Preparing Engineering Graduate Students to Teach: An Innovative Course Design and Evaluation

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Introduction

In spring 2000 we designed and delivered a three-credit course to prepare students for careers in teaching. The course was offered through the industrial engineering department and was open to all engineering graduate students. Fourteen students enrolled—seven men and seven women—representing the industrial, civil and environmental, electrical, bioengineering, and materials sciences engineering disciplines. The course met for 100 minutes twice a week for 10 weeks.

The course content was defined by the instructors, but the instruction was (to a high degree) tailored to the understanding of the students because it was the students themselves who designed the instruction. The course focus was on reflective practice and on findings from cognitive science and education research and their application to engineering teaching and learning. Throughout the quarter, we tried to maintain a tension between theory and practice. On the theory side, students became familiar with conceptual change, memory, motivation, and other learning concepts. On the practice side, students were exposed to innovative teaching methods through the example of their instructors, through their readings, through exercises such as creation of concept maps and conceptual probes, through reflective essays and e-mails, and through two teaching assignments.

In this paper, we provide background on our rationale for course design and describe the course structure. We then show one student's responses to a few of the assignments and activities used both to promote learning about the course concepts and to elicit student thinking about teaching and learning at different points in the course. Finally, we describe our course evaluation methods, summarize student responses to these evaluations, and provide our own reflections on the course.

Our Course Design Rationale

Ph.D. graduates who obtain faculty positions are well qualified in their discipline knowledge, but few enter their academic careers with any formal training in teaching. The dominant source of the conceptions of these new instructors about the teaching endeavor is based on their experiences as a student, and possibly as a teaching assistant. These experiences are dominated by lecture format courses where the student classroom involvement is primarily passive. Such

traditional teacher-centered approaches frame instruction as a presentation—a performance centered on the course content—with little if any consideration of student perceptions about the content. It is becoming widely accepted that such traditional approaches promote limited learning, yet teaching practice in college classrooms is still dominated by this teacher-centered style. A number of educators have addressed this problem in various forms in an attempt to teach future and current instructors about student-centered methodologies.[1,2,3,4,5,6]

Learning (whether it is learning about engineering or learning about teaching) is a process in which students must relate a "new" view to their "old" view—that is, to relevant concepts they already know.[7,8,9] As an example, one old view of the problem-solving process is that problems are solved by finding the "right equation" and plugging in numbers. A new view of problem-solving in engineering involves understanding that a central part of the process involves defining the problem scope and analyzing the situation—before any equations are even introduced. In regard to the process of learning about teaching and learning, the old view is that of instruction as a performance, centered on the content, and the new view is that of instruction as a response to the course content and what students already know about that content. Student-centered instruction aims to help students develop an increasingly structured, useful understanding of the content by working from their knowledge base.

Researchers have identified a set of processes that can facilitate the learning of new views.[10,11,12] In this set of processes, teachers provide students with the following:

(a) An introduction to relevant concepts, knowledge content, language, and issues—and examples of effective applications and instantiations of the concepts.
(b) Practice in the application of the newly acquired concepts.
(c) Timely, constructive feedback about the practice.
(d) An opportunity to reflect on the practice, both on one's own practice and that of others.

The introduction of relevant concepts, vocabulary, and issues gives students a framework within which and around which they can construct their understanding of the content. Appropriately designed active practice in applying the concepts deepens student understanding of the concepts and their interrelationships. An important accompaniment to active practice is timely feedback about the products of that practice. Feedback given during or immediately after the practice will have a more powerful impact than feedback delivered many days after the practice. Finally, an opportunity to reflect on their own practice and to observe and critique other's practice of the skills to be learned gives learners an opportunity to identify concrete examples of effective and ineffective applications and of instantiations of the concepts being learned.

Most student experiences are dominated by processes (a) and (b), because most courses are dominated by those processes. Typical course designs provide few, if any, opportunities for students to observe and critique the work of others or to receive timely feedback and critique from their peers. Thus, when we designed a new course on teaching for graduate engineering students, we wanted to make sure to include examples of and experiences in all four processes—(a) through (d). Secondly, we aimed to design the course so that students would develop an expanded and more structured set of ideas about how instruction can be designed and implemented.

Course Goals and Organization

We assumed that a 10-week course was much too short to cover in great depth all of the topics we wanted to include in the course. Furthermore, we assumed the individuals taking the course were learners who would continue to learn after the course. It was our goal to provide a foundation of knowledge and experiences from which students could continue to learn about teaching and learning. Our objectives for meeting this goal were (1) to introduce basic ideas, concepts, and strategies related to teaching and learning engineering, (2) to model and give examples of applications of those ideas, concepts, and strategies (3) to provide opportunities for students to practice the implementation of those concepts, (4) to ensure that students received timely feedback about that practice, (5) to encourage students to reflect on the practice, (6) to introduce students to published resources, and (7) to introduce and illustrate the value of colleagues as resources for ideas and feedback about developing teaching skills.

Through implementation of these objectives, we hoped that students would develop the following abilities by the end of the quarter:

- The ability to analyze instructional design choices in the context of research and theory of learning.
- The ability to make and implement instructional design choices that take into account the complexities of teaching and learning processes, especially in engineering contexts.
- The ability to design effective assessment approaches and strategies.

Activities during class meetings varied substantially from class to class. Many of the instructional activities were led by the students, both in groups and individually, and focused on course topics and readings. Each of these activities consisted of three sub-activities: (1) students designed the instruction before class and delivered the instruction to the class, (2) immediately after the instruction, students in the class gave constructive oral critique of the activities in the context of the concepts being learned in the course, and (3), students who delivered the instruction wrote a self-critique as homework and submitted it at the next class meeting.

As shown in the summary of the course syllabus in Table 1, the course was divided into three parts. Several other topics that were deemed too important to exclude, such as teaching portfolios, teaching for diversity, ABET criteria, and course planning, were integrated into classroom activities during the term. These topics were covered in various ways, including lectures given both by visitors and the instructors. The primary course text was *McKeachie's Teaching Tips.*[13] This text was extensively supplemented with selected readings. One additional significant activity in the course was the writing of a personal statement of teaching philosophy. This activity was integrated into the last half of the course and took place primarily outside of class, although it facilitated rich interaction among students. Each student wrote a draft teaching philosophy statement, got feedback from instructors, revised the statement, got feedback from peers (over the Internet), and revised the statement again. All teaching philosophies and feedback comments were available to other students in the course over a password-protected page on the course Web site. Each course activity and sub-activity was assigned points, for a total of 100 points. Grades corresponded to the number of points students accrued: 4.0 for 100 points, 3.6 for 90 points, and so forth.

Part 1 of the course (in week 1) consisted of course introductions and two probes of student initial knowledge and perceptions of teaching and learning and of their expectations for the course. One of the probes was an "entry" essay, written as a homework assignment in which students wrote about their experiences as a learner and a teacher and about their thoughts on teaching and learning processes. The other probe was an "entry" concept map that each student generated on the first day of class and that centered around "teaching and learning." Students also generated "exit" concept maps, also centered around "teaching and learning," on the last day of the course to help us better understand the impact of the course on student thinking about the topic.

During Part 1 of the course, students were introduced to a significant theme of this course: that all participants in the course were expected to contribute to the learning throughout the course. To facilitate this participation, a class listserv was set up, and each student was required to post brief comments about assigned course readings at least 12 hours before each class meeting. These postings were automatically sent via e-mail directly to all students and instructors in the course, thus allowing an ongoing asynchronous conversation throughout the quarter.

Part 2 of the course took place during weeks 2 through 4. In this part, students were introduced through the readings to the basic vocabulary and concepts of learning processes, to information on student motivation, and to instructional design strategies. Students were also provided with concrete experiences in classroom roles that were unfamiliar (or less familiar) to them, including designing and delivering instructional classroom activities, justifying and assessing their own designs, and observing and critiquing the designs and delivery of others. One aim of these concrete experiences was to provide a common foundation for discussion around the concepts being learned and for later discussions of specific classroom implementations.

To maximize the efficiency of our limited classroom time, homework and classroom activities in Part 2 were designed to provide the concrete experiences at the same time that students were building knowledge of basic concepts and vocabulary. In addition to reading background material on each topic and posting reflections to the listserv before class, groups of two or three students led the class in an activity relating to the assigned topic for the day. Each group was assigned one of the seven topics in Part 2 of the syllabus. Groups met outside of class to prepare for their activity. (Students were encouraged to be "creative" in their activity design.) Immediately after each activity, students in the class gave oral feedback to the group that led the activity. The group then wrote a homework assignment—due two class meetings after their particular classroom activity. The write-up included a description of the instructional design, a rationalization for it, and an assessment of its implementation.

Part 3 of the course (weeks 5 through 9) focused on giving students opportunities to design, implement, assess, and get feedback on classroom learning activities in their own engineering discipline. By the end of this part of the course, students had designed three different types of classroom learning activities. These activities were (1) a conceptual probe for student understanding about specific content knowledge, (2) an assessment of student learning, and (3) classroom instruction about a specific engineering topic.

Table 1. Summary of the Course Syllabus

	Topic	Out-of Class Activity	In-class Activity
Part 1 (week 1) Introductions, overview, student probes	Introductions Student probes	Write an entry essay. Read assigned readings and post reflections to listserv.	Course overview Concept maps
Part 2 (weeks 2-4) Introduction to theory of learning, approaches to teaching, and initial practice in and feedback on design and delivery of instruction	**Introduction to Cognition** • Expert/novice differences • Knowledge organization • Memory • Representations **Student Motivation** **Instructional Approaches** • Student-centered instruction • Discussion/lecture	Read assigned readings and post reflections to listserv. Prepare student-led activity with group members for assigned topic. *After class meeting:* Write up reflections on your activity.	Lead (with your group) learning activity for assigned topic. Give oral feedback after each group delivers learning activity.
Part 3 (weeks 5-9) Active practice and feedback on design, delivery, and assessment of class instruction	**Methods of Teaching** • Cooperative learning and peer collaboration • Direct instruction • Problem-based learning • Teaching large classes/ classroom discussion	Read assigned readings and post reflections to listserv. Prepare summary of readings for in-class discussion.	Teach each other assigned methods of teaching through jigsaw activity. (Jigsaw method is modeled for students.)
	Conceptual Probes	Read assigned readings and post reflections to listserv Design a conceptual probe for a topic in your own engineering discipline. *After class meeting:* Write up reflections about design, results, assessment, future improvements.	Administer conceptual probes to classmates. Give oral feedback on conceptual probes.
	Assessment of Learning	Read assigned readings and post reflections to listserv Design an assessment of learning for a topic you may teach in your own engineering discipline.	
	Classroom Instruction	Read assigned readings and post reflections to listserv. Design a 12-minute learning activity for a topic in your engineering discipline. *After class meeting:* Summarize your learning activity—objectives, design details and rationale, self-assessment, future improvements.	Deliver learning activity. Give oral and written feedback to other students.

Design of Conceptual Probes. Information about what a student knows about a topic can richly inform instructional design.[14,15,16,17] Although this idea is increasingly recognized among those who do educational research, few students or instructors outside of this group have first-hand experience with the design and use of tools to gather relevant information about what a student knows about a specific topic. To illustrate the power of information about what students know and believe and to provide concrete experience with the design and administration of such probes, students designed a brief (less than 5 minutes) written probe for conceptual understanding about a specific topic in their own engineering discipline. They then administered the probes to the class during part of one class meeting. The class discussed the probes immediately afterward. In this discussion, students talked about the process of design of the conceptual probes: their difficulties in deciding on a conceptual probe design and their expectations of the results. Students also talked about the probes from the point of view of having to respond to them: what was difficult, confusing, and interesting. As homework, each student analyzed the results from the completed probes, wrote a rationalization and description of the conceptual probe design, analyzed the results, and proposed improvements on the design.

Design of Assessment of Student Learning. Each student designed an assessment for a specific engineering topic he or she may teach. Students wrote and handed in the assessment design as homework. The write-up included details of and rationale for the design.

Design of Classroom Instruction About a Specific Engineering Topic. Students used the results from their conceptual probe design exercise, as well as the background from the rest of the course and their own experience, to design a 12-minute in-class learning experience for the rest of the students. The learning activity was delivered and videotaped during classes in weeks 8 through 10. Assessment of the activity was done by students and by instructors, who used a brief set of assessment criteria that the students developed earlier in the quarter. The assessment criteria consisted of four categories: organized (clear learning goals, continuity of learning experience, and timing), student-centered (builds on prior knowledge and active engagement), material (appropriate level and relevant to learning goals), and delivery. As homework, students wrote a rationalization and description of their own classroom instructional design and proposed improvements on the design. In their write-up, students used their own perceptions, the feedback from students, and the videotapes of their classroom instruction.

The Evolution of One Student's Understanding of Teaching and Learning

One student's entry essay, teaching philosophy, and concept maps provide examples of how students incorporated their new knowledge from the course into their existing knowledge and value systems. (Concept maps are schematic devices for showing relationships between concepts.[8]) This student is working toward a master's degree in electrical engineering. He took the class because he would like to teach electrical engineering in a university setting, particularly in a "cross-cultural" context such as in a developing country. He does not have any teaching experience, other than in informal small-group settings, and says that he feels uncomfortable in guiding discussions or talking in front of a class.

In his entry essay, which was due the second day of class, this student said that he is an experiential learner and that his most significant learning has taken place outside of the

classroom. He says, “I wonder if this is not how much of engineering learning is done, and whether engineering courses are really designed to properly facilitate experiential learning.” He loves to learn, especially through thought-provoking material. His best classroom experience so far was in an undergraduate course on the history of Christianity. What made this class so memorable was the challenging material that prompted discussions and debates. “Without the lecture discussions and the required reading and writing I would not have been able to fuel such debates, but without the debate, I would argue, I would have never *really* learned.”

He believes that engineering education can be improved. Engineering classes have been the least thought provoking for him. These classes usually follow a lecture format, which he considers boring. Instructors should invite student involvement in classes. Interjecting short exercises or questions keeps the students “involved and awake.” An instructor also should be more approachable, be “a real person” for even a minute in each class, be sincerely interested in the material, and be organized. He hopes that through taking this class he can be part of the improvement in engineering education.

In his teaching philosophy statement, he says that teaching is not an end in itself. The only reason for teaching is to cause learning. Teaching is only one means to learning. Students should be able to see instructors as fellow learners who involve the students in their own curiosity. He stresses that engineering is an applied science. Learning is successful when students apply knowledge outside of the assigned material. Learning also is not an end in itself but rather is a means to service:

> For me, this desire to serve leads to a continuous quest for knowledge and understanding. This curiosity is fuel for my learning and is what I desire to share with my students. If I can enable students to be curious and hungry for knowledge, they will not only learn the material for the course I am teaching, but will be empowered to effectively serve the world with their continually growing knowledge.

From his perspective, the ultimate goal of learning is for students to integrate course material with knowledge from multiple disciplines and then to apply it to other contexts. Future engineers must consider the people that engineering (technology) will affect and must gain competency in working both alone and with others. To accomplish this goal, instructors should try to create a “cooperative learning community,” with a variety of learning activities, and encourage students to relate engineering with non-engineering material and everyday life. He claims that the measure for success of a course is “the extent to which the material…is integrated into the students’ prior knowledge and given a high value in the students’ minds.”

In his entry concept map (Figure 1), *Teaching and Learning* serves as the center of the map with five hubs leading from this center: *Methods of Teaching and Learning* (“how”), *What Should We Get from Teaching and Learning* (“results”), *Schools* (“done in”), *Non-Schools* (“done [where]”), and “done by.” (“Done by” is considered as the hub name, even though it does not appear in a circle.) Items branch from each hub; sub-items branch from the items. For the most part, the overall map and the hubs seem to follow a straightforward organization.

The exit concept map (Figure 2) is similar to the entry map in that methods and outcomes lead from a central item, but this is where the similarity ends. During the class discussion that

occurred after completion of the exit maps, students said that their entry maps were more general and superficial than were their exit maps, which certainly is the case with this student. In his exit map, teaching and learning are separate items. *Teaching* seems to serve as the center of the map, even though it is located on the left side of the page. Placing *Teaching*, rather than *Teaching and Learning*, as the center of the map allows *Learning* (*Knowledge and Understanding*) to become an outcome **from** T*eaching* and allows *Service* to become an outcome from *Learning*. The exit map shows only one goal (*A Better World*) leading from *Service*. The connection between *Service* and *Better Communities/World* is made in the entry map, but *Service* is on the methods side and *Better Communities/World* is on the outcomes side. Moreover, the entry map shows several other goals (freedom, passion, satisfaction, career/work), all on the same level as *Better Communities/World.*

The consolidation into one goal on the exit map highlights the major difference in the two maps: The entry map focuses more on personal values and beliefs, whereas the exit map focuses on specific techniques and knowledge that inform teaching, such as methods, assessment, and cognitive science. For example, the methods hub on the entry map branches to broad and prescriptive items. It contains only one specific method (*Books*). The methods hub on the exit map, on the other hand, branches to a whole group of teaching methods and accompanying strengths and weaknesses. These strengths and weaknesses seem to emerge both from the course readings and from the student's own experience.

The exit map seems to be devoid of people. It stresses the role of the teacher and what is done to and for the learner, rather what the learner does in the process. The *Assessment* item, for example, leads to *Teaching* with no indication that assessment can serve as feedback for the learner. Sub-items leading from the *Assessment* item (*To Give Grades* and *To Help Teacher Teach Better*) also seem to be teacher-centered. In the same vein, attributes of the learner shown on the map, such as types of memory, misconceptions, and learning styles, seem to be presented in terms of informing the teaching process. The only place on the map where the learner takes an active role is in fulfilling the goal of teaching. This focus on teaching was evidenced in other student exit maps. During the class discussion of the maps, some students mentioned that they had made teaching the focus of their exit maps. They said they were focusing on teaching tools and methods. Some students said, after being asked, that their focus might have been different if the prompt had been "learning and teaching" instead of "teaching and learning."

The focus on teaching in this student's exit map, however, may not necessarily indicate that the map is a teacher-centered as opposed to student-centered representation. The teacher is thinking about the learner when he or she considers the learner's way of processing information, the research regarding the efficacy of teaching methods to facilitate meaningful learning, and the students' diversity and learning styles in selecting methods. Moreover, the link from *Assessment* to *Teaching* could provide information not only for assigning grades but also for how well the students are learning.

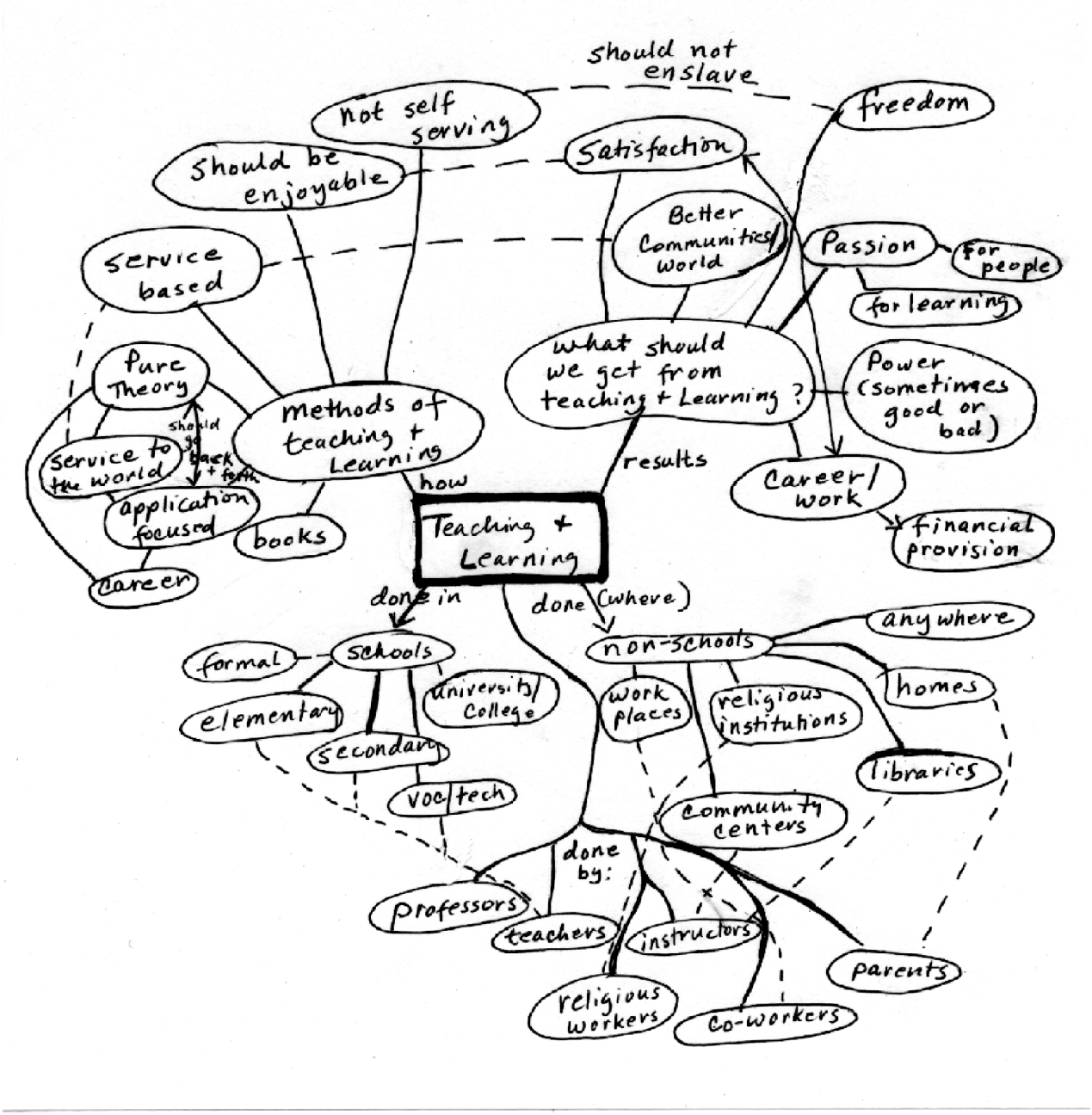

Figure 1. Entry Concept Map

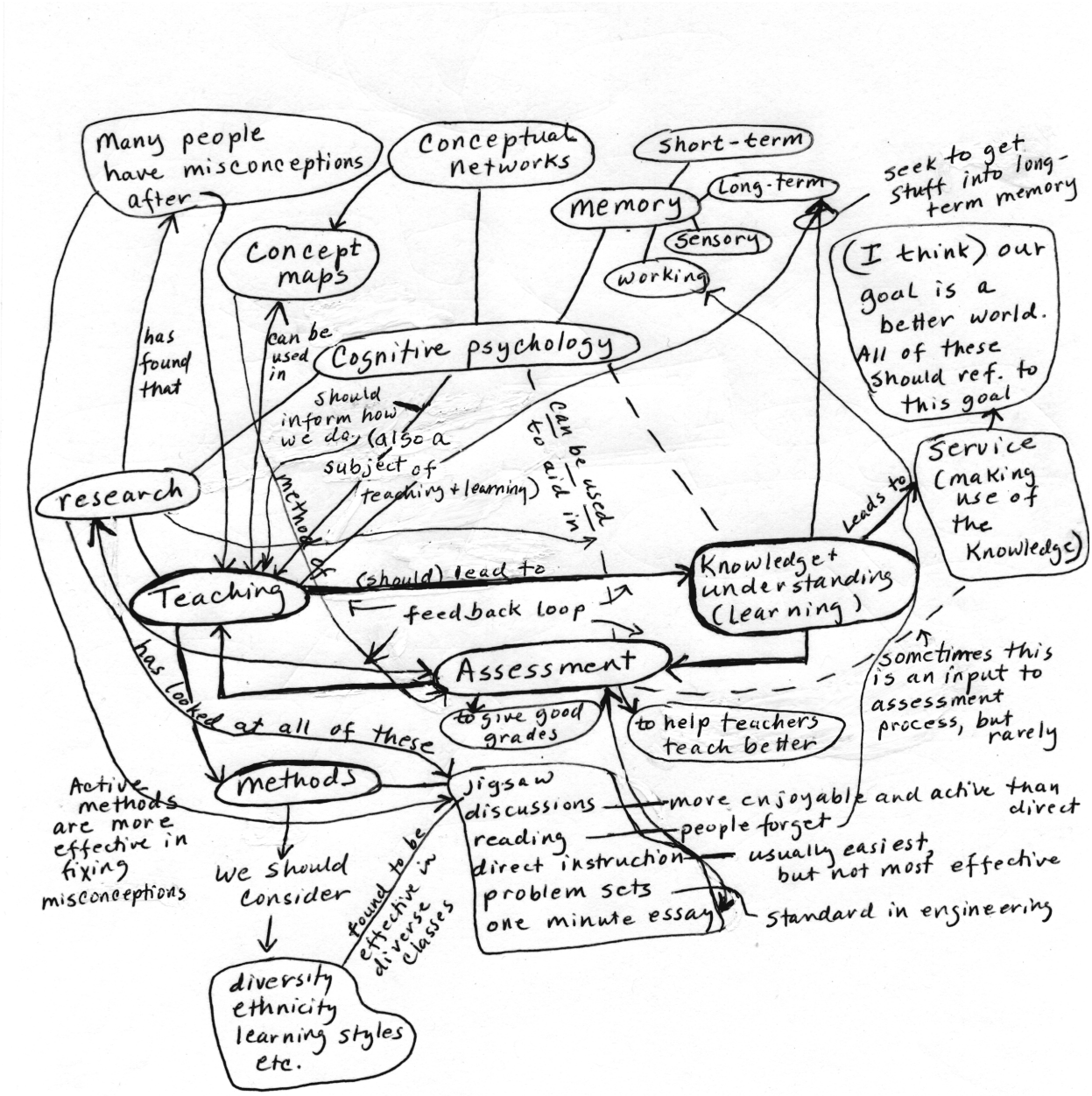

Figure 2. Exit Concept Map

The theme that knowledge should be applied carries through the student's writing and concepts maps, regardless of changes in organization and content. This theme seems to take on two different meanings. One meaning for application is the use of knowledge in a practical way, as evidenced by *career* appearing on both the methods and the outcome sides of the entry map. The other meaning of application is the use of knowledge as a means to serve and to create a better world. It seems that only the second meaning of application (as a means to serve and to create a better world) carries into the exit concept map. The word "career" does not appear on the exit map, as it did in the entry map. It could be inferred that *Making Use of the Knowledge*, which appears beneath *Service*, could apply to both meanings, especially because this item is linked to *Assessment* with a broken line and the linking text, "sometimes this is an input to assessment process, but rarely."

(Note: Concept maps were redrawn to fit vertically on the page.)

Student Evaluations of the Course

To chart how well the course was working we sought frequent feedback. In addition to the usual means of receiving student feedback—comments in class, conferences with teachers, and end-of-course evaluations—we implemented the following feedback devices:

- A consultant from the Center for Instructional Development and Research (CIDR) on campus conducted a mid-quarter evaluation.
- Students completed a course-specific feedback form as their last reflection for the quarter.
- We set up a means for students to submit anonymous comments via the course Web site.
- A graduate student in education observed the class.
- The two instructors and the observer met regularly during the quarter to share observations.

The CIDR consultant conducted the mid-quarter evaluation with the students for the first part of one class period. Instructors did not attend the evaluation session, but later received a summary from the consultant. The students were asked to break into four small groups. Each group discussed and wrote their responses to the following questions: What is helping you learn in this class? What are the major strengths in the course? What recommendations for change do you suggest? And how should these changes be implemented? The representative then conducted a whole-class discussion.

Two course strengths, according to the students, were the high degree of participation in class discussions and the flexibility and openness of the instructors. Students said that the instructors were open to student ideas, perspectives, and contributions. The instructors did not "put-down" the students. All opinions and ideas were accepted. Other strengths were the team teaching, the textbook, and the e-mail reflections on the readings. The students said that the e-mail reflections forced them to think about the readings and to expand on them. And the reflections helped them to see what others thought about the readings.

Students also considered as strengths the diversity of student backgrounds and disciplines, the variety of course content and methods ("each class period is a different activity"), and the opportunities to practice teaching. One group said that being allowed to lead parts of the course provides the opportunity for learning by doing.

Many of the recommendations for changes centered on the course readings. Students said that they needed more of a sense of how to apply the abstract theories to teaching, especially to **engineering** education. They expected, however, that this gap between theory and application would narrow as the course progressed. Other problems were logistical, such as keeping track of changes in the syllabus, getting access to the readings, and understanding expectations. One group wanted more group discussions. "Discussions are great!"

By the time the students completed the course-specific feedback form at the end of the course, we had smoothed out course logistics. The form was divided into two parts: topics and instructional strategies. Students rated each topic or activity on a scale of –3 (I strongly disagree with the statement) to +3 (I strongly agree with the statement) for four different categories: *It challenged me, I know more, It helped prepare me, and I enjoyed it.* Space was provided for written comments. Table 2 shows the student ratings. All ratings were on the plus side of the scale, and most were 2 or 3. The lowest ratings for instructional strategies were for the guests who came to discuss teaching portfolios, conduct the mid-quarter assessment, and talk about diversity. These lower ratings were reflected for corresponding topics: teaching portfolios and diversity.

For topics, the highest ratings across all categories (a 3 in all categories, or a 3 in three of the categories and a 2 in the remaining category) were for alternative conceptions, learning and teaching strategies, and instructional design/student teaching exercises. The corresponding instructional strategies—the conceptual probe and individual student teaching—showed the same higher ratings. One student said, "I really appreciated the student teaching experience, and I feel that I would have really benefited from doing more activities like it." Another student said, "I learned a lot by trying and getting it [conceptual probe] wrong." Other highly rated instructional strategies across categories were the teaching philosophies and general discussions.

Some of the differences in ratings for categories in one topic or instructional strategy yield interesting insights, especially when combined with student comments. For example, the introduction to cognition received a 3 for *I know more,* a 2 for *It challenged me,* and a 1 for both *It helped prepare me* and *I enjoyed it.* Even though students did quite well in applying the material on cognition to their teaching activity, some expressed a desire for more explicit links between theory and practice:

> The course has been planned out very well. The way it started with cognitive material is kind of fun, but it's hard to link deep information of the first week to the design of instruction or to teaching. Creating a link through discussion may help.

Table 2. Summary of End-of-Course Student Feedback for Graduate Engineering Course on Teaching (scale: -3 to 3)

Topic	Challenged	Know More	Helped Prepare	Enjoyed
1. Teaching portfolios	2	3	1	0.5
2. Introduction to cognition	2	3	1	1
3. Motivation	1	2	1	1
4. Learning/teaching strategies	2	3	3	2
5. Misconceptions/alternative conceptions	2	3	2	3
6. Assessment	2	2	2	1
7. Diversity	1	1	2	1
8. ABET	1	2	1	1
9. Instructional design/student teaching exercises	3	3	3	3
10. Engineering design research and teaching	3	3	2	2
11. Overall course planning	2	3	2	2
Instructional Strategies				
Visitors				
1. Teaching portfolios	1	1	1	1
2. Mid-term assessment	1	2	1	1
3. Diversity	1	1	1	1.5
Assignments				
4. Conceptual probe	3	2	3	3
5. Assessment	2	2	2	2
6. Student teaching (individual)	3	3	2.5	2
7. Teaching philosophy	3	3	3	3
8. Peer reviews of teaching philosophy	2	2	3	2
9. Reading reflections	2	2.5	2	2
Classroom Activities				
10. Group student teaching	3	2	2	2
11. General discussions	2	3	3	3
12. Small group discussions	2	2	2	3
13. Lectures	2	2	1	2
14. In-class activities (jigsaw, concept mapping, misconception probe, feedback form, engineering design coding)	2	2	2	3
15. Video—*A Private Universe*	1	2	2	2

The small group discussions and the in-class activities received a 2 for three categories, and a 3 for *I enjoyed it.* In contrast, the large group discussions received a 3 in three categories, and a 2 in *It challenged me.* It appears that some students for which English is not their native language preferred the small groups. One non-native speaker said, “I really liked in-class activity and jigsaw. It is very fun. Small group discussion is good. My English ability is low. So I’m kind of shy to speak to general discussion. In jigsaw and small group discussion, I have some chances to discuss and I really like it.” A native English speaker expressed the opposite sentiment: “I like the general discussion a lot. The small groups are difficult unless [you’re] in with the right people. I would have liked the opportunity to discuss and learn from the in-class activities—meta discussion.”

One theme that comes through is that the students perceived that they learned a lot and that what they learned will help them in the future. With the exception of the visitors and the diversity topic (which was covered by one of the visitors), all topics and instructional strategies received a 2 or 3 rating in the *I know more* category. The ratings were slightly more mixed in the *It helped prepare me* category, but still were predominately 2 and 3. One student said, "I enjoyed this course as it has provided material that I will apply to my future classes, both in teaching and how to facilitate learning." Again, the visitors received a 1 in the *It helped prepare me* category. Other items receiving a 1 in this category were mostly topics: the teaching portfolios, introduction to cognition, motivation, and ABET. The only activity given a 1 for helping students prepare are the lectures (only a few) that we gave. These ratings seem to be telling us that the information alone is not sufficient to prepare students for teaching. The assignments and activities—the active learning and application of the information—were important pieces in completing the circle. One student said, "I really appreciated the student teaching experience, and I feel that I would have really benefited from doing more activities like it."

The ratings indicate that students clearly enjoyed and were challenged more by the instructional strategies than by the topics, perhaps because the topics and the guest speakers were not integrated sufficiently into the overall flow of the course. The strategies that were most challenging and enjoyable were the conceptual probe, student teaching, teaching philosophy statement, group discussions, and in-class activities. One student appreciated that we "modeled a wide variety of methods through this class." One of the main challenges for some students, as noted earlier, seemed to be linking theory with practice:

> I struggled a bit as we laid the foundations, although it was new and interesting, because I wondered when we'd get to some of the engineering-specific stuff and the practicals of course design. Topics were selected well overall, though. Maybe could have used some of the time each day to hear your perspectives as teachers on each topic, what you've found practically (e.g., motivation, misconceptions, learning probes, etc.).

Another challenge for a few students was linking all the pieces of a course that was laden with information and activity. One said, "The course covered many topics, which made me lost at first." Interestingly, not only the exit concept map but also the feedback form itself served as a means to help one student, at least, tie all the pieces together:

> I think there was a good mix of topics in this class. Looking over the list in an organized way solidifies what it is that we have covered, i.e., doing this evaluation, is mildly helpful, just because I have not had much of a chance to put all the pieces together in my mind.

Our Reflections on the Course

Did we meet our example student's measure of success of a course: "the extent to which the material…is integrated into the students' prior knowledge and given a high value in the students' minds"? We think that we did.

Students in the course were provided with background information about concepts and ideas in education, they were given examples of applications of the ideas and concepts introduced, and they were given a number of opportunities to apply those concepts, to receive feedback, and to reflect on their practice. We believe the students now possess a foundation of knowledge and a

set of tools that will help them continue to learn about teaching and learning in the future. Student feedback in the form of course evaluations indicates that students share our belief.

We also share with our students their views on what could be improved. One improvement we could make, if possible, would be to give students even more practice in designing and delivering instruction, but without sacrificing any of the introductory material in the course. Doing this will require some extreme creativity and juggling skill—or perhaps a two-quarter sequence. We would also add more substantial coverage of several topics, including diversity, relevance of course material to engineering education, overall course planning, and discussion and debate about ways to best use time inside and outside of the classroom and about the various goals of instructional design. (Various instructional goals include completing a task, stimulating interest in and curiosity about an activity without necessarily completing the activity, and providing a foundation for future learning.) Although student course evaluations indicated low interest in the diversity and ABET topics, we suspect that student perceptions of the intrinsic interest and value of these topics could change if they were presented differently. Both of these topics were presented in stand-alone lectures (by us or by visitors), without adequate instructor-led preparation before and reinforcement after the lectures.

The probes that we gave our students provided further valuable feedback for future course design. For example, the exit concept maps suggest that many of the students may still perceive teaching and learning as a teacher-centered endeavor, particularly in regard to the function of assessments and concept probes. Many of the maps link assessment and conceptual probes as a source of information for the teacher, with little recognition of their potential value as learning experiences and feedback opportunities for students. By asking students to construct the map around “teaching and learning,” we may have inadvertently suggested that teachers are the centerpiece of the process. Before we teach the course again, we will investigate ways to raise student awareness of the role of students and teachers in the teaching and learning process (*what* or *who* is central) and the role of assessments as learning devices.

Certainly, the behind-the-scenes work time will be substantially lower the next time we teach this course. Although a great deal of the classroom activities were run by students, the logistics of setting up the student-led activities required a lot of planning time. Technology (the course Web page, the listserv, and the Web-based peer-review of teaching philosophy statements) greatly enhanced the communication between students and between instructors and students, but the design and maintenance of these aspects of the course were very time consuming.

All in all, given the limited time in terms of number of class meetings and demands on graduate student schedules, we feel that we made appropriate decisions in the priorities we set. We accomplished a lot in this course, especially for a first implementation, and we have many pieces in place for a successful subsequent implementation. Much of the credit must be given to the students, who were extremely motivated, responsive, and patient.

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