Putting Discussion-Based Engineering Education Courses Online

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Introduction

The School of Engineering Education (ENE) at Purdue University began offering graduate degrees in 2004. As word of the new program spread, ENE faculty began to hear from engineering students and faculty who were interested in learning and applying fundamental engineering education principles even though they did not have the time to pursue a graduate degree. In response, the department developed a graduate certificate, Teaching and Learning in Engineering, which consisted of four courses that provided current or potential engineering educators with knowledge and skills to help them be more effective. Unlike the teaching certificate offered by the university’s center for teaching and learning, completion of the graduate certificate appears on the student’s transcript. The four graduate certificate courses are

- ENE 506 Content, Assessment and Pedagogy (3 credit hours), teaches students how to design a curriculum and guides them through the process of developing a course in their field.
- ENE 685 Engineering Education Methods (3 credit hours), provides students with a variety of techniques for teaching courses that are both engaging and effective.
- ENE 687 Mentored Teaching in Engineering (1 credit hour), enables students to deepen their understanding of teaching and learning through feedback and reflection as they perform their regularly assigned teaching duties.
- ENE 695 Succeeding as an Engineering Professor (3 credit hours), covers other skills valuable to faculty members such as writing proposals, selecting and mentoring graduate students, and managing projects.

All four courses were initially offered only on campus to students currently enrolled in Ph.D. engineering programs at the Purdue University. All of the courses relied upon extensive student-student and student-faculty interaction. Students read assigned materials, discussed them in class with the instructor, and then used information gleaned from the reading and discussions to complete assignments that would be useful in performing their duties as faculty members. Some examples of assignments are a syllabus and materials for a course in the student’s technical field, an interactive presentation of course materials, a detailed teaching philosophy, and a plan for mentoring graduate students. Students often peer reviewed materials prepared by classmates, and faculty members provided detailed, individual, written feedback on each assignment.

A year ago, we began hearing from students, faculty, and administrators, asking whether the Teaching and Learning in Engineering graduate certificate was available online. We decided to offer online sections of the certificate courses in parallel with the on-campus sections, taking care to ensure that both sections had the same learning outcomes. We were dedicated to preserving the strengths of the face-to-face courses in the online sections, including extensive student-student and student-faculty interactions. In addition, we wanted to ensure that online students had the same quality of experience as the on-campus students. Since the four courses
were different from each other, each faculty member used a slightly different approach to online course delivery. The faculty members coordinated their efforts so that they could all learn from each other and from the technology experts working with them. This paper describes the course characteristics the faculty wanted to preserve and provides a summary of what was learned from a literature review of relevant previous work. It outlines how the faculty members’ efforts were coordinated to prepare the certificate courses for online delivery, how each individual course was designed for online delivery, and what has been learned to date.

Preserving Valuable Characteristics of the Face-to-Face Courses

Students taking the certificate courses on campus over the past few semesters have noted the value of student-student and student-faculty interactions. They have commented on the richness of discussions with their classmates and the instructor. Most participants are Ph.D. students in engineering who expect to pursue a career in academia. They have a variety of backgrounds. Some have many years of teaching experience (at the college or pre-college level, in the United States or abroad) and are returning to campus to earn a Ph.D. Some have been in industry and want to move to a faculty position. And many have come to graduate school directly from an undergraduate engineering program. They come from almost every engineering discipline and dozens of different countries. Students also appreciate that most of the certificate courses involve some small group work, with reports to the entire class so that students get an opportunity to both explore ideas in depth and benefit from broader experiences of the entire class. Another strength of the courses is detailed feedback on written work – in the form of comments from the instructor within a week and often from peers during class.

In addition to gathering students’ feedback on what they found most valuable in the certificate courses, we surveyed the literature related to implementing effective learning environments for online courses. In attempting to achieve this goal, scholars have conducted research for guiding institutions to develop and implement effective online courses [1]. A recognized result of this research is a theoretical framework named Technological Pedagogical Content Knowledge (TPACK). The authors of this framework stated that designing online classes requires using new technological tools to teach, which implies that instructors are involved in learning how to use those tools with pedagogical purposes. Moreover learning to use these tools, teachers also need to reassess how they are pedagogically approaching content delivery, and how they help students to learn specific pieces of content using a specific technological tool [1]. Using this framework, these authors attempted to bring a theoretical grounding to the area of educational technology [1], [2]. Other researchers have used this framework as one of the lenses through which to observe further research in the area of online education.

TPACK asserts that effective teaching relies on knowledge regarding three main components: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). Moreover, the intersections of these domains also contribute to teaching effectiveness. Those intersection domains are pedagogical content knowledge (PCK), content technological knowledge (CTK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). This framework has been assessed multiple times for refinement and clarity. For example, Angeli and Valanides [3] question the definition of technological
knowledge and for clarity, they add the acronym ICT which stands for information and communication technologies. Their work helps faculty use this framework in online settings. Others have also contributed to improvements to this framework such as adding two previously unconsidered elements namely student knowledge and context knowledge [4], [5].

In addition to TPACK, there are several studies related to online settings. Kebritchi and Lipschuetz conducted a literature review to identify issues related to online courses [6] and found three major categories of issues, which were related to online learners, instructors, and content development. First, they reported that learners experienced issues with the stated expectations, being ready for online classes, their identity, and their participation. Second, instructors faced issues related to changing roles, switching from face-to-face to online settings, needing other teaching styles, and managing their time. Finally, content issues are linked to what the role of instructors is in content development and decisions concerning the integration of multimedia for content development.

Other studies discussed struggles instructors experienced in online settings [7]–[9], student-student interaction in online settings [10], quality of the learning experience and knowledge acquisition in online courses [11], and translating assessment practices from the face-to-face environment to the online setting [12]. In general, what all these studies highlight is the importance of student learning and the quality of their experience when they take an online course as compared to a face-to-face setting.

These studies also reported some solutions for the problems discussed. For example, Kebritchi and Lipschuetz [6] stated for tackling these issues in online education, institutions must provide technical support for content development, training for learners, and professional development training for instructors. Similarly, O’Hara and Pritchard [8] argued institutions need to support faculty working on online courses. Moreira, Henriques, Goulao, and Barros [9] stated interaction among instructors is important in developing an effective online environment. Referring mainly to students, Bickle and Rucker [10] report when students are required to interact even in an asynchronous setting, they are more willing to share their thoughts and learn from other peers. These authors also stated that this willingness does not come without hesitation and resistance from students. However, students who visualize the benefits engage more readily in the interaction. Beebe, Vonderwell, and Boboc [12] report “… the instructor’s role in the online environment requires rethinking and reconstructing assessment practices traditionally employed in f2f settings.” Here, they state that instructors need to evaluate their pedagogical approach, particularly their assessment practices, when they move to an online setting. Finally, Politis and Politis [11] state an effectively designed online setting contributes to enhanced student content knowledge acquisition, and online learner’s motivation is increased when students have easy access to the learning management system.

While our literature review provided us with general guidance on developing online courses, we found no studies discussing online courses for Ph.D. students. We were particularly interested in Ph.D. level courses that require reading, analysis, discussion, and writing with feedback. We hoped to answer three questions ourselves: (1) Given the Ph.D.’s students’ high levels of motivation, what kind of environment would foster their engagement in online courses? (2) How can an institution best support faculty members for designing, developing, and delivering this kind of course? (3) What are the students’ experiences in these courses?
Developing Online Courses for the Graduate Certificate

Coordination of the Effort

As noted before, our goal was to develop the group of four online courses in a way that led to the same learning outcomes, preserved the desirable characteristics of the face-to-face courses, and provided online students with the same quality of experience as the on-campus students. We also wanted to minimize the additional faculty effort required to transform the courses and to teach them in the online format. The face-to-face and online courses were designed to be taught in parallel, usually with on-campus and online students interacting with each other, and we wanted the faculty members to focus their time and effort on the students and the course content, not on struggling with the technology.

To accomplish these multiple goals, we established a team to work on each course. Each team consisted of the faculty member(s) teaching the course, a quarter-time teaching assistant familiar with the course, and an instructional designer provided by the university, with assistance as needed from technicians, marketing people, and administrators from the university’s online learning organization. One course was developed initially as a pilot. Bureaucratic, policy, and technical issues were identified and resolved during the pilot, and lessons learned were documented. As the other three courses were developed, faculty members leading the teams met regularly, along with other team members as appropriate.

The faculty members each reviewed the learning outcomes of their courses and worked with the instructional designer to identify an approach that would allow them to meet those outcomes for both the face-to-face and online sections when the two sections were taught concurrently. Three of the courses are 3 credit hours each and meet for three hours each week. The fourth course is one credit hour. Two of the three-credit hour courses were hybrids of synchronous and asynchronous instruction – one of them with one hour of synchronous discussion and the other with one hour of synchronous discussion plus one hour of virtual small team meetings. The third three-credit hour course and the one-credit hour course were asynchronous. Descriptions of how each of the online courses was designed and taught follow.

Descriptions of the Courses

ENE 506: Content, Assessment and Pedagogy An Integrated Engineering Design Approach is designed to help participants build a foundation of knowledge, skills, and modes of thinking that facilitate the alignment of content, assessment, and pedagogy for curriculum design. The course has two overarching learning objectives. At the end of the course, participants should be able to (1) apply the principles engineering design to the design of a course, module, workshop or other instructional unit, and (2) articulate an evidence-based rationale for their curriculum design decisions.

Our approach is essentially an engineering design approach also called backwards design. One begins this process with requirements or specifications, and asks, “What do you want students to know, do, or feel at the end of the session?” The second step is to emphasize metrics and here the essential question is, “What evidence should you gather to determine if the desired outcomes have been met?” In engineering design, the final step is the preparation of prototypes that meet the requirements. The parallel in backwards design is to ask, “What kinds of learning
experiences or materials should you provide the students to help them practice the desired outcomes?” Rather than treat each of these areas separately we strive to help the participants consider all three together in a systematic way. Thus the key word in ENE 506 is aligning content, assessment, and pedagogy. The primary deliverable in the course is the creation of an extensive curriculum design project that students deliver both as a written document and as a poster presentation.

Two major challenges have arisen in converting this course for an online audience. One challenge lies with the content itself and the second challenge lies in a core aspect of the teaching philosophy.

What about the content is challenging to convey online? The essence of ENE 506 is the ability to align various aspects of curricular design into one unified whole. The goal is for students to see how aspects of what is learned (content) map to how to measure learning (assessment) and how students practice that learning (pedagogy). This process, which is at the heart of the course, is a very holistic, integrated, iterative process. However, the learning management system we currently use (Blackboard) displays items in a linear, fragmented fashion that adds an additional learning burden on the students as they assemble this mosaic of content pieces into an integrated larger picture. This challenge has been addressed by providing a tight, organized structure that lays out the pieces of the course as clearly as possible. This helps. But the students must provide the added energy to make sense of the many pieces.

The second added burden of the online format is created by our assertion that learning is a social activity. The course has been designed so that students receive feedback from intellectual neighbors - self-selected groups of students who have shared interests. In face-to-face versions of the course, students have in-class time to find and work with their intellectual neighbors. In the online class students make use of a discussion board to identify intellectual neighbors and then can choose to meet synchronously or asynchronously. The discussion board is a useful tool for helping students find each other. But students need to form connections without the benefit of promotive face-to-face interactions. So here again, as with the first challenge, the students are required to expend more energy to achieve a course goal.

ENE 685 Educational Methods in Engineering is a course centered on the practical applications of theory and research to teaching undergraduate engineering courses. Specifically, this course is designed to help prepare students for college teaching and put them in touch with resources that can sustain their development as an effective teacher. The course emphasizes reflection and discussion as a means of learning the content. The course is structured as a hybrid of synchronous and asynchronous activities, with a one-hour joint weekly meeting. There are four reoccurring weekly activities: 1) individual readings and reflection, 2) learning community 3) Flipgrid video discussion, and 4) whole class discussion. The course has a combination of team and individual assignments.

The students are split into groups of 3 to 4, referred to as Learning Communities, based on their time availability and teaching interests. Each learning community (LC) is expected to schedule a minimum of 1-hour a week for everyone to virtually meet at a time of their choosing. In these
meetings, the LC members discuss assigned course readings, (2) collaborate on reflections and team assignments, and (3) provide each other feedback on individual assignments. The purpose of the learning communities is to foster learners’ knowledge and skill development alongside others. Through the process of working together, discussion, and feedback, they have the opportunity to learn from each other and develop a deeper understanding of the concepts covered. They also hold each other accountable to achieving personal goals set for the class and can develop friendships that may span many years. The intention is that this group can be a long-term resource for the students.

To start a week, students complete the assigned readings and write an individual reflection. In the reflection, students are asked to write what concept or issue they felt was most important and then reflect on how it informs their understanding and what the applications are. Students submit individual reflections as a weekly individual assignment. Students are also encouraged to ask questions to the instructor. When students meet for the LC, they share their reflections and work together on an assigned group activity intended to foster deeper thinking about the readings. One student from each LC then posts a synthesis of the LC discussion as a video for the whole class to watch. Students are encouraged to watch all the LC videos and post video responses. The instructor also watches student videos and posts a video response. The synchronous course meeting is used to guide critical discussion related to the readings and assignments and answer questions that students have.

**ENE 687, Mentored Teaching in Engineering**, serves as the practicum for the certificate program. To take ENE 687, a student should have previously completed ENE 506 or ENE 685, or be concurrently enrolled in one of these courses. In addition, the student should have significant concurrent responsibility for teaching a course, usually as a graduate teaching assistant. The primary purpose of ENE 687 is to learn from this concurrent teaching experience through self-reflection and through feedback from a mentor, from students in their classrooms, and from peer students in ENE 687. As a consequence, although students in ENE 687 read and discuss selected chapters of a textbook [13], chapters which complement the topics in the prerequisite courses, the readings and classroom content are secondary to the processes of reflection, mentoring, and feedback.

ENE 687 takes a scholarly, professional approach to the teaching of engineering. Because teaching is a scholarly practice, ENE 687 students relate their teaching activities to the research literature, as summarized in the textbook. Because teaching is a professional practice, students’ teaching experience should resemble an engineering internship. As in an internship, ENE 687 students work with a mentor to improve their skills. Like all professionals, engineering teachers have special ethical obligations that the course explores as well.

Each week, students in ENE 687 write an individual 300-word reflection paper on their teaching experiences. In these reflections, students are encouraged to think critically about the relationships between these experiences and the readings in ENE 687 and in the prerequisite courses. Two of these reflections respond to the two observations by the student’s mentor. Each student posts each weekly reflection in the Discussion area of Blackboard and comments on other students’ reflections. (The ENE 687 instructor also posts a weekly reflection and comments
on all students’ reflections.) At the end of the semester, each student submits a 1500-word course synthesis, essentially a reflection paper that integrates the student’s learning about teaching during the semester. In addition to these reflective assignments, students assemble a course portfolio [14], a short form of a teaching portfolio. The course portfolio in ENE 687 comprises two 1500-word essays and accompanying artifacts. The first essay describes the course activities that the ENE 687 student led and the justification for the choices of pedagogies, materials, assignments, and assessments. The second essay documents and analyzes evidence of student learning. Typical artifacts include lesson plans, classroom assessments, and samples of student work. In sum, the course portfolio enables the students in ENE 687 to demonstrate the quality and scholarship of their teaching.

As originally designed, ENE 687 meets once per week for a one-hour, face-to-face class session, since it is a one-credit course. (Students may register for an additional two credits if they want to undertake a scholarship of teaching and learning project in conjunction with their teaching assignments.) During the class session, students discuss the textbook readings and short cases about problems that college teachers encounter. The cases come from a variety of sources [15], [16], [17]. Most sessions include a “Teachers’ Corner” segment: students can ask questions about practical teaching problems, and the instructor and other students can suggest solutions by applying knowledge from the readings and from their diverse experiences. The “Teachers’ Corner” activity enables the sharing of the wisdom of practice [18] in a classroom community of learners.

The one-credit, online section of ENE 687 is designed to be completely asynchronous. Both the face-to-face section and the online section share the same Blackboard site. Each week, students in the online section go to Blackboard to post answers to questions about the same readings and cases as in the face-to-face section for that week, and the online students respond to other students’ answers in Blackboard. Online students participate in “Teachers’ Corner” in a forum in the Discussion area of Blackboard. Occasionally, online students watch short, pre-recorded videos of a presentation that the instructor delivers in the face-to-face section in the same week. Online students are expected to spend one hour each week on these tasks, corresponding to the one-hour class session for the face-to-face section. For online students, the instructor holds virtual office hours via the WebEx web conferencing system. Although he sends course announcements to all students via e-mail each week, he records short videos to personalize these announcements for the online students.

The asynchronous design of the online section of ENE 687 enables students to complete assignments and activities on their own schedule, without requiring attendance at a class session, even online, at a particular time. As an unexpected benefit, the asynchronous design also accommodates absences by students enrolled in the face-to-face section. Since most students in ENE 687 are advanced doctoral students, they travel to professional conferences and to job interviews. When their travel conflicts with the meeting time of a face-to-face class session, they can instead complete the tasks designed for the online section for that week. Even the ENE 687 instructor can miss a class session and direct all students to the online tasks.
**ENE 695: Succeeding as an Engineering Professor** provides students with an opportunity to learn about and practice skills, other than teaching, that are important for success as a tenure-track faculty member. These skills include identifying research topics and writing a proposal with a complete budget in response to a published solicitation. Some other topics are taking full advantage of participation in a professional society, managing projects and people, and recruiting, selecting, and mentoring graduate students. The course is discussion-based, with “lectures” consisting of a structured discussion around the topic of the day. The instructor presents information, and students are encouraged to share their own relevant experiences or ask questions related to the topic. Most of the assignments are written documents in which students reflect on and prepare for the responsibilities of a faculty member. Students receive detailed feedback on their assignments from the instructor, and in some cases, the documents are also peer reviewed. One presentation is assigned. Students identify three faculty or postdoc positions of particular interest to them and describe how they would demonstrate that their education and experience have prepared them for each of those positions. They present that information to the class and also say how they learned about each position. Finally, each week there is a 30-minute student-led discussion on a topic selected by the discussion leader and approved by the instructor. The discussion leader identifies materials for students to review and poses 3 or 4 discussion questions.

Preparing ENE 695 for online delivery required finding ways to give the online students similar experiences to those of students in the face-to-face course. We needed to present the material related to the topic of the day and give students a chance to share their experiences and ask questions. Online students would complete the same assignments as students in the face-to-face section and receive the same types of feedback. In addition, online students would have an opportunity to participate in the student-led discussions and take their turns as discussion leaders.

The first step in developing the online course was to deliver the material related to the topic of the day. Unlike the other certificate courses, ENE 695 does not use textbooks and articles as the primary source of content. Instead, in the face-to-face version of the class, the instructor provides information based on her decades of experience as a faculty member and administrator. To deliver this content online, 36 videos were created in collaboration with a team of professional videographers. The videos are mostly five to ten minutes long, and one to four videos are assigned viewing for each week of course instruction. Students participate in discussions and ask questions about the material in the videos through Blackboard’s discussion board. Expectations for the content, quality, and length of student posts and responses are established at the beginning of the course. The instructor participates in the discussions.

Online students submit their written assignments and receive detailed feedback from the instructor through Blackboard. E-mail with attachments seems to be the best way for students to pair up and provide peer reviews of each other’s work. Online students participate in the student-led discussions during the synchronous hour through WebEx.

Accessibility of course materials for the online students was a major concern. Full transcripts of all videos were posted in Blackboard. In addition to accommodating students with hearing disabilities, these transcripts proved to be helpful to students for whom English is a second
language. Accessibility was also a factor in setting up the course page on Blackboard. For example, a color-coded calendar was created to inform students of the various deadlines related to the class. This document was evaluated by an accommodations specialist, who suggested revisions such as revising the colors to accommodate color blind people and formatting the text so that it could be read by text-to-voice programs.

**Observations and Lessons Learned**

Pilot Course Development and Observations

ENE 695 Succeeding as an Engineering Professor was the first graduate certificate course to be prepared for online delivery. There were three phases to the course development: (1) identify learning objectives, select the content to be delivered, and determine how to assess student learning, (2) decide how to deliver the content online in a way that accomplished the learning objectives and provided online students with the same quality of experience as students in the face-to-face course, and (3) determine whether and how to integrate the face-to-face and online sections of the course. The first phase was easy since the course had been offered on campus several times and decisions about content, assessment, and pedagogy had been made. The second phase was entirely new to the instructor. Fortunately, detailed workshops on use of the learning management system, Blackboard, were offered by the university. The Online Learning organization assigned an instructional designer to work closely with the faculty member developing the online version of the course, and the Online Learning technical staff provided equipment and coaching on recording videos. Decisions about the third phase, whether and how to integrate the online and face-to-face sections, had to be made at the very beginning. Two portions of the course, the student-led discussion of current topics and addressing questions about and providing general feedback on assignments, were deemed to be best handled in a synchronous setting. Presentation and discussion of course content could be handled asynchronously as could individual feedback on assignments.

Three students participated in the online section of the pilot course. One student could not be on campus, and one could only attend some portions of the course. The third student participated as an online student and attended the course face-to-face in order to compare the two sections. Twelve students attended only the face-to-face section of the course. The 15 students involved in the pilot were from 11 different countries and 6 engineering disciplines.

This section presents observations by the faculty member responsible for the pilot course and students who took the course. Faculty observations included:

- For a faculty member unfamiliar with teaching online, it was essential to collaborate with a knowledgeable and dedicated instructional designer who was willing to work with the faculty member to customize her course rather than insisting on a standard format.
- Other resources were equally important: time to develop the course, graduate student assistant, workshops, websites, video recording equipment, and individualized instruction on using equipment and software.
- Reviewing the course content, assessment, and pedagogy from the perspective of an online student focused and improved the delivery of the face-to-face course. For
example, identifying the key points to cover in a class session and condensing them into a 7-minute video sharpened the focus of the face-to-face discussions. In addition, having the videos and their transcripts as well as the very detailed description of assignments and how they would be graded was useful for face-to-face students who missed class.

- Having taught the pilot as a hybrid synchronous/asynchronous course and observed the students’ behavior, the instructor was convinced that it could be possible to offer this course asynchronously, with some modifications.
- The quality of the pilot (measured by student satisfaction with what they had learned and the quality of their experience along with faculty satisfaction with the quality of the work) depended heavily on student effort and willingness to participate fully. The course was populated primarily by advanced Ph.D. students in engineering who aspire to academic careers. It might be difficult to achieve the same quality with less motivated students.

Student observations include:

- Class discussions, either face-to-face or through an online discussion board, were valuable – especially so given the varied backgrounds of class members.
- Detailed written feedback from the instructor on assignments was welcome.
- Having transcripts of the videos available was very useful to online students for whom English is a second language.
- The student who participated in both the online and the face-to-face sections of the course kept a journal with weekly entries comparing the two sections. In the fourteenth week he wrote, “I could see how this week the discussion in the online class has increased in amount and quality as compared to the discussions in the first weeks. We could share our experiences and we also connected the topic with our future plans in our careers and with mentoring future graduate students. In the classroom, the discussion was also interesting. There the instructor guided the discussion using questions that helped to connect with our experiences and plans. Even though, the online version and the regular class have different dynamics I think they both bring equivalent learning experiences to their graduate students.”

Lessons Learned from Developing the Four Certificate Courses

All four online graduate certificate courses were designed to preserve the valuable characteristics of the face-to-face courses and to be offered in parallel with face-to-face sections. Faculty members used several different structures to achieve those goals. Since the courses were ready just in time for Spring Semester 2019, as this paper is being written, the faculty members have only preliminary comments on lessons learned. Some of those are:

- We used several course structures: one hour of synchronous class discussion + two hours of asynchronous activities, one hour of synchronous class discussion + one hour of small group virtual meetings + one hour of asynchronous activities, totally asynchronous course with small, self-selected groups using the discussion board to make connections, and totally asynchronous with all students participating together on the discussion board.
While we are not yet able to evaluate the various approaches, we have not discovered any serious drawbacks to any of them – for the population we are serving.

- Our learning management system (LMS) requires a separate site for the face-to-face and online sections of the course until enrollment in each section is complete. Then it is possible to merge the two LMS sites if the instructor desires. If the two sites are not merged, students in the online and face-to-face sections cannot access the same discussion board. One of our instructional designers has found a software product that allows students from two different course sections (and the instructor) to access an external discussion board.

- It is important to think about how to structure and manage the online course before meeting with the instructional designer and work with him or her to find the technology that will provide the desired structure and features.

- Spending time thinking about how students will learn the material and how to structure the online section often leads to improvements in the face-to-face section. For example, to condense the course into a series of short videos containing the key ideas in the class, it is important to identify what those key ideas are. To ensure that online students have meaningful engagement with the course materials, the instructor must create insightful, meaningful prompts for the discussion board. A clear, concise statement of key ideas and use of well thought-out discussion prompts lead to more valuable discussions in the face-to-face class.

- Materials developed for the online section can often be used effectively in the face-to-face section. For example, once the videos of the essential elements are created for the online class, the videos can be viewed before class by the face-to-face students. This allows the face-to-face class to be “flipped” and allows class time to be used for discussion of points that were not clear or to explore how the material can be applied to their class project.

- While a substantial up-front effort is required to prepare the courses for online delivery, that investment leads to reduced time preparing for each class meeting.

- Developing a pilot course first to identify and resolve bureaucratic, policy, and technical issues, as well as to identify resources available to faculty developing online courses, is useful.

- Regular meetings of faculty members who are developing online courses for the same program are helpful. They allow faculty to coordinate course content, establish common policies, learn from each other, and avoid pitfalls.

**Concluding Remarks**

The goal of the effort described in this paper was to offer an online graduate certificate, Teaching and Learning in Engineering, having the same learning outcomes as the face-to-face version and also preserving the student-student and student-faculty interactions that characterize the face-to-face versions of the four certificate courses. In addition, although the on-campus and online experiences would be different, we were dedicated to providing both groups of students with a high-quality experience. While we are just beginning to offer the courses online and cannot yet provide a detailed account of which aspects of the courses work well and which ones need to be
modified, we are able to share some observations. First, the technology exists to preserve valuable student-student and student-faculty interactions in an online setting. Quality interactions depend on a clear statement of expectations, students motivated to participate actively in the course, and about as much faculty time as interactions with face-to-face students. Second, faculty members have found that the process of thinking about how to meet the learning objectives of their courses in an online setting has resulted in improvements in the face-to-face courses as well.

References


