formative assessment teaching practices with colleagues, furthering adoption of research-driven techniques and thereby bridging the "valley of death" between engineering education research and the engineering classroom. Second, by analyzing a collection of memos, common themes and unique features of such formative assessments can be found. Our long-term goal is to develop a sharable assessment guide that can be used to improve teaching. The process of designing sharable guides is an opportunity to bring best practices for teaching into a manageable format that is easily disseminated and absorbed. Overall, we also achieved our objective of having small groups of faculty begin and continue conversations about specific teaching strategies in order to help them try new teaching strategies with support from other faculty facing similar challenges.

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