Final Evaluation Report
Pilot of First-Year Design Course
1994-95

"Introduction to Engineering"

College of Engineering
University of Wisconsin - Madison

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prepared for

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Executive Summary[1]

Background: The Coming Together of Faculty, Administrators, an ARPA-TRP Grant, and Other Funding Sources

The first-year design course evaluated in this report is a key element of an Advanced Research Projects Agency-Technology Reinvestment Program (ARPA-TRP) grant to the Engineering Research Center for Plasma-Aided Manufacturing (ERC for PAM). The principal investigator of this TRP ARPA grant is J. Leon Shohet, ECE Professor and Director of the ERC for PAM. The grant manager is Denice Denton, ECE Professor and Leader of the Education Thrust Area of the ERC for PAM. The Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center is conducting a third-party evaluation of the course. This report, a product of that evaluation, focuses on student learning experiences as well as instructor course implementation processes during the pilot year, 1994-95.

The ARPA-TRP grant and funding by Procter and Gamble financed summer 1994 faculty salaries for the course planning, five pentium-based personal computers and peripherals, stipends for the senior assistants, supplies for students' projects, and other costs associated with the course. The ARPA-TRP grant, matched by a Graduate School project assistantship, LEAD start-up support from the Chancellor, and a portion of the IBM Quality Award, supported the LEAD Center evaluation. Some of the professors were granted release time from their regular teaching schedule by their departments to teach this new course. Others simply participated on an overload basis. The departments of the seven faculty and the administration have been supportive in terms of providing space for lectures and laboratories and photo-copy services. Departments encouraged others including machinists and shop managers to be consultants to students. In summary, departments and administrative offices have supported the instructional effort.

When resources to develop a first-year design course were made available through the ARPA-TRP grant, seven faculty who, through the College's pilot Teaching Improvement Program, had participated in a year-long study of effective teaching and learning strategies volunteered to develop and pilot this course. First presented as an elective titled, "Introduction to Engineering," eighty-two first-year students (out of a total pre-engineering class of 783) completed the pilot course during the 1994-1995 academic year. Students registered for the two-credit course under one of three titles: ECE 379, ME 602, or NEEP 602. Sixty-seven completed the course in the fall, while fifteen completed it during the spring. Seven labs or sections of up to 12 students each were taught in the fall and two labs of seven and eight students each in the spring. Students were both male and female. Females represented 30% of the fall class, a higher proportion than the 22% females in the fall 1994 entering pre-engineering cohort overall. Only one female participated in the spring. Other minorities represented less than five percent both semesters. The low enrollment during spring was likely caused by three factors: the course was difficult to find in the

[1] The authors extend special thanks to Andrea Bailey and Lyman Lyons for their help in preparing this report.

Course Timetable, was not on a list of courses that fit the engineering curriculum, and did not benefit directly from promotion during Summer Orientation and Registration (SOAR).

The first year retention rates for students in the course were 96 and 67% respectively for the two semesters. These rates compare to a lower average first year retention rate for entering pre-engineering cohorts of approximately 75%. Of note, the retention rate for women who enrolled in the design course was high: 18 of the total 20 women finished the course and were still enrolled in the College as of summer 1995.

Goals and Methods: An Emerging Philosophy and Approach

Based on input from business, industry, colleagues, and students, the faculty articulated the objectives and goals first during their summer 1994 planning sessions. They designed the course around these goals and presented them to students in the fall semester's course notes. Based on their fall semester experience, faculty recognized the need to revise the goals during spring, 1995. After much discussion among themselves and with their colleagues, and following a number of formative feedback discussions with the third party evaluators from the LEAD Center, they articulated a philosophical framework for the course. This philosophy describes specific concepts that the faculty want students to learn. The concepts are grouped into "process" and "product" categories. The process concepts include design methodology, team interaction, communication, and confidence-building. The product concepts focus on engineering science topics and tools. A copy of the "Philosophy of `Introduction to Engineering'" appears in Tab 8.

A comparison of the goals listed for first semester and second semester demonstrates how the faculty modified the course goals and objectives.

Fall semester goals for the students as stated by the faculty in the student handbook are as follow:

* work constructively in a design team.
* learn some engineering principles and engineering language
* seek out, digest, and use information from diverse sources
* learn from and teach your colleagues
* get to know your customers: wheelchair users and building staff
* communicate your designs effectively
* understand the design environment (business, legal, social)
* keep a personal record of your design process and your learning

By the end of the semester, one member of the faculty team expressed the goals of the course in an email message to other College of Engineering faculty this way:

Major goals of the class include introducing students to the scope and breadth of engineering, developing team skills, building student confidence and abilities, and creating a framework within which students' college curriculum makes sense.

Spring semester goals for the students as stated by the faculty in their "Philosophy of

"Introduction to Engineering'" follow:

* allow students to learn how to form and work in teams (team dynamics)

* provide the opportunity for a sequence of successful experiences for the student

* have students acquire a feeling (hands-on) of what engineering entails and might encompass

* develop design process skills on a "real" design project with "real" customers

* develop skills for hardware and software usage in the projects in an as-needed basis

* develop context for engineering curriculum, so students see connections among math, science, and technology classes

* develop confidence in engineering as a career, particularly for students with little prior knowledge or experience in engineering-type activities

The faculty anticipate that the goals and philosophy that emerged during 1994-95 will continue to evolve as they strive to meet the need of the students and various stakeholders. As the following representative interview excerpt makes clear, the faculty believe that although they laid a strong foundation for the course during the pilot year, additional improvements will be made.

R: I think [our discussion] has made all of us more curious about assessment of student learning, and provided us with a lot of questions. We're very much aware that where we are is kind of neat, but we're probably going to end up in a different place--[although] not substantially different, philosophically different. What we've got now is a good start, but it's not the finished product yet.

The section on instructor experiences elaborates on faculty expectations for further course revisions, based on dialogue and interaction among the students, faculty and others. For a comprehensive look at the design project, the learning environment, course organization, and facilities, please refer to the student handbooks for both semesters. For a closer look at the process by which the course was designed and the manner in which the course was conducted, refer to the paper which the faculty presented at June 1995 annual meeting of the American Society for Engineering Education.

The Students: A Learning Community of First-year Students

During both semesters students worked in small laboratory groups of seven to twelve students. Within each lab, students worked in at least two smaller teams throughout the semester. During the first half of the semester, the team created a proposed solution to the "real-world problem." During the last half of the semester, the entire lab was once again a larger team, but students created new teams to accomplish the task of designing and testing their proposed solution.

The student teams became small learning communities in which students made connections among themselves by working together to design and test solutions to real-world problems. The value of the common experience that the learning community provided them became apparent through interviews and focus group discussions with the students. For example, during a focus group discussion, two male students, one from each semester, described the value of the small group learning community this way.

S1: Definitely [making friends in small design teams] makes a difference. You come there and you don't know anyone pretty much and you walk around and you see all these new people. And you take these classes and you get to know people [in general], and then you are just walking around campus you see these [friends from the design class] and you say, "Hi" just as you walk by. And it's really nice to feel like you fit [in engineering], that you know people. You're not a stranger. It just feels nice to have someone to say "Hi" to you!

S2: Once in awhile it's like scary. Like if you are going down University Avenue or something and you see 3 people in a row that you know from other classes. It's like "Hi!" "Hey!". I only stay in touch with one person that I know from my high school... pretty much everybody that I know down here, I met down here. It's just weird.

I: Do you feel it was easier to recognize the people that you were with in your design course last semester vs. some other class? Does the group size make a difference?

S2; Yeah, because you know them better. I'll recognize a lot of people, but it's like, "Hey, I know you!" ...So everything becomes more familiar, but it's easier when you actually know the person and you might know both their first and last name and some stuff about them. You've actually worked with them.

I: Let's talk more about that: you've actually worked with them. What role does that have to play here and in making you, to use your words, feel like you fit here in engineering?

S1: Well, you've had a common experience. You've got something you can talk about--remember when you did this or that.

Moreover, the students made connections among the various components of the course. As the following representative excerpt indicates, they became aware during the course of how these different components worked together in support of the learning process.

S2: It just seemed like an on-going process even though you only met twice a week. It would have been almost nicer if we had two labs a week because things tended to get rushed. The email even brought you closer. Like I said, you had it twice a week and lab just once a week, but you felt the whole connection going on all week pretty much. And we had to do those Friday reports, which was good.

I: So you're saying that there was a connection all week because of the email?

S2: Yeah, and like in a physics course, you go to your lab, you have your discussion, and you have your lecture, and whenever you're in class that's kind of when you are concerned with it, besides studying outside of class... But in the design course, it's "I have to get this ready for next week." And if it's something important, everybody is going to be depending on you, and you are depending on them for other things. Whereas in a [regular] course you have maybe a quiz every once in awhile and then you have your midterms and it's like segmented in these big time frames.

For more details on the student experience, see Tab 2.

The Instructors: A Learning Community of Faculty and Senior Assistants

Faculty represented four of the nine engineering disciplines taught at UW-Madison:

Mike Corradini, Professor, Nuclear Engineering and Engineering Physics and Mechanical Engineering
Pat Farrell, Professor, Mechanical Engineering
Dick Marleau, Associate Professor, Electrical and Computer Engineering
John Mitchell, Professor, Mechanical Engineering
John Moskwa, Assistant Professor, Mechanical Engineering
Katherine Sanders, Post-doctoral Program Director, Industrial Engineering
John Webster, Professor, Electrical and Computer Engineering

The course was additionally supported by seven senior engineering students each semester, known as "senior assistants" (SAs) who assisted faculty and students in the laboratory sections.

Lauren Barker, Civil and Environmental Engineering, first semester
Burvil Chang, Civil and Environmental Engineering, both semesters
Bob Gustafson, Engineering Mechanics, second semester
Bryan Hutchinson, Mechanical Engineering, both semesters
Derek Mayer, Nuclear Engineering and Engineering Physics, first semester
Luciano Oviedo, Electrical and Computer Engineering, second semester
Robin Possell, Industrial Engineering, first semester
Janet Reesman, Chemical Engineering, second semester
Robyn Ryan, Mechanical Engineering, first semester
Leah Samson, Mechanical Engineering, both semesters
Melanie Vrettas, Electrical and Computer Engineering, second semester

Both faculty and senior assistant teams functioned as learning communities as well. They learned from one another and recognized that students were observing them as they too grappled with the challenges of teamwork. This faculty comment illustrates what all the faculty members said in one way or another:

Because of the kind of class, the faculty team was very helpful. The other issue though is faculty working as a team. I have to say it is difficult if not somewhat hypocritical for faculty in a class like this to preach teamwork and really grade students on teamwork and not demonstrate or learn or experience it themselves...demonstrate their own teamworking abilities. I wouldn't want to say that everybody should be graded for their goodness or badness as a team member, but I think that it is a very different thing to have experience first hand being a member of a team. rather than just the academic issue of "oh teams are good, so theoretically you should all like being in teams. So go be a theoretical team." So in that sense, I think that the experience of working in teams is pretty important for faculty if they want to have any sense of what their students are experiencing.

For more details on the faculty experience, see Tab 3.

The Content and Teaching/Learning Methods

This section describes the course components as they would appear to an observer.

Lectures: Students attended one 50-minute lecture at 8:30 a.m. each Tuesday. Lectures took place in rooms in Engineering Hall (EH) that featured blackboards as their only education technology. Final presentations took place in room EH 1610 (first semester) and EH 3609 (second semester), which featured more advanced educational technologies.

Labs: Students attended one of seven, three-hour labs each week during first semester and one of two evening labs during second semester (Tuesday and Wednesday). First semester, two labs were in the evenings (Tuesday and Wednesday) and the other four were held during the day (either Tuesday, Wednesday, or Thursday). Lab size varied from seven to twelve each semester. Faculty and students received an outline of lab activities for each week. Students attended labs regularly; seldom did students miss.

Project: A "real" engineering project with "real" customers is the cornerstone of the course around which the design process revolves. The concept of the "real" customer sets this first-year design course apart from similar courses across the nation, as one faculty person learned at the 1995 ASEE Annual Conference. The fall design project on which the students focused was access for wheel chair users for historic buildings at Old World Wisconsin. Wheel chair access to an additional building, T23 on the University of Wisconsin-Madison engineering campus, also was involved. The spring project was a counter system to determine the number of people who enter the Kurt F. Wendt Library and Olbrich Gardens. Students in small design teams evaluated customer requirements, brainstormed solutions, selected the best solution, designed the product, and constructed and tested it.

Homework: Students completed several homework assignments early in the semester. Topics included computer software for word processing and drawing, stress analysis, and a library search at the Kurt F. Wendt Engineering Library.

Journals: Students kept a personal design journal to track both the design process and class learning throughout the semester. Faculty reviewed the journals periodically and incorporated them into the course grade.

Notes: For fall semester, a handbook that the faculty had prepared during summer 1994 constituted the textbook. Additional notes were often distributed during lectures and labs throughout the semester. For spring, the handbook was more extensive since handouts in the previous semester were incorporated into the handbook.

Presentations: Students prepared and delivered two presentations during the semester. The first was within their own lab when each team of three or four students presented their team design. The second was presented to all students, all instructors, some real customers, COE faculty, and COE dean. Each lab group of up to twelve students presented their lab's design using the multimedia facilities of a high tech classroom.

Assessments: Students participated in peer and self assessments after both presentations. Faculty used the results to help assess student learning in terms of team process and project. Some faculty shared the assessment results after the first presentation; most did not. A new assessment second semester was an end-of-semester essay that students wrote to reflect their engineering experience. This essay accounted for a portion of the grade.

Office hours, Email Dialogue, and Weekly Updates: Both faculty and senior assistants held regular office hours and encouraged open communication by electronic mail throughout the semester. A large number of email messages were exchanged, with the weekly number received ranging from two to ten. Often faculty shared these replies by forwarding them to all students and instructors because the answer to one students' individual question would benefit everyone involved in the course. (A log of email dialog among faculty and students is available in the LEAD Center.) We have insufficient information to report how frequently students attended office hours. During second semester, students submitted weekly individual progress reports by email. This replaced the team reports by email that were part of the first semester course. Faculty responded to each student's weekly update on a regular basis.

Research Questions and Preliminary Answers

The purpose of the qualitative research reported here is to yield contextualized understanding of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college. Further, the research centers around a case study of a curriculum innovation. The curriculum innovation is the new freshman design course. We list here the research questions investigated by the evaluation project, as articulated in the evaluation proposal. This section distinguishes between research questions regarding student learning experiences and questions regarding instructor teaching and learning experiences. The methodology and procedures for analyzing and reporting both student and instructor experiences are described in Tab 9.

Research Questions Based on Instructor Objectives for Student Learning

1. What is the impact on students of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college?

2. Can qualitative evaluation methods provide insightful answers to the question of how, how well, and what are students learning in this course?

3. Do student assessment procedures (journals, homework, observations) adequately measure what students are learning and foster the learning process?

4. How well is the course achieving the faculty's goals for student learning?

Research Questions Based on Instructor Objectives for the Course

5. What is the impact on instructors (faculty and senior assistants) of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college?

6. What do and how can the faculty who are team-teaching this course learn from each other while investigating the key question, "What and how are the students learning"?

Preliminary answers to these questions are provided in the remainder of this Summary.

Research Question 1.

What is the impact on students of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college?

The qualitative evaluation, supported by the limited available quantitative data, indicates that the first-year design course has had a positive effect on the students. We are confident that effects are present and have important consequence for student learning and undergraduate curriculum in the College of Engineering. Effects based on the quantitative data are listed first (a - c, below); effects based on the qualitative data help answer the question "Why is the course having the effects?" and are listed next (d - k).

Key patterns emerging for the students include:

a. Students who completed the first-year design course are staying with engineering at a higher rate than students who did not enroll in the course.

b. Students who completed the first-year design course are selecting a major, as opposed to remaining with a BS or BA classification, at a higher rate than students who did not enroll but were on the waiting list for the course.

c. Students who completed the first-year design course are choosing more different engineering disciplines to pursue than students who did not enroll but were on the waiting list for the course.

d. Students experienced engineering in a supportive environment and got a background to make informed career decisions.

e. Students acquired knowledge of the engineering design process.

f. Students experienced context which gives them 1) an understanding of why they need math and science courses, and 2) motivation to pursue an engineering career.

g. Students developed a real-life appreciation of the need for excellent communication skills and worked to improve these skills.

h. Students increased their confidence and self-esteem, and experienced engineering through the teamwork that revolves around real-world, customer-based projects.

i. Students perceived the faculty and senior assistants as a team working together to provide instruction to meet students' learning styles.

j. Students connected with engineering by building common experiences that led to strong friendships and, therefore, increased motivation to learn.

k. Students discovered that they can succeed in engineering if they choose to follow that direction.

See data points and learning outcomes in Tab 2 for information that would support these conclusions.

Research Question 2.

Can qualitative evaluation methods provide insightful answers to the question of how, what, and how well are students learning in this course?

Yes, qualitative evaluation methods provide insightful answers to the question of *how* students learned in the first-year design course. Virtually all students mentioned how the group work which was intrinsic to teamwork helped them learn. They frequently mentioned in one-on-one interviews, focus group discussions, and on the open-ended question survey that hands-on experience with a real project and real customers helped them learn. Although few students mentioned their journals as a tool to help them learn, faculty who reviewed the journals are confident that students' reflective writing in the journals helped students learn. Data from observations of lectures and labs support the conclusion that student teams, hands-on experiences, and journals are effective tools to effective learning. Although the observation method revealed that students were learning specific skills like teamwork, presentation, and design skills, only the interviews and survey methods were able to confirm from the students' perspectives that teamwork is instrumental in *how* they learned. Conversely, data from across all sources show that the homework and notes were the least effective as tools that fostered student learning.

Yes, qualitative evaluation methods provide insightful answers to the question of *what* students are learning. Student responses during one-on-one interviews, focus groups, and on surveys provided open-ended opportunities to identify what they were learning. Using structured interview protocols and referring to the goals for the course, student respondents gave more insightful answers than traditional methods may be able to capture.

Yes, but to a limited degree, qualitative evaluation methods provide insightful answers to the question of *how well* students are learning. Although the student interviews could capture some of the enthusiasm that students had about their learning, the qualitative methods are not designed to determine how well students are learning. It is necessary to make careful observations over time to assess whether the course successfully improves students' abilities to form, interact, and present information as teams. This type of intensive observation data was not collected by the third-party evaluators. Faculty alone are in a position to determine how well students are learning specific information and skills.

See data points and learning outcomes in Tab 2 for information that would support these conclusions and Tab 9 for a description of the evaluation research methodology.

Research Question 3.

> *Do student assessment procedures (journals, homework, observations) adequately measure what students are learning and foster the learning process?*

Faculty used a variety of assessment procedures to measure what students learned in the course, including continual observations, peer and self assessments, and journal writing. Yes, the student assessment procedures foster the learning process. Minor adjustments may improve the assessment procedures so that they more adequately measure what students are learning. Researcher interviews with students indicated that students perceive these procedures as measuring what they are learning and that they do, in fact, help students in their learning process. Virtually all students commented about how the non-threatening, non-competitive teaching environment with the journal writing, instructor observations, and self-and peer assessments helped students' learning process. Virtually all students also commented on how frequent reviews and comments from faculty helped them as well.

According to interviews with faculty, the assessment procedures measured what students learned. Given the goals and objectives for the course, almost all the instructors were comfortable using their own observations, student journal entries, and peer and self-assessments to assess what student goals were accomplished. The question of what students were actually learning in the first-year course was debated throughout second semester among the faculty. Faculty recognize the need to continue to experiment with assessment procedures to help them determine what their students are learning and what they as faculty can do to improve the learning. (See data points and learning outcomes in Tab 3.)

Research Question 4.

How well is the course achieving the faculty's goals for student learning?

Data from across all sources support the conclusion that the first-year design course is achieving the faculty's goals for student learning. Interviews with students help document what and how the students learned. Their UW-Madison classifications at the end of their freshmen year help document that most students who completed the design course are still interested in an engineering career. Interviews with faculty help document faculty perceptions as to how well the course is achieving the goals for student learning. Virtually all the faculty agree that the course they designed is helping students achieve the intended goals. Virtually all the faculty also agreed that goals related to process were more successful than goals related to product; that is, they recognized that the weakest parts of the course were helping students develop skills for engineering tools and engineering science principles and business, and integrating industrial ties into the course.

Worthy of note is that faculty debated the course goals throughout the year, especially following the first semester. Although a few faculty were concerned that they never reached consensus, virtually all faculty recognize the goals set forth in the "Philosophy of 'Introduction to Engineering'" as the goals for the course (see Tab 8). These goals, while somewhat different from those stated in the 1994-95 student handbook, are the result of the faculty's debate over appropriate goals and how to measure them. Also worthy of note is that goals stated by the principal investigators in one-on-one interviews are aligned with the goals stated in the philosophy (see Tab 4). Both faculty and principal investigators describe the goals in terms of giving first-year students a series of successful experiences as they explore real engineering problems. (See data points 3, 4 of Tab 2.)

<u>Research Questions Based on Instructor Objectives for the Course</u>

Research Question 5.

What is the impact on instructors (faculty and senior assistants) of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college?

The qualitative evaluation, supported by the limited quantitative data, indicates that the first-year design course has had a positive effect on the faculty, although some negative effects became apparent. Key effects emerging for the faculty are listed under instructor learning outcomes (LO) as described in Tab 3.

LO1. Achievement of goals for first-year students and SAs is an outcome by which faculty gauge the value of the course.

- Faculty saw tangible benefits in a first-year design course for freshmen students because such a course helps students make earlier career-decisions, specifically to stay or not to stay with engineering. Those students who took the course stay in engineering at a higher rate than students who did not enroll in the course.

- Faculty developed an appreciation for the importance and difficulty of developing and articulating student goals for all stakeholders including students, faculty, parents, administrators, and potential employers.

- Faculty became aware of and used many strategies to send a message to all students that "there's a place for you here."

- Faculty recognized the role of the design project with its real-world problems and real clients with whom students can interact.

- Faculty questioned the value of standard assessment strategies to determine student learning and some conflated the *assessment of what* students learned with *evaluation of the processes by which* students learn.

LO2. Faculty develop their own learning community, but find it may be more difficult for faculty to function as members of a team than for first-year students.

- Faculty experienced the need to develop their own team building skills as they recognized that their faculty team modelled teamwork for the students and senior assistants.

- Faculty recognized the value of a common ground and common language in their own development as a cross-disciplinary team designing a cross-disciplinary course.

LO3. Faculty develop as individuals.

- Faculty identified and differentiated among various instructor roles including the senior assistants and industrial visitors; they recognized the value in working closely with both groups and learning from that interaction.

LO4. Departments/administrators affect and are affected by the course.

- Faculty were motivated to change not only other courses they are teaching, but also department curriculum to meet the needs of students, parents, and employers.

LO5. Faculty become aware of the value and challenges of shifting teaching into a collaborative mode in a public arena.

- Faculty shifted to teaching in a collaborative and "public" mode.

LO6. Faculty express excitement, pride, and anticipation of an even better course in future years.

- Faculty began to articulate and prepare for scale-up issues including how to achieve consistency across labs, avoid excessive demands on faculty time, and achieve widespread faculty buy-in.

- Faculty recognized the major effort and time commitment that their role demanded, yet remained enthusiastic and proud of their contribution to undergraduate engineering education.

Research Question 6.

What do the faculty who are team-teaching this course learn from each other while investigating the key question, "What and how are the students learning?"

Faculty who team-taught the first-year design course *learned a variety of things from each other in a variety of ways*. Again, the key patterns emerging for the faculty are listed under instructor learning outcomes as described in Tab 3.

LO1. Achievement of goals for first-year students and SAs is an outcome by which members of the faculty team gauge the value of the course.

- Faculty learned that students can be active participants in their own learning by observing what and how the students were learning and comparing their observations.

- Faculty learned strategies to help students build confidence and self-esteem by discussing student experiences among themselves,

- Faculty were surprised to learn the degree to which student learning and confidence-building depends on the social aspect of an engineering experience by observing and interacting with students and each other.

- Faculty worked continuously to improve the course goals, content, teaching methods, and assessment strategies to meet the needs of students by constantly revising these components.

LO2. Faculty develop their own learning community, but find it may be more difficult for faculty to function as members of a team than for first-year students.

- Faculty established a common ground by participating in weekly discussions about teaching and learning through the Teaching Improvement Program and by planning the course together in regular meetings throughout the summer.

- Faculty experienced the benefits and frustrations of building their own faculty team by meeting often, distributing tasks, and writing collaboratively about their experience. Building an effective teaching team is a difficult task within the traditional higher education culture.

LO3. Faculty develop as individuals.

- Faculty learned that they need to make personal connections with students by recognizing the value of these interactions both personally and through formative feedback from students. They have both an individual and a collective responsibility to their students. Keeping the right balance is essential.

- Faculty learned that designing and teaching a course with a team of faculty from different departments (a cross-functional team) can be a life-changing experience by reflecting upon their pilot-year experience.

LO4. Departments/administrators affect and are affected by the course.

- Faculty learned new teaching and learning strategies by observing each other, especially during lectures. Some began to apply and adapt these strategies to other courses as well as the first-year design course.

- Faculty began to recognize the role of business and industry representatives as participants in the laboratory experience by observing one such representative who visited the labs, asked students questions about their processes, and shared stories about similar situations in his company.

- Faculty realized that an effective course is a dynamic course by seeing how what they did affected their colleagues and the College curriculum.

- Faculty recognized the importance of their roles in helping institutionalize the course by discussing their roles and vision with others outside the team.

LO5. Faculty become aware of the value and challenges of shifting teaching into a collaborative mode in a public arena.

- Faculty shifted their teaching into a collaborative mode by recognizing that team decisions result in a better product. They explained that an effect of their understanding of the teaching-learning process was a new understanding of the "public" nature of their teaching.

LO6. Faculty express excitement, pride, and anticipation of an even better course in future years.

- Faculty recognized that continuous improvement is the mode in which they are operating by realizing that changes are necessary. Virtually all realized that almost every feature/component of the course is evolving or emerging: the goals and assessment strategies and the faculty understanding of the teaching and learning process.

- Faculty were surprised at the skills and enthusiasm of freshmen. Working with students was enjoyable. Several stated that faculty in the College of Engineering may not expect enough of juniors and seniors.

Upon subsequent analysis, additional answers to these research questions may become apparent.

Analytic Generalizations: From the Researchers' Point of View

Analytic generalizations (AG) from the researchers point of view about the teaching and learning processes are divided into two groups: those pertaining to students and those pertaining to faculty.

Analytic Generalizations for Student Processes (Tab 2)

AG1. *Approach to problem-solving*: Systematic, teamwork engenders creative, multiple approaches to problem-solving.

AG2. *Attitude toward learning*: Virtually all students demonstrate a positive attitude toward learning and pleasure in connecting the engineering design process to real-world problems.

AG3. *Sources of affirmation*: Interaction with peers and "more-experienced others" helps students create and build their own design and feel comfortable in both a social and professional engineering environment.

AG4. *An "island" of connected understanding and real learning*: The course needs to "count" as a standard part of the College of Engineering curriculum.

AG5. *A family away from home*: The instructor team provides the environment and curriculum to help students make informed decisions about engineering as a career.

Analytic Generalizations for Faculty Processes (Tab 3)

AG1. *Approach to teaching and learning*: Collaborative teamwork engenders creative, cooperative approaches to teaching and learning.

AG2. *Attitude toward teaching and learning*: Faculty demonstrate positive attitudes toward teaching and learning and pleasure in connecting their TIP study of cooperative, collaborative teaching to a freshman engineering design course where they are both teachers of student teams and learners in a faculty team.

AG3. *Sources of affirmation*: Interaction with colleagues helps faculty develop their self-confidence in designing a curriculum that meets the needs of students and other stakeholders.

AG4. *An "island" of connected understanding and cross-disciplinary teaching and learning*: The course needs to gain buy-in from other faculty for acceptance within the College of Engineering.

AG5. *Early connections with high schools*: Faculty come to believe that the "before" connection with high schools is as important as the "after" connection with business and industry.

AG6. *Assessment of student learning and evaluation of the learning process*: Faculty are addressing these significant issues.

AG7. *Project with real customers*: This feature is essential to the "spirit" of the course.

Technical Information

The following information will help the reader understand the presentation of qualitative data presented in this report.

1. Use of Verbal Quantifiers in Reporting Qualitative Data

Specific verbal quantifiers are used to denote the relative size of a group of participants who presented particular perspectives or described particular experiences in interviews. It is important to note that due to the nature of qualitative interviews, the size of a group that *discussed* a particular type of experience does not indicate the size of the group who *had* this type of experience. Although the same interview protocol was used in each interview, respondents' answers often prompted discussion on a particular area that may not have emerged in other interviews.

The verbal quantifiers used in this report are

"a few" used when up to 30% of those interviewed presented the perspective under consideration

"many" used when 30 to 70% of those interviewed presented the perspective under consideration

"most" used when 70 to 90% of those interviewed presented the perspective under consideration

"virtually all"
used when 90% or more of those interviewed presented the perspective under consideration

"a subset"
used to articulate more gradations within a group referred to previously by "a few," "many," "most," or "virtually all." A subset includes at least two individuals.

2. Presentation of Transcribed Materials

Dialogue from interviews is presented inside boxes. Students are denoted with "S:", instructors and principal investigators with "R:", and the interviewer with "I:". If more than one respondent is involved in a conversation as is the situation with focus group discussions, responses are denoted with "R1:" and "R2:" and so on. Ellipses (...) in quoted material indicate deleted dialogue occurring within the reproduced material. Deletions are made so that readers can appreciate the speakers' views on a particular topic without having to sort through the divergent twists and turns of the raw dialogue. The quoted material is presented as faithfully as possible to the speaker's intent. If additional text is necessary to understand the quote in context to the rest of the discussion, it is added in brackets.

Acronyms Used in this Report

AG: Analytic Generalization

ARPA-TRP: Advanced Research Projects Agency - Technology Reinvestment Program

ASEE: American Society for Engineering Education

CEE: Department of Civil and Environmental Engineering

CHE: Department of Chemical Engineering

COE: College of Engineering

ECE: Department of Electrical and Computer Engineering

EH: Engineering Hall

ERC for PAM: Engineering Research Center for Plasma-Aided Manufacturing, College of Engineering

IE: Department of Industrial Engineering

LEAD: Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center

LO: Learning Outcome

ME: Department of Mechanical Engineering

MEEF: acronym for the "Diversity and Cultural Change: Manufacturing Engineering Education for the Future" (#ECD-8721545) grant awarded to the ERC for PAM

MS&E: Department of Materials Science and Engineering

NEEP: Department of Nuclear Engineering and Engineering Physics

SAs: Student Assistants, engineering students with senior or sometimes junior class standing

SOAR: Summer Orientation and Registration

TIP: Teaching Improvement Program, College of Engineering

The Students: A Learning Community of Freshmen

The Students: A Learning Community of Freshmen

Based on analysis of data from across all sources, this section of the report presents the learning process and outcomes from the students' point of view as well as analytic generalizations about student learning experiences from the researchers' point of view.

Data collection with students during second semester confirmed the results of data analysis based on first semester data collection with very few exceptions. The quotations appearing below are representative of the students' perspectives and articulate with clarity themes apparent across all data obtained from the students. Those familiar with the End-of-semester Report dated January 30, 1995, will recognize some of the quotations from first semester students used to support the themes described in this sections.

I. Learning Processes: From the Students' Point of View

A. Key Features of the Learning Process

1. <u>Teamwork: A Process that works</u>

Teams were the most frequently mentioned "effective part of the learning process" by almost all students from both semesters. Within labs, faculty determined teams of three to four students each. These teams dissolved two-thirds of the way through the semester when the whole lab reached consensus as to which design all the students in the lab would pursue for the final design. Smaller work groups then formed to accomplish tasks, but the original teams were no longer officially in place. This process was consistent for both semesters as described by two students in the focus groups held during the middle of second semester. (S1 took the design course in the fall and S2 in the spring.)

S1: It's really nice to have the personal atmosphere where you get to know your professors and your SA, and you really feel that you make a difference in what you do because you are so involved with it.

I: Could you give an example of how you make a difference, like what are you referring to here?

S1: Well, like when you go through the engineering process of brainstorming for ideas, and once you do that, you get in a group. You do everything as a group, and you evaluate your ideas as in the goods and the bads, the pros and the cons, and throwing out ideas.

I: So how are you making a difference in that process of brainstorming and coming up with ideas?

S1: Coming up with ideas, and criticizing other people's ideas, and stuff.

I: Is that similar to how you remember your experience?

S2: The point where you're at now is kind of like generation of ideas.

S1: No, we're done with that.

S2: Oh, you're working on a proposal?

S1: Yeah.

S2: That's good.

I: Could you describe the process that you went from in terms of coming up with the design that you're now working on?

S1: Well, first the first lab was pretty much an intro. And a few labs later we split into two groups. Groups of 4 each. And we pretty much separated and went on our own ways on figuring out ideas on which design we could--which device was the best, which design was the best, how we would use them, and everything. And after a few labs we had a presentation put together and presented what we--our device we thought was best and how we would use it, and everything, to the other group. And they did the same for us. And after that, we combined our efforts and decided on which device between the two that we came up with and the design and the usefulness of all that, so we narrowed it down to one idea, one device, one design. And right now, we put our whole group together and then we split off into little groups on the different parts of the aspects of the device. One on the design of the device itself. One on the hardware of the computers and stuff. One on the software, the programming and stuff.

I: And are these three new groups? Or are you back to the original two groups?

S1: They are new groups.

S2: It [last semester] was exactly the same except there were more groups. There were three in our lab group. We presented to those on the first level, and then once we all came together, and we split apart again for the individual aspects. And then we presented to everybody at that area.

I: And were your second set of groups the same as your first?

S2: No, each set was different every time.

Data-point 1a: Teamwork allows each student to develop confidence and go beyond his/her individual capacities.

Many other student interviews clearly presented the idea that teamwork allows each student to develop confidence and go beyond his/her individual capacities. For example, several male students described how the team helped them overcome their natural shyness and build their self-confidence.

S1: It was pretty obvious right off the bat the characteristics of everyone and their personalities. Some people are outgoing right away, involved, show leadership, and then there's some people who are kind of shy, quiet, who just kind of sit in the corner. And I was pretty much one of those shy people to begin with. That's usually where I'm at, but I made myself get involved and it's a lot more fun when you get involved! And--

I: But that took some effort on your part?

S1: Yeah.

I: What helped you? Or held you back initially?

S1: Well, initially, I felt what I said wasn't being considered and wasn't really up to what everyone else was doing. So I didn't want to hold them back, you know, in a sense. But then I kind of caught on. I was up there.

I: ...what made you feel confident to go ahead and contribute a little more?

S1; Well, first off, like brainstorming. I would throw out ideas, and it seemed to me, I don't know if it was true, but it seemed to me that every idea that I threw out they were like, "alright, next!" And then after a while I must have been throwing out better ideas or something because they actually considered them. Actually debated them awhile, and that made me feel like I was actually participating and actually having a positive influence.

I: Right. Right. Was there anything that contributed to that? Did you notice anything that was going on in the group dynamics that your ideas were finally catching on? Was there anything different or was it more internal do you suppose? Or external? I just wonder--

S1: Well, it was pretty much a little bit of both, I think. After awhile the people got a little more comfortable with everyone else and were more willing to listen to everyone and be more responsive to everyone. And [I was] a little bit [different] on the inside because I was growing into the atmosphere. I was so used to big lectures where you don't really know anyone. Everyone is pretty much just a number.

I: Do you [addressing S2] remember how it was?

S2: I pretty much agree with what he said. I tend to be a little more "introverted," I guess, would be the word, for the most part. And then when you get more familiar, and when you get in smaller groups, you can't just not say anything because there's three of you and you are all responsible for certain things, and if you don't do it, you won't get it done, then. And as far as submitting ideas, I think that you always have to submit every idea.

Data-point 1b: Teamwork develops friendships that help students remain connected and motivated to learn.

Teamwork gives students a common experience. They recognize it as a valued and relevant skill for the real-world and for their own learning. Students discover that certain strategies lead to more effective teamwork for the whole lab.

S1: Definitely it [the course with its teamwork] makes a difference. You come there and you don't know anyone pretty much and you walk around and you see all these new people. And you take these classes and you get to know people, and then you are just walking around campus you see these people and you say, "Hi" just as you walk by. And it's really nice to feel like you fit in, that you know people. You're not a stranger. It just feels nice to have someone to say "Hi" to you!

I: Yeah, right. [laugh]

S2: Once, in awhile it's like scary. Like if you are going down University Ave. or something and you see 3 people that you know in a row that you know from other classes. It's like "Hi!" "Hey!" But yeah, I only stay in touch with one person that I know from my high school. You know, once in awhile I see other people, but pretty much everybody that I know down here, I met down here. It's just weird.

I: Do you think it was easier to recognize the people that you were with in your design course with last semester vs. some other class? Does the group size make a difference?

S2; Yeah, because you know them better. I'll recognize a lot of people, but it's like, "Hey, I know you. So everything becomes more familiar, but it's easier when you actually know the person and you might know both their first and last name and some stuff about them. You've actually worked with them.

I: Let's talk more about that: You've actually worked with them. What role does that have to play here and in making you, to use your words, feel like you fit here in engineering?

S1: Well, you've had a common experience. You've got something you can talk about--remember when you did this or that.

Students never appeared to doubt the need to develop team skills; they seemed to understand that engineers really do work in teams, as this student indicated when asked about the value of the course:

S1: If you look at almost all of the engineers, to my knowledge, they all use a team design process. You are going to have to work as a team. I don't see many people working by themselves out in industry. My parents work at 3M and so they do a lot of stuff, the design process kind of. You just basically need that.

Most students discovered that they learn best when they are in a group of people who can discuss the issue among themselves with faculty to guide them when necessary. The teamwork provided the best learning environment, as this conversation during a second semester focus group indicates.

S2: One thing it did show me is that I think I learn best amongst a group of people sitting together discussing, rather than having a professor lecturing to a bunch of people. Even at lectures they wouldn't just stand up there and lecture and class was over, go away. They would lecture and talk and involve the students, bring students up to the board sometimes, or ask us questions and have them be answered in the class. I think that's a better way of going at it 'cause it keeps you more interested...They [the faculty] were able to get us more involved [than the chemistry and math professors]. The way it was presented too, that's another big thing. They were fun.

I: The design class? You're talking about that?

S: Yeah. At the lecture they were always happy and making jokes and acting like students themselves.

I: Is that important, the happy part?

S: Yeah, 'cause they come down to your level, and they don't make themselves out to be better then you.

Certain strategies led to more effective teamwork for the whole lab. For example, one student explained that having one person from the original team on each new group that formed within the whole lab and knowing how to reach consensus were helpful strategies.

I: Were there certain things that you did, consciously or unconsciously, that made the whole group work together?

S1: ...When we split up, we made sure we had people working on the presentation that were in the original group, and people working on the building that were in the original group, so that the main idea was there, and if anybody else had other suggestions to add to it, they added. So it had a strong base.

S2: It was surprising that we all came to a consensus and put it all together.

I: Was this a new experience to you at all, the idea of reaching a consensus and agreeing and working together? Was it like similar projects in high school?

S2: I've never worked in a group that big, with the 12 people. It was always two or three. I don't think the reaching a consensus, the thing we were trying to reach a consensus on or agree on in high school was ever a big deal like this was. Now we're actually building something.

Data-point 1c: Teamwork "gets things done."

Several students commented on their increased capacity to accomplish work when working in a team. . One comment representative of remarks made by both female and male students explicitly shows that a team "gets things done":

I: So you actually feel like you do learn better that way, when you're involved in a group. Was that new to you, or did you know that?

S: That was actually a little bit new to me, 'cause I always thought in groups I could never get anything done. It would be more like you'd just talk and wouldn't get it done, and I learned that you can actually work.

All the students were able to see the value in shared decision making although some thought it would be easier to do it [the design and work] themselves, as these two representative comments show.

S: Cause otherwise (without teamwork) you're just still going to be one person, limited to your capacity then.

S: Well, to me it [the team process] was pretty much a common sense process that I just do in my head. What we did in about 2 or 3 labs work, I do in my head in about 15 min. I just jot down a few ideas for brainstorming and evaluating and stuff. It was kind of important so you get the feel of getting everyone's ideas together rather than just your own, and combining it. Having a team effort thing--in that sense it was good.

Data-point 1d: The teamwork component of the design course gives students a context in which to see the importance of and to develop their communication skills.

When asked to identify goals that seemed most important, students often listed team work, customer analysis, and communication skills. The following representative quote illustrates this point. Note this student's recognition of how working in a team helped him understand the importance of communication skills:

S: I think that working constructively in a design team is very important and that getting to know wheelchair users, learning something different about the facet of society that you normally didn't think that much about. Communicating your designs effectively, I think, was important.

I*: And you think that was accomplished in your lab?*

S: A whole lot. We had to explain some ideas that at first, I just remember you know, yelling out these incredibly general ideas that made perfect sense to me. But everyone else went "what?" And so I had to learn to stop and think and find the right words and put them in the right order and even phrasing them in the correct way so that what I was saying made sense to everybody else. And so yeah,...it doesn't matter how much you know, I don't think, if you can't communicate it. 'Cause otherwise you're just still going to be one person, limited to your capacity then.

Data-point 1e: Getting to know others on the team contributed to students' higher comfort levels in the College of Engineering.

These comments from a second-semester focus group discussion supports what many students said during both semesters:

S1: Well, getting to know the professor and the SAs is a big thing, and them getting to know you. [pause] And in that sense they can design the course around the different people, the different personalities.

S2: I pretty much agree with that. Just also having your professor and your SA in the same room. In some of the bigger courses, your professor and your SA or your TA are totally separate, and sometimes they conflict and they just disagree and there are discrepancies. Not that there wouldn't be in the small one, but they are together and it's more unified like that and just the size [helps]...

S1: Like most of the big classes like chemistry you have a professor and you have your TA, you get to know your TA really well, but unless you make a really--effort to see the professor, and get to know him, you don't really get to know him--he's just pretty much out there talking to you. But this--with the size of these groups and the way it's set up, you get to know your SAs just as well as your professors, and sort of like a family almost. The professors are sort of parents and the SAs are like your bigger brothers and sisters, and you're just little siblings.

I: And is that good? Is that helping you learn?

S1: Oh, yeah. It provides for a comfortable atmosphere and it's just a lot easier to learn when you're not all up tight and alone and stuff.

I: When you're not up tight and what?

S1: Feeling alone. You're part of a group.

Most students said that the team process helped them feel more comfortable among their peers. This comment from a female student illustrates this feeling:

S: Oh, very comfortable. Very, very comfortable. Everybody got along really well. It was kind of uncomfortable at times. I mean, the guys were the majority. I would just feel uncomfortable sort of, sometimes. They were really good about it too. I was kind of scared to begin with, because I know engineering is such a male dominated field and stuff.

I: Do you think that this team approach helped?

S: Yeah. I think that it did. Because, the girls didn't have jobs always that were supposedly, I don't know. We had the same types of jobs as the guys and it worked out fine.

Data point 1f: The teamwork that students experience in design reflects teamwork in the real-world.

Teamwork that students experience in design is somewhat different than teamwork in traditional classes. It reflects teamwork in the real-world, as this representative quote points out.

S2: In calculus, everybody should understand everything. That's the biggest goal. So some people that understand it can explain it to others. But in the design course, we divide up into groups and then in the end we put it together.

I: Do you think it would make a difference to the effectiveness of this course, that you know everything that's behind the process?

S2: No. I think the main idea is that we're all working together to complete one final task at the end.

S5: I think that if they tried to make everyone try to understand all the different details then it would have another purpose...That's the whole point of having engineers work together, because each of them are specialized in their respective fields. And that's why the teamwork aspect of this class is so important, because later on you're going to have different engineers with specializations in other fields working together so they can share that expertise on subjects that they know.

2. <u>Hands-on Teamwork Activities: Early Intimations of Professional Identity</u>

The hands-on activities in the course helped students get involved with the design process, connect with each other, and develop a sense of belonging in a small community in which all members were both teachers and learners.

Data-point 2a: The hands-on lab in a supportive learning environment and the lectures with practical examples and group exercises help to develop a sense of involvement and "fun."

All students enjoyed the small lab setting because it provided "hands-on experience;" a chance to work in a team towards a common goal; the opportunity to adjust and communicate with peers; and proximity to interact openly with professors and SAs. The following student conversations represent the majority of students who found the "hands-on" lab an exciting learning environment:

S: There's a motivation challenge for getting people to [lecture], but as far as motivation in the labs, we really got into it. We had the tools out and we took stuff apart. But sometimes we were just sitting around talking for three hours...That's when it got boring so [we need to do] the kind [of tasks] that makes the engineers excited, I guess.
I: And you said take stuff apart, can you recall?

S: At the beginning people were taking things apart and they thought it was the greatest thing ever. Like you want to know how it works, you know. "Here, I'll show you this now." You get what's inside and then find it and that was cool. 'Cause I didn't know how it worked and that was really interesting.

Another conversation went like this:

S: At the beginning [the course was] kind of weird, you know, because you didn't really know anybody...but the last couple weeks it was just hilarious because we were all involved. We just had a great time! [The labs are] long but fun.

I: What makes them fun?

S: It was fun because the work wasn't really too stressful. You know, we had our outline of what we had to do and we did our work and, but it wasn't like totally structured where, "Oh you've got to do this and that and all this stuff." I mean, it was fun because we had a lot of laughs putting the stuff together and floating around ideas.

Almost all students commented on how the fun in the lectures and small groups led to increased learning, as this representative comment illustrates.

S2: One thing it did show me is that I think I learn best amongst a group of people sitting together discussing, rather than having a professor lecturing to a bunch of people. Even at lectures they wouldn't just stand up there and lecture and class was over, go away. They would lecture and talk and involve the students, bring students up to the board sometimes, or ask us questions and have them be answered in the class. I think that's a better way of going at it 'cause it keeps you more interested...They [the faculty] were able to get us more involved

[than the chemistry and math professors]. The way it was presented too, that's another big thing. They were fun.

I: The design class? You're talking about that?

S: Yeah. At the lecture they were always happy and making jokes and acting like students themselves.

I: Is that important, the happy part?

S: Yeah, 'cause they come down to your level, and they don't make themselves out to be better then you.

Data-point 2b: Designing and building in real teams helps students "test the water" before plunging into engineering.

Students recognize the value in taking the course to help them make career-decisions. They encourage others to experience it and learn that engineering is not just some distant place, as seen in this conversation during a focus group discussion with students from both semesters.

S2: Well, I have a few friends who are kind of upset with the major that they're in now, and then I go, "Maybe you should consider engineering." If they are interested, I'd recommend them taking the course. I'd recommend this course to anybody who was slightly interested...I think they should have to go through that. Otherwise they can wind up going maybe 'till their sophomore second semester or may even junior year without taking a course through engineering. It's just like some distant place that you pass on campus maybe. Kind of an involvement with the actual college.

I: OK.

S1: Well, last semester, I got to know a person through Spanish 204 and I remember talking to him about this course.

I: Oh, really!

S2: I recommended it to him.

S1: Yeah, he said it was really cool and pretty neat, and that's pretty much the major force in spurring me on to take the course. Also, recommendations from the advising counselor. But with respect to my other friends in engineering who haven't taken this course. I think that they're missing the experience of going through this and meeting people through this experience, and it is a good a good experience which they are missing out on. But I don't think it's that mandatory if their heart's really set on engineering. But if you are up in limbo, if you don't really know what you want to do, then this is really a good course to take.

Students conveyed that the design course positively affects students' decisions to pursue engineering. All students found the course helpful in one way or another. Many students indicated that one way the course helped was that it "showed different angles of what engineering is" and "reassured their direction." By the end of the first semester, many students said they now felt comfortable in engineering. Two students expressed the idea as follows:

S: [I am] Staying in engineering. Like I said, I feel comfortable here already. And I was, during the middle of the semester I was kind of considering switching out of engineering. I was going to switch to the business school. And I looked into the business school and stuff. And it seemed almost weird to want to switch because I already felt so comfortable here. So I decided to major in industrial engineering which is kind of business related engineering, because I want, I know that an engineering degree is really useful and stuff. I also wanted a business side of it too, so I decided to stay in engineering, even though it is going to be really hard. But I think I will be able to do it.

S: My SA said that, you know, we're just going to be a whole lot more comfortable coming down to that [engineering] end of campus now and I think she's right.

Several students found that the interaction, problem-solving, and organizational skills they developed in the design course affected how they felt about their future. One student put it this way:

S: I like the idea of interaction and solving problems and I think that whatever I do with my life it's going to be part of that and I would say that this course will have helped. I still feel pretty strongly that I'm probably going into engineering, and that's the track I'm on right now full-steam.

I: Have you learned anything else here that you will use in the future?

S: Yeah, I'd say the time management and organizational skills. I would also say that simply getting to know some of the professors that I'll be taking courses from later was nice.

Data point 2c: Students tried to picture themselves as engineers and found the course and instructors instrumental in helping them to make informed career-decisions.

These comments during a second-semester focus groups capture what most students expressed throughout the year about the course and its relationship to their career decision-making:

S2: It's kind of funny because I entered pre-engineering and I was thinking of going into computer engineering or maybe computer science or computer engineering, and I don't know if it's necessarily the course that turned me around, but I'm pretty much definite that I don't think that I'm going to study any engineering which is not necessarily bad or good.
...It's a big decision. I was kind of surprised that I felt like that. Now I'm kind of, like, searching around trying to figure out what I want to do.

I: Do you have questions that perhaps could either be answered in a course like this or answered earlier in life?

S1: Actually participating in an engineering project like this--seeing what it's really going to be like, actually participating in something rather that just reading out of a book--it really makes a difference in what you think.

S2: I guess it's hard to accept --that's what I thought I was going to do and now I don't want to do that. How do I know what I really want to do? And once I get there, is that what I really want to do?

I: Do you feel like the course is giving you a glimpse of real engineering?

S1: Oh, yeah. We're actually doing a project that's effecting real life. That's actually going to be implemented maybe a few years down the line when we come back, we can say, "We did that." and "That's us." It's not some thing out of a book. It's not some experimental thing in the lab. It's actually something useful.

Comments from two second-semester students in a focus group illustrate how they heard about the course and how it helps them make decisions about their career.

S4: Yeah, I had no expectations, but I've found it's a pretty good course. It's good that I'm learning what an engineer does. Next year I could change out of engineering. I really haven't decided yet, but it's good that, for the students, whether they choose to stay in the engineering or they choose to leave, it's good. Even if they don't like engineering they can see what it's about. I've found it a positive experience.

S2: ...I was in the same situation (name of student) was where I was thinking about what classes, and I just decided to take it. I was really excited once I got into it, about actually designing something that's going to be in use, so that's about my feeling right now too.

S1: I heard about the class at the SOAR session, and I guess I didn't have the opportunity to get in (first semester) - it was already filled up. My main attraction to it was the hands on experience and just getting out and doing something. I wanted to see how they were going to intertwine engineering with that. Right now we will be getting on to the hands on part, so halfway through the semester.

Throughout the semester students tried to picture themselves as engineers and valued the variety of sources that gave them a glimpse of what being an engineer would be like. During the mixed focus group, students commented about their career decision-making concerns; their comments about how hard it is to picture themselves as engineers echo almost all students. Their comments about a senior assistant demonstrate the value the students place on interactions with SAs. However, the cautions about an engineering career presented here are not typical across all data collected. Most students found the SAs' encouragement helpful in their decisions to pursue engineering.

S4: Well, there's one SA in particular. I guess we can't really name names, but it's kind of scary to hear him talk. (laughter) Because I heard previously, maybe when I was in high school, some of my teachers, I heard somewhere that once you get past your freshman year, if you did pretty well you're going to do pretty well for the next three years - four, five - you're gonna do fine. But now I heard that, except from somebody who's actually a senior in engineering, and it's kind of spooky coming from the source like that.

S5: I was convinced I wanted to be an engineer, but I don't think I really knew what an engineer was. I think that I've heard that if you're good at math and science then you should go into engineering. So I said, well, I like math and I like science kind of, so I went into engineering, you know. I guess I'm going through a little transition. I don't know if I'm going to stick with engineering or if I'm going to go into a more math-based major or not.

S4: I'm also kind of in a transition period. The remarks by the SA in question didn't really push me toward the engineering department!   My options are still open, and I'm not really sure what I'm going to do now, but hopefully I'll know by the fall.

I: How has this course or any other experiences that you've taken helped answer some of these questions or just bring up more questions? How has it been part of this?

S2: It's highlighted the responsibilities you have to take later.

I2: How do you feel, since you haven't taken the design course? How do you feel *about engineering?*

S3: I'm still just not really sure about it. I'm going into geological engineering, so I'm taking an intro class to that, and it still doesn't answer a lot of my questions about it. I'm just learning about geology and careers, but I still don't - I can't quite grasp what exactly I will be doing. It's just hard to picture myself as an engineer.

I: Has the design class helped you picture yourself as an engineer, even though you may be decided that it may not be for you. Does it help you picture yourself as an engineer?

S4: It helps me picture myself just in a career, not necessarily engineering, because, you know, the teamwork is in a lot of careers...The course isn't necessarily showing you what engineering is like, but any career after college or whatever. A few weeks ago we had to do team presentations of what each team had planned to design. I happened - when I came home for spring break I was telling my mother about the class, I think, and telling her all the different things that we do, with the teamwork and the presentations and everything. She was amazed, and she told me, you know, she's in a career organization, and she said it's very similar to what she goes through every day. So I guess I'm learning what the "real world" is like.

I: The real world of work?

S4: Of work, yeah. It's a lot different from college...And there's no way to see what an engineer does day to day because of all the engineers out there each one probably has a different type of schedule, either in planning or design, or some of them dress in a suit and tie. Some of them dress in like - are actually working on the mechanics of things and they're - it's just such a diverse field that there's no real way to tell.

I: So is that a plus about engineering, or is the ambiguity a problem?

S4: I'd say it's a plus.

S5: I'd say it's a plus later on, cause it probably means that there will be a lot of variety in your career, and you won't be doing the same thing day in and day out. But as being a student looking at engineering you don't really know what you'll be doing, so in that respect it's hard. It's hard to know.

Almost all students identified how the course gave them a "peek behind the scenes" of engineering, as revealed by this female student's comments:

S: It was kind of a behind the scenes engineering peek.

I: Behind the scenes, what do you mean by that?

S: You're actually going through what a real engineer does without being an engineer yet. That's why I think it's cool that this is my freshman year, so people understand what they're getting into.

When asked to identify the most important goal, the same woman expressed her surprise at being able to "feel what it's like to be an engineer so early."

S: I would say understanding the design environment had the biggest effect on me because I never thought I would be able to feel what it's like to be an engineer so early. Like that actual nerves with the presentation, that actual building without professors telling you what to do, but you decide what you want to do. I thought that was a big thing for me personally. And then the whole communication deal, how we all shared our ideas to come up with the best solution. But I think that kind of goes into the whole design environment deal.

I: Do you have the sense that others felt the same way that you did? You may not even have a feel for how they thought.

S: I know one of the guys in my group, he was saying that it was cool the way we did this, how it's like a behind that scenes - that's the way he described it too, it's like being an engineer without being an engineer. So I know some people felt the same way.

3. <u>A Cooperative Teaching and Learning Environment Fosters Both Interdependent and Independent Learning</u>

Instructors created an environment in which students learned from each other and met course goals. Interview data show that not only students, but also instructors and senior assistants learned from each other. Peer and group learning was the norm expressed among most of those interviewed.

Data point 3a: The teaching and learning environment allows students to go through the design process and teach themselves.

One response from a particularly articulate first-year female student represents the views of most other students with respect to how the design process encourages students to become active learners. In the following interview fragment, this student commented on all of the course objectives, as presented in the course notes. Note how she described the class as one in which you teach each other and also "teach yourselves."

S: [Looking at the list of course goals, presented by the interviewer] We definitely worked constructively in a design team because we got the presentation of the ramp done...Half of us had to work on the ramp, and half of us had to work on the presentation. Then we would get together and decide who's going to speak, and everybody still would understand what's going on. So I'd say that's pretty constructive... Understanding engineering principles and engineering language [a listed goal], yeah. I went in there not really knowing much, being a girl [laughs], not knowing much about mechanical things and wood and putting things together, and now I've got some knowledge of building and some of the engineering things we learned. I definitely learned how to seek out, digest, and use information from diverse sources [listed goal]. We used the CAD programs and the different programs on the computers in the CAE labs. I wouldn't probably even have been able to learn how to do email [if I had not taken this class]...And then learn from teachers and peers [listed goal], yeah, because if I didn't understand something, they would tell me. That's why I think the whole course was more like, you teach yourselves. You learn from each other more than you do from the professor. He's just kind of there to supervise it. 'Cause if I don't understand it, the guys would explain it to me, or if I was trying to get something across and they didn't understand it, I would explain it to everybody else. And then, we did get to know our customers. [listed goal]...And then understanding the design environment [listed goal], I think that we really learned because we started out with the whole planning and how to start figuring people's wants and needs, and then slowly it developed into more of the actual engineering designs behind it, like how we're going to put what they want into the engineering specifications, and then using that to actually build the ramp. So it was like the whole process...

I: ...you thought there was a lot of learning going on among yourselves. Can you think of some specifics where you were asking them and they were asking you?

S: ...Like if someone proposed a certain change in the design and I didn't understand it right away, other people would join in and help explain it so I understood the whole thing. They

wouldn't just say, "Oh, forget it." They would make sure I understood it, and then I would do the same if I had an idea.

Data point 3b: Having instructors, both faculty and senior assistants, who act as facilitators and let students think for themselves, helped the students learn, feel comfortable, and be more creative.

In the following conversation, a female student revealed the importance of a professor who would set the stage for learning and then get out of the way in order to let the students think for themselves.

S: I also know that people really like the way we got to think for ourselves rather than the professor telling us what to do. I know we discussed that a lot in our labs, we were like "wow!" among ourselves...a lot of times the professor's intimidating, and you don't feel like saying something cause you might sound dumb, or you're more open with your classmates than you are with the professor, and more ideas came out that way.

I: What did the professor do, if it was that person, to set the stage so that you could be working by yourselves that way?

S: They would have an outline for what we should do at lab. They'd go, "Well, the first part of lab we want to work on getting together the presentation, or the design, or thinking about the customer needs, and then the second part this." And we'd have a break in between. So then he kind of started us off, and as he saw us getting into it...and we would just continue. ...We were like, "Wow, I don't believe we're doing this. He's not even here." We liked the way it was all on our own. I think a lot of the people thought a lot of the ideas wouldn't have come out if he was there. I'm sure I wouldn't have said some stuff if - cause, a lot of times you say something sarcastically and people are like, "Oh, that sounds good." And then it comes out to actually working.

I: Can you remember a specific time?

S: Yeah, actually, 'cause I know this happened to me when I was being kind of sarcastic, and I went, "Yeah, why don't we put music into it - the presentation?" And they're like, "yeah!" So we started talking. I'm like, yeah, I tell a story. And we ended up starting our whole presentation like that, and it was all a joke to begin with.

When asked if they would like more guidance especially when they were deciding which of the three designs the lab would choose to build, students indicated a desire to work it out themselves. This student explained the process this way:

S: Finally, just when we finally said everybody could put in other ideas later and just think about what we can do, that's when everybody started thinking not about their own projects, but what was best for the group.

I: Do you wish you had had more guidance, or was that the natural way for this to happen?
S: The way it happened, actually! (laughs) I know our professor and our student assistant, they were both getting a really big kick out of our arguments. I just figure if they came in and started saying something, other people would be less expressive about their ideas. They'd be like, "Well, the professor's right. Just let him pick." And this way it was totally us.

I: And that's important to you?

S: Yeah. That's why I like this whole class. It's totally the students. What you accomplish is what you put together.

As did the faculty, the senior assistants facilitated teamwork, motivated students, and then got out of the way. All students commented favorably about having seniors in engineering as assistants in the course. Representative comments include:

S: I think having SAs really worked good. They were kind of just like the professor, you know. They would ask a question and they were "What about this or what about that" you know - kind of to give us direction and help us with stuff we don't understand. So I think they were helpful and cool 'cause they were more on our level, kind of the go-between. And the professors, I think, were kind of intimidating at first, but after a while, once you get to know them, it was oK.

Many students mentioned that the SA gave valuable information about engineering careers, like this comment demonstrates:

S: I thought that the SA was useful as to talking about what kind of engineering there is. It was almost like she was an advisor.

4. <u>Students' comments about the process, not the design, as the important learning component in this course seems to match the faculty's desired outcomes or goals.</u>

During the mixed focus group discussions that occurred second semester, a question from one student (S3) who did not take the course prompted the other students' reflections about the course. These reflections are indicative students' perspectives from across the data collected. S3's question seems like a question that other pre-engineering students would have.

S3: Basically I want to know what you all thought about just the designs and everything and how it applies to engineering. Because I don't have a clue, you know, what engineering is really about.

S1: Do you think you're finding out what design is in this class?

S5: Yeah, I think it's not necessarily what you're designing, it's the process that you go through that you learn a lot about in this course, as far as, like, the teamwork aspect of it, and

you have to work in - in my group we ended up, when we actually had the hands part that you guys are approaching now, I noticed each person kind of took on a specific task that they were stronger in, so you kind of divide up the tests within smaller parts. Like, dealing with how to design. Is that the answer to your question?

S3: Yeah.

S5: I don't know - I mean, I can't say that our project necessarily applied to one specific field of engineering, but I think that in general it was the process that we had to go through and do - within our lab group, there were 10 people in our lab group, and then within that we divided up into 2 or 3 people, and then we each had to come up with a design, 1 design, and then we put all our lab groups together - not the lab groups, but all the 10 people. We had like what, five designs within our group, and then we chose the best one that we thought was the most feasible to work on, to build. Then together we took on that project, and we each worked on different parts of it. That's what I got out of it, as far as how it applies to engineering and math.

S4: And it's good that we're getting this as freshmen because qualities like teamwork and stuff are very important to engineering, and a lot of the design courses, from what I've heard, aren't really offered till your senior year, and when you're dealing with teamwork and the design process you don't need to know advanced quantum physics or calculus equations, but, you know, these other qualities are almost just as important as the complex math and science, so I thought that was real good that we were getting that.

I: As freshmen?

S4: As freshmen.

5. <u>Belonging and Identity: Small-group Interaction with Professors and Peers Enhances Students' Confidence and Self-esteem.</u>

Students value the class because it provides hands-on experience and helps them make an informed decision about an engineering major. Comments from students during a focus group discussion with students from both semesters as well as one student who had not taken the course, but was on the waiting list, echo comments from most of the students interviewed. (S1, S2, S4 were second-semester students, S5 was a first semester, and S3 never enrolled in the design class.)

Data point 5a: Faculty and senior assistants played an important role in the students' perception of themselves as to their ability to succeed in engineering.

Students were asked how comfortable they were communicating with faculty, SAs and other students. Again, students responded very positively in all three categories, but often expressed different types of comfort levels. Survey data indicate that about half of the students interviewed approached their own lab instructor but did not contact other professors in this course when a question came up. Students felt at ease sending email messages about problems to their professor or SA. Some students mentioned the willingness of their instructor to take that extra step and come in to open the lab during the weekend. Many students commented on the expertise and professional standards of the instructors. This following student comment is typical and expresses students' satisfaction with the instructors:

S: I think one of the high points of the class is key professors teaching such a basic class.

Some students explained that they took the course to benefit from small group interaction with engineering faculty, as these comments state.

S1: Then right before I chose to take the class I was talking to my advisor, and he said it was a good opportunity to meet some good professors, and that's been true.

I: That has been true, for all of you? [all agree] How is that different or the same as other courses you've been in?

S4: Well, in other courses we'd get, you know, basically only a teacher who we'd rarely interact with, or TA's that were just a couple years older than us. The professors we're all working with are - I'm not saying they're old or anything, but they've been here awhile and they have a lot of teaching experience, and they really know their stuff.

S1: You get to see who's, you know, a lot of these are like top professors in the department, so you get to see who you're going to working with if you decide to stick with engineering, and they're all really nice people, so it's a good aspect.

S5: Well, last semester I was in a design course also, and the project was to build handicapped accessible machines, or anything that would access buildings that were at Old World Wisconsin, and the challenge was to uphold the historical aesthetics of the buildings while at the same time making it accessible for those in wheelchairs. I too, I really liked the one-on-one contact I had with my professor who was in charge of my lab. I think that was really neat. I also really appreciated how eager and, I don't know, the professors were real eager to find out what you thought, and they wanted to make sure it was worthwhile your time to go there, whereas in comparison to other courses that I had been taking last semester, just calculus and chemistry, I probably never even spoke to my professor, and he didn't really - well, from my perspective, he didn't really care if I understood it or not! You just take the test, and, you know, whatever you get. All you are to him is a number on paper, so I think I really enjoyed and benefitted from the one-on-one contact with the professors.

Data point 5b. Students perceived an increase in confidence and self-esteem as they experienced the teamwork.

Many students conveyed how their confidence and self esteem grew as they experienced the teamwork where they are needed and wanted. They also noted how their confidence and self

esteem decreased with poor grades. Comments from students during focus group discussions excerpted below reflect information from virtually all students across all data sources.

From one focus group with students from both semesters:

S1: For myself, my confidence and self-esteem grew as the time went on, which is good. Usually in a large setting you're just working and you are pretty much no one. You're just a number as I said before. Knowing that you actually are participating in and having a positive influence is just really nice to feel inside, to know that you're needed--that you're wanted.

S2: Pretty much the same thing. You're assigned--well, not assigned but you decide to do certain things and you're responsible for getting it done. If you do it well, you will sometimes be complimented, which is nice. Not all the time...Plus...other people depend on you. Whereas in other courses if you have an assignment or a lab, sometimes you work with lab partners, but for an assignment it's you and that's it.

From one focus group with students from both semesters plus one student (S3) who never took the course:

S3: I've noticed that grades have a lot to do with your confidence. I mean, if you get a good grade then it's like, "Oh great, I am smart, I can hack it." I have two friends who dropped out of engineering because they got a C on an exam in another course, so they're like, "Oh, I must not be cut out for this."

I: How do you feel about that? I see you kind of wincing a bit. Do you think that's true, that that was a good move on their part?

S3: I don't think it was a good move necessarily, cause I don't think how you did on a chemistry exam or midterm or something has anything to do with how you're going to do out in the work force, or what you can contribute to engineering.

S4: I'm kind of similar in that I did pretty well for me. I mean, I'm not a genius or anything, but I did pretty well my first semester. Now that it's second semester, my math class and everything, I was certainly in for a shock at how difficult I found it. I mean, I took my first test, and it really blew me away. It was a reality check because I got a pretty low grade, and I'm going to redeem myself, but right now I'm sitting on a really bad grade. I guess when I got that grade, though, my confidence in engineering went down a little bit, and that's when I started examining my options. Is this really the field for me? As of now, you know, I'm still a pre-engineer and everything. But yeah, she's right. Grades really have a lot to do with how you feel about if you can handle things.

S3: I think if the teamwork helps you to understand the concepts better, then it can really boost your self-esteem. But if you get in a group where there's someone really domineering or dominant, then my confidence goes down cause I don't understand.

S4: ...I think it kind of boosts my confidence when I suggest an idea and people seem to like it. Or if I just suggest an idea. If everybody's contributing, things seem to go better.

Data-point 5c: The design course allows students to discover "a place here [College of Engineering]" and recognize incentives to keep going through other classes.

During a mixed focus group discussion held second semester, one student who took the course first semester reflected on the value of the course. Her comment about working with people and understanding the context of college to prepare for a career is typical of most students:

S5: ... I really enjoyed the course. I can't say it was 100% beneficial. I can't say I learned hard facts that are going to be useful in life, but it was a general experience that...lightened school up for me, and I looked forward to it - even though the lab was three hours long and I had it from 7 to 10 at night. I mean, I started out at 7:45 in the morning, so it was a long day for me. I kind of dreaded going there, but at the same time I knew once I'd get there, I mean, it was a lot of fun. That made me realize that all the work that we're going to be doing in college is going to pay off eventually. And we'll find careers that we'll hopefully enjoy, to a certain extent. And it also made me realize that we aren't going to be locked up in some lab or in some office never to see another human face again. I mean, you're going to be working with people, and that gives you hope.

Many students commented on the value of the class in terms of understanding why they needed to take more advanced classes. For example, one student commented that this was her favorite class because it "gives you incentives to keep going."

S: This was probably my favorite class out of all the rest of them. So that kind of gives you an incentive to keep going through all of those hard classes. Because you know when it gets later on, the classes are going to be a little bit more interesting, and more what you want to do instead of doing all of the calculations and stuff like that. So, I think that it gives a good incentive to do that. And yeah, I think it did all of those [met all the course goals]...It was nice to meet some of the professors too. It kind of makes you feel like you already have a place here. Which as a freshman, this college is so big, so, I don't know, you get kind of scared because you don't really know where anything is and everything. It is kind of nice to come over here where some people actually know you. As a freshman that is kind of nice.

Data point 5d: Students would like the course to "fit" into the engineering curriculum.

The importance of getting this course to "fit" into the students' curriculum relates to a pervasive "cram in the credits" pressure that students describe. Students take pleasure in actually having time to work together and think a project through from beginning to end, a situation which they frequently contrasted with the cramming they do in the rest of their curriculum. This "content cramming" is related to learning just what you need to get the grade. "Content cramming" contrasts with many of the elements of learning that the students described as occurring in the design course. The design course is a little island of "connected understanding and real learning" as contrasted to the pressure students feel in the rest of the curriculum.

We noted with interest that even students recognize the need for faculty and students to sell the course to others:

S: Just like I've always tried to sell people on stuff, like especially my dad would go "buy this, you got to buy that," so you [faculty have] to be a salesman, you know. And when I was studying and I was getting interested in engineering, I was like, "Oh, you know, I'd like to get into sales, you know, in engineering, sales." So, you know, the presentation part of it was a big, you know, chunk of what I would actually do. So I thought that was interesting that I could actually do [experience] the real thing...I think that's one of the big motivation factors that a lot of the freshmen here have, especially this first semester. Everybody has chemistry and calculus and all the other classes that really count towards their degree. So that's why this was definitely the last on the homework pile for me. That's why I think a lot of people dropped it too, because it didn't count.

(Almost no students who enrolled in the course dropped it. Perhaps the student meant that some students "dropped" the idea of enrolling in the course.) One student had already talked to some seniors in her old high school about the course. The only two reservations that students had in recommending it for next semester were 1) the "fit" into the curriculum and 2) the project itself. They enjoyed designing a project that had a social meaning and many options and were unsure if a people-counter would present an interesting challenge. Regarding "fit," one student at the end of first semester was still concerned:

S: If someone takes this class, [you need] to have it count for something because halfway through this semester I sat there and I said that I could have taken something that counted towards engineering. I learned a lot, but..[it] would have been nice if I could have taken care of my EPD credits with this course.

The next comment articulates the view of many who reflected on the importance of the course fitting into their curriculum and being part of a "core" curriculum:

I: Do you know yet how this course is going to fit into your curriculum?

S: So far, now it doesn't count.

I: Not even as an elective?

S: ...I think if it counted a lot more people [would take it]. I think that's definitely the biggest factor by far, [the fact that it doesn't count]. If you have the opportunity to take an interesting class that counts, someone's going to take that over something boring.

A few students from both semesters also supported the design of the course with its one lecture and two labs. The design seemed to "fit" their learning styles since they perceived the need for more hands-on opportunities in labs than in lectures and felt the need for more time to build their product. The following conversation captures the caution about the two lecture and one lab combination proposed for 1995-96.

I: OK, now one of you made the comment earlier about the number of times you meet and how you feel kind of connected all week...There is a possibility that they will be going to keeping one lab--the long lab, but having two lectures per week. Now, how do you feel about that? If they did that, what would be important to consider? You would be meeting more often and you seem to want that.

S2: I don't know if that's really the right way to go about it. I would think the other way around would be the better choice, but you have to fully analyze it, I guess, because I was thinking just more work time just in terms of getting things honed down a little better. I don't--It's kind of hard to say, but we treated lab a lot more seriously than we treated lecture.

6. Materials to Accommodate Varying Learning Styles

Integration, organization, and a variety of course components help students learn. However, getting the right mix of materials was a continuing challenge for the faculty. Students wanted to know why they needed to complete specific tasks, including homework, readings, and lab activities. To accommodate the variety of students' learning styles, faculty included diverse course components. By second semester, revisions to homework and labs helped to correct the frustrations that many fall semester students expressed as stated here.

S: Well the homework, like a few assignments I thought were just busy work and time consuming, like the one that we had to look at the patents...I think it's important that we learned information about patents. I think it's something they can talk about in lecture, which they did a couple weeks ago. But I don't think we needed to do the whole search because it took up 6 hours...Then we were supposed to find a book. If we were supposed to actually bring the books back and check them out and then use the information from them. But I checked the book out and then I brought it back and they are like "Oh, you didn't need to do that, you just needed to find the books." Then I thought what's the point?

I: Uh hum. That a good point.

S: They should have incorporated it somehow, to something we needed, but ..

Most fall semester students commented how the homework should be integrated into the course more specifically and, in addition, how faculty should give a brief presentation about the homework before it was assigned. For example, one student said:

S: Like the Went Library [homework]...have your lab section go over there so you can have a tour. So you know what is there, and then you give homework from that or do your homework during that lab. And then have, like AutoCad, have a little presentation on that in your lab sections.

I: Okay.

S: They gave homework on Wendt Library, and the AutoCad and some other computer stuff, but it would have been more helpful if they had a little presentation, kind of. Like that would cover the engineering aspects. And also do that in the labs so that you are kind of putting all of that interesting stuff right up front. And then you go, after a couple of weeks, you start getting into the design process.

Survey responses indicated that course notes were not an important learning resource. Faculty began to question the value of the notes; however, to accommodate varying student learning styles and to help faculty plan effectively, they decided notes were essential. Only a few students commented on the positive value of the notes. For example, the following excerpt is from a student who learned from reading the notes.

S: Yeah, I read the notes before the lecture, the night before I'd read them. And they weren't that long so that was good, and some were like, you know, a couple pages at the most, and I thought they were well written and you could learn a lot just by reading the notes.

I: So would you advise others to read them?

S: Oh yeah. I think the notes helped me more than the lectures did.

I: Could you identify how?

S: Well, reading the notes, I mean, then it was going over some of the concepts that are, like, when we got into building. And with stress - they did some examples that were parallel to the notes. But a lot of times they would talk like this, you know, and then they would have the mock boardroom meeting or whatever. It was kind of funny but, it's a different angle, so I guess it was good. I think it was worth it. I really go for the notes.

7. <u>Student Self-Assessments</u>

Data-point 7a: The ability to conduct self and peer assessments and use the

information to make improvements is challenging for students; feedback is essential for improvement to occur.

Only a few students expressed satisfaction with the self and peer assessments; those few recognized that is the "way business works." Most students were uncomfortable assessing themselves and others, as these representative conversations reveal:

S: I did it [the assessment] but my basic attitude towards it was that it was too general for the case and I wasn't going to dock somebody's grade on a general kind of thing. They didn't have a category for N/A. I think the grading process should be boiled down to more than, you know, put grades between one to five.

I: So what would be the ideal options that you would see?

S: ...I understand that an evaluation is a technique to learn and all, but I don't think that too much of one's grade should rely on what your peers think of you at any given time.

Another student said:

S: I think they're [the assessments are] useful, but I think a lot of times you saw one person working more, and another person might have been working a lot too, but outside of class...The people [whose work] you don't see, you grade all the same, and the one's you see you put up highest.

Still another student said:

S: I don't like having to grade other people in my group. But I guess it was important because you need to know...,from a student team perspective, how they thought the person [was] functioning...just go through each person and have written [comments] on what you thought the strong points were and what you thought the weak points were, so it wouldn't be a numbering system. Because this way, with a numbering system, it's almost easier within any section just to compare the numbers when that doesn't mean so much..., but they should take comments into consideration with the grade. I think maybe that [the comments] are more important.

Still another student said:

S: I don't like doing that [assessing myself and peers]. I don't think it's right. I dislike assessing myself, especially...So whenever I have that kind of an assessment, I always grade everyone really high. And I don't do it honestly. I mean, obviously some of the people who work harder should get more points, and it comes out in the end, but usually I don't separate the hardest working and the lowest working by that much.

I: So, can you think of any options? If the professor wanted to get an assessment?
S: As an assignment he could ask you to just write about how you think that the group is working, and mention any problems that would arise with anyone in the group, and

kind of point out anything that you think is, would be useful to the professor. But I don't think it should be a requirement to do the assessment. And I also don't think that it should be like a grade. I think that suggestions would be much better. And I'm sure that would inform the professor as to how certain people are working with other people.

Despite most students feeling uncomfortable with assessing their peers, a few students commented on their ability to accomplish the peer assessment. An example follows:

I: Is there a good way to maybe identify or share with your faculty person or others the fact that maybe the work wasn't distributed very well, or were there any things...?

S: We had that opportunity at the end to evaluate others. We did student evaluations and the ones right after the presentations, where we did the individual group forms...

I: Do you think this works? Do you think that you're able, as a student, to differentiate contributions that people make?

S: I think [it works] well, yeah. You know who did the work so, I mean you could tell who did the work...If everybody says they're the best and everybody else is working, that's no help so. I think people were pretty honest.

Students expressed an interest in receiving the results of the peer assessments:

S: When we did peer evaluations, it would have been nice for me to get my evaluations back, maybe printed out so that I don't know who gave me what, so that I knew what I was doing. Well, we graded our teams or whatever, and I never got any feedback at all, so that didn't really help me at all.

Having identified themes that emerged throughout analysis of data collected for the 1994-95 pilot course, we conclude this section with one student's comment about whether the design course could make a difference. Although all students suggested that it would benefit them and mentioned a variety of ways that their experience would change them, this student verbalized the importance of determining whether "engineering has a soul."

I: As far as your college experience, did this course make any difference? Are you going to stay in engineering?

S: This entire year I've been sort of thinking about it and contemplating it...There's a guy that's an art major in my computer science class, and from talking with him I found out that he had a year to do whatever he wanted....In Letters and Science, I guess, you get a lot more give in your major, and so he loaded up on the science this year and he is just dead sick of it, and computer science is the worst. He phrased this the best: he said it has no soul. You know. and he's right. And so I've been trying to determine if a field such as mechanical engineering has a soul in it to be found, and I'm still trying to do that.

**B. Key Opportunities for Improvement of the Learning Process:
From the Students' Point of View**

Throughout the data collection and analysis, we compiled a list of opportunities for improving the learning process from the students' point of view. Throughout the year, faculty have made adjustments so that suggested improvements that may have been on such a list at the end of first semester are no longer on the list. These opportunities for improvement are listed in no particular order. More opportunities for improvement will become apparent as faculty discuss this report; therefore, space is provided to continue the list.

* Continue to refine the self and peer assessment process, especially the feedback to students so they can learn from the process and identify specific steps to improve.

* Connect homework, labs, lectures and other course components so that students can see the value of each.

* Follow through on more structured questions for some journal entries so students can see their learning.

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II. Learning Outcomes

A. Learning Outcomes Indicated by Qualitative Data

We present learning outcomes (LO) based on qualitative data below. During subsequent analysis, additional outcomes may become apparent.

LO1. Students experience engineering in a supportive environment and get background to make informed career decisions.

LO2. Students acquire knowledge of the engineering design process.

LO3. Students experience context which gives them 1) an understanding of why they need math and science courses, and 2) motivation to pursue an engineering career.

LO4. Students develop a real-life appreciation of the need for excellent communication skills and work to develop these skills.

LO5. Students build confidence and self-esteem, and experience engineering through the teamwork that revolves around real-world, customer-based projects.

LO6. Students perceive the faculty and senior assistants as a team working together to provide instruction to meet each student's learning style.

LO7. Students connect with engineering by building common experiences that lead to strong friendships and, therefore, increased motivation to learn.

LO8. Students discover that they can succeed in engineering if they choose to follow that direction.

B. Learning Outcomes Indicated by Quantitative Data

Learning outcomes indicated by quantitative data are outside the boundaries of this third-party evaluation process, with the exception of reporting student classifications. Although a student survey was one component of the methodology, the format with its open-ended questions does not provide true quantitative data. Student classifications gathered at the end of the 1994-95 pilot year show quantitatively how many students are still in engineering, how many have transferred to other areas, and how many have left the university.

The classification of students who were enrolled in the pilot "Introduction to Engineering" course during 1994-95 as well as those who were on the waiting list is one indicator of the effects of the course. A manual search of the UW-Madison database reveals that a higher than usual proportion of students who completed the course first semester is continuing in engineering. Statistics support the conclusion that the pilot "Introduction to Engineering" is meeting its goals of helping students 1) recognize that they "fit" in engineering and 2) identify a specific engineering discipline to pursue.

We present learning outcomes (LO) based on quantitative data below. During subsequent analysis, additional outcomes may become apparent.

LO1. Students who completed the first-year design course are staying with engineering at a higher rate than students who did not enroll in the course.

LO2. Students who completed the first-year design course are selecting a major, as opposed to remaining with a BS or BA classification, at a higher rate than students who did not enroll but were on the waiting list for the course.

LO3. Students who completed the first-year design course are choosing a greater variety of engineering disciplines to pursue than students who did not enroll but were on the waiting list for the course.

The learning outcomes are based on the following data compiled from the manual search of the UW-Madison data base.

<u>First Semester Students (fall 1994)</u>

- All but three of the 67 students who completed the first semester course, 96%, have an engineering classification; one transferred to animal science, one to family resources, and one is no longer at UW-Madison.
- 57% of the students who took the first semester course are classified as sophomores in engineering.
- 39% of the students who took the first semester course have already selected a specific engineering discipline.
- Seven of the eight engineering disciplines are among those selected by students who completed the first semester course.
- No one who completed the first semester course has a BS or BA classification.
- Five of the 67 (7%) have a junior classification; all five have different classifications: EM3, ECE3, IE3, CHE, and EGR3.

<u>Second Semester Students (spring 1995)</u>

- Ten of the fifteen students who completed the second semester course, or 66%, have an engineering classification; one transferred to dance and four have either a BS or BA classification.
- 33% are classified as sophomores in engineering.
- 33% have already selected a specific engineering discipline.
- Four of the eight engineering disciplines are among those selected by students

who completed the second semester course.

- Three of the students who completed the second semester course have a BS classification; one has a BA classification.

- Two of the 15 students (13%) have junior status; one of whom is classified as ECE and the other as BS3.

Students on the Waiting List (1994-95)

- Of the forty students who were on the waiting list in fall, 1994, six were able to enroll in the course; five in the first semester and one in the second semester.

- Twenty-six of the remaining 34 students who were on the waiting list, about 75%, have an engineering classification; one transferred to family resources and seven have a BS classification.

- 50% are classified as sophomores in engineering.

- 25% have already selected a specific engineering discipline.

- Five of the eight engineering disciplines are among those selected by students who were on the waiting list.

- Seven students who were on the waiting list, almost 25%, have a BS classification.

- One of the 34 students (3%) is a junior with a BS3 classification

Overall

- Of all the students who completed the design course and who were on the waiting list, only one student has left UW-Madison. Two students are unable to be found on the system data-base at this point; work will continue to find their classification.

Sixteen students no longer have engineering classifications including three students from fall, five from spring, and eight from the waiting list. Further research involving these 16 students is planned to help faculty and researchers understand why students made decisions to leave.

See Table I for a quick comparison of these data.

Table I. Classification of Pilot Students as of June 26, 1995

Classification	First Semester 1994-95	Second Semester 1994-95	Waiting List 1994-95
EGR 2	38 of 67 57%	5 of 15 33%	17 of 34 50%
Engineering disciplines	26 of 67 39% seven disciplines: CHE (5) ECE (9) EM (2) GLE (1) IE (3) ME (5) NE (1)	5 of 15 33% four disciplines: ECE (1) EM (2) ME (1) NE (1)	8 of 34 25% five disciplines: CHE (1) EM (1) GLE (1) IE (1) ME (4)
Outside engineering including BS/BA	3 of 67 4% Animal/Life Science (1) Family Resources (1) no longer at UW (1) BS (0) BA (0)	5 of 15 33% Dance (1) BS (3) BA (1)	8 of 34 25% Family Resources (1) BS (7) BA (0) * 2 unknown

III. Analytic Generalizations: From the Researchers' Point of View

We structure our analytic generalizations (AG) about the learning processes under the following headings: approach to problem solving; attitude toward learning; sources of affirmation; an "island" of connected understanding and real learning; a family away from home.

AG1. Approach to problem-solving: Systematic, teamwork engenders creative, multiple approaches to problem-solving.

Students demonstrated a systematic, creative team approach to problem-solving. Their approach was systematic in the sense that they followed a step-by-step design process. It engendered creativity because both faculty and students, separately, together, and alone (among their peers) used brainstorming techniques, were open to one anothers' ideas, and were not limited by their individual capacities. Finally, relying primarily on their peers and secondarily on senior assistants and instructors to generate multiple approaches to problems, they used the team approach to create a better product. (See data points 1, 2, 3, 4)

AG2. Attitude toward learning: Virtually all students demonstrate positive attitude toward learning and pleasure in connecting the engineering design process to real-world problems.

Students demonstrated a positive attitude toward learning. They were generally attentive, involved, and made connections among the lectures and labs and other course components. (See data points 1, 2, 7)

AG3. Sources of affirmation: Interaction with peers and "more-experienced others" helps students create and build their own design and feel comfortable in both a social and professional engineering environment.

Students sought affirmation from senior assistants, faculty, and each other. Of the three sources of support, peer support seemed most important to students. Senior assistants were primary sources of advice and answers to questions; students were comfortable approaching senior engineering students. Most students were comfortable communicating with their faculty person as well. (See data points 1, 5, 7)

AG4. An "island" of connected understanding and real learning: The course needs to "count" as a standard part of the College of Engineering curriculum.

Both male and female students express a concern about the course fitting within their engineering curriculum. The course needs to count. Both students and faculty need to "sell" the course to others. (See data points 5, 7)

AG5. A family away from home: The instructor team provides the environment and curriculum to help students make informed decisions about engineering as a career.

Career decision-making is difficult for students; the earlier they can experience a real-world project as an engineering student, the better. (See data points 2, 6, 7)

The Instructors:
A Learning Community of Faculty and Senior Assistants

The Instructors:
A Learning Community of Faculty and Senior Assistants

Based on analysis of data from across all sources, this section of the report presents the learning processes and outcomes from the instructors' points of view as well as analytic generalizations about instructor learning experiences from the researchers' point of view.

Instructors for "Introduction to Engineering" included both faculty and senior assistants. The faculty worked together for several years, first as part of the Teaching Improvement Program that started in 1993 and then as the teaching team that piloted the first-year design course. They became a learning community in the sense that they continued to meet regularly to discuss teaching and learning strategies. They designed and taught the pilot "Introduction to Engineering" in the 1994-95 academic year and have identified issues to revisit as they prepare for the 1995-96 academic year. Having completed the pilot year, virtually all the faculty felt a sense of accomplishment and pride. As of June, 1995, the faculty recognized that they were still in the developmental stage of the course, and of other curriculum innovations within the College of Engineering. Along with this realization, the design faculty shared a vision that "with the needs of the students first...good things will happen." This faculty comment about the "students first" idea is representative of the faculty.

R: We're in the early development stage. And I hope that the development of this [course] is based on the needs of the students rather than, you know, the politics and turf...You can turn a good thing into a bad thing by doing that kind of thing. So, if there are some strong faculty who keep the needs of the student first, then good things will happen.

I. Teaching and Learning Processes: From the Faculty Point of View

A. Key Features of the Teaching and Learning Process

1. <u>The Emerging Goals for Students and the Course</u>

Faculty recognition of the emerging nature of the goals for students and for the course is a key feature of the faculty learning that took place throughout the pilot year of "Introduction to Engineering." Virtually all the faculty agreed that the underlying goals were to prepare students for the future and make the course an interesting engineering experience. These ideas served as the basis for the goals and accompanying philosophy that emerged in the middle of the second semester. See Tab 8 for "Philosophy of `Introduction to Engineering'."

Data point 1a: Fitting students for the future includes giving them "a general picture of

what design is all about," complete with team interactions, communication skills, and engineering and business tools.

Early in the first semester, one faculty person expressed the need to fit students for the future this way:

R: Well, [my] number one [goal] is fitting students for the future. Bring about change in them so that they can adjust better in the future. And I guess number two would be organizing the course so that it is interesting and enjoyable to accomplish the first goal.

Another faculty member, by the end of the semester made this representative comment:

R: A lot of these goals are more... what I'd call an experience. That is, the goal doesn't really state that something's supposed to happen to you other than you will have experienced this thing... in writing these [goals] we didn't necessarily prescribe what was supposed to happen, other than, presumably, "you're active and interested in participating in the experience." For many of the goals, [a student] could say, "Well, yes, I was there. I showed up for class. I did what was asked of me. I did it." [These are] sort of measurable. It isn't necessarily a great objective, but... the thought here is people who are doing these things really do have the experience...

There are some other [goals], though, which involve more skill development... I don't think it's realistic to expect that they have the same design skills that a senior does, and that wasn't our intent when we set out, but [we expect design skills] in the sense of getting a general picture of what design is all about and a general notion of how you come up with designs... It was rewarding to see a change in the students' interest in working on teams.

Data point 1b: Faculty use teams to help students "test the waters" of engineering by providing "a chance to see engineering in context."

The faculty conveyed that just as design is the vehicle for inviting first-year students to discover engineering, teamwork is the vehicle for making engineering more inclusive in terms of gender, ethnic origin, and engineering background. Virtually all the faculty considered the course as one way to "make engineering as a discipline a lot more welcoming than it has been in the past." This representative comment illustrates the value of teams for letting students "test the waters" of the engineering profession and giving them access to a regarding career.

R: We chose design because we thought that would be a really good vehicle to bring in a lot of the things we thought were important for first-year students to be exposed to. And, of course, it's not just a made up thing. It is a real process. I think students appreciate that because we're not just making up something so this other junk fits in. But it really happens.

I: Just review again what kinds of things you do think are important for the students to learn.

R: ... teamwork, I think, is very important, not just because of the team, because that's kind of a fad these days, but as a vehicle to make engineering a lot more inclusive. By inclusive here I don't just mean by gender or ethnic origin, but inclusive of people who don't have what we think of as a traditional engineering background. Team-based systems are a good way to do that because I think they tend to make the environment a lot less competitive, a lot more cooperative. In particular the problems that are challenging, force students who feel they're quite competent to rely on the students who, at first glance, they may feel are somewhat less competent, and vice versa. I think both groups learn a lot about what their true competency... really is and really is not. So I see the teamwork as being more than just the kind of faddish, "prepare for business where everybody's going to be in teams" as much as a way to make engineering as a discipline a lot more welcoming than it has been in the past, with individuals working on their own, competing against one another for a grade.

With that as a basis then, I'd like to have students get an exposure to engineering, what it really is. What we talk about as problem solving...doesn't mean much to most first-year students. They think that's algebra problems in the text book. That's not what most engineers think. That may be an element of the problem, but for some people that's a big part of the problem. But in most engineering problems, that [algebra] is a little part of the problem. Being able to do the algebra doesn't help a whole lot.

The other part is the part that's usually more challenging. So I guess the secondary goal is to give students a chance to see engineering in context, in terms of the communications elements, the people contact elements, the ambiguous elements...trying to really identify what exactly is the problem here that we're trying to solve. So all those important elements of engineering, I think, will give students a much better idea of whether or not they like this and whether or not they feel they can really fit in [engineering]. [Much better] than an analytic problem solving class or something where math or science skills are emphasized. I guess those are my biggest objectives for the class. As I said, design is a great way... to involve almost all of these elements of engineering in a fairly coherent and sensible way. But design, per se, is not for me a particularly big objective.

By the end of the semester, more faculty and students viewed teamwork and a sequence of successful experiences as more important than any other goals. The following interview excerpt is representative of this viewpoint.

R: Obviously, [the course] allowed students to learn how to form and work in teams, that's obvious, they worked in teams the whole semester. The context of the students' questions and their activities shift from an individual orientation to a team orientation...I think that by the end of the semester, they do really appreciate the value of team operation and team activities.

Regarding the opportunity for a sequence of successful experiences, well, what we're hoping is that by splitting the semester up into two sections, where they first have a smaller paper design--a sequence of little exercises that we had had as homework, and then they have the larger group thing at the end,... would give them a little confidence. Since... it's not a weeding out class, nothing is graded harshly, it's not a competitive environment, we were hoping that they would feel successful, and become more and more sure that they belonged and felt welcome and felt that they could do it.

Data point 1c: Faculty want to send students a message that "there's a place for you here."

Another objective/goal expressed by the faculty is to send students the message that "there's a place for you here." Faculty understand that many stakeholders want this message sent to students. The following excerpt from one faculty interview articulates this goal.

R: They all care... the people who gave them the money care [including ARPA-TRP and IBM]... and then the Dean cares, and then the College. Each department cares because they have to know if this is worth putting into their curriculum or not. And then of course, the industrial people care because they're hoping that this represents a substantial change in the way we're structuring the curriculum and teaching students, and that they can get some of their objectives met. And certainly not least, the students care. The students are watching closely to see what the heck's going to happen here... What we're doing is trying to send a very positive message to the students and I'm hoping that that message goes across. I don't mean it's a message that everybody should be an engineer. It's a message that if you want to be one you can be, if you work hard. There's a place for you here [in engineering].

The goal that "there is a place here" especially for women and minorities was formulated when faculty expressed concern about attracting minorities and more women into the course.

R: Uh, first semester I think we had enough of a population that I think that we could tell [the effect on women students]. Second semester... I couldn't draw any conclusion. There were just not enough... I think we should have had even more women than we did first semester. We had a lot, [but not] as many as I would liked to have had.

I: You had thirty percent.

R: It wouldn't have hurt if we had fifty. But that's one thing. I think the minorities depressed me. We had almost none...

One faculty member formulated a strategy to recruit minorities into the course: waive the requirement for co-enrollment in calculus and design.

I: What is being done about the... challenge, getting more women and minorities into the course? Are there certain strategies that you as faculty have looked into for next year?

R: Well, I can tell you what I have thought about, but haven't gotten everybody to agree with. We are definitely going to [be more stringent about] the... rule that nobody is allowed in unless they have concurrent registration in calculus, except for minorities. I think that we can draw them in and actually get them more comfortable with engineering, even though they may not have that linkage. And the only reason that we draw that linkage is that it appears that there is a high success rate between those that come in and are able to even place into calculus, and those that stay in engineering. It looks like, that's the highest correlation between the two. That's what I am told, based on the limited numbers that we have so far show. But I don't think that sort of linkage will hold with the minorities, because a lot of them will come in with a background that they may not fit into that category yet. The socialization that you get in this course could be helpful for them. So what I am saying is I would make an exception to the prereqs for them and still think that they would do fine in the course. To them I would just simply say, "It is open."

Data point 1d: The design process is a vehicle for learning other things about themselves: how to transition to college and how to work independently and in teams.

Several faculty recognized the importance of helping freshmen make the transition from high school and saw the design process as a vehicle for this and other learning. This faculty comment illustrates the point.

R: So I see the design process as a vehicle for learning other things.

I: Okay. And these other things are-

R: Things about themselves, and how to work--kind of a work ethic, too: how to direct yourself, the fact that you're in college now, and not in high school. This is the first year I've ever taught anyone who wasn't a junior or senior in college, and I think that's a big lesson in and of itself, that "you're not in high school any more, and although we do care about you, we can't hold your hand." You know. "I can hold your hand while you're here in class with me, but there has to be work outside of class." Many of the students don't have a problem with that at all, in fact they seem to understand it immediately, but some of them really haven't quite caught on yet. And this is something that they have to do for themselves, and no one can do it for them.

Data point 1e: Introducing students to the realities in industry is a challenge.

Some faculty expressed the goal that the course should introduce students to the realities of industry. For example, the following speaker believes that if the course has stronger ties with industry, not only students but also faculty and engineering professionals would benefit. The idea that industrial representatives can reinforce what the faculty are teaching and add reality to what students are doing is expressed.

R: I would like to have seen more of (industry ties). Now that's the thing that we would have a lot of if we tied it with 100. If we do it too much--get that into a routine every week of someone coming in, it kind of loses its value. But if [we get] one or two outstanding people, and lock onto them. I think I would like to see us bring in someone...from 3M. Their basic thing is to bring young people in and "hit the floor running," is a term they use. They give you a project right away, on day one, or on week two maybe. And then if it was too much they back off and give you something simple. If it is something that you can handle, they let you run with it. And then other companies... give you a full year--two weeks here, four weeks here, kind of a further training session. And different companies do it different ways. Let's let the students hear about these kind of things. They both exist out there. Industry is what we are working for, I think. I would like to bring a project in from industry, but that is not happening.

I: Can you think of any strategies that they might consider to propose projects for you?

R: There is nothing like first time touch. You have to go out there to the local company down the street here...But we should go out to this place on the east side... talk to the people out there, and try to find engineering type projects that our guys can do... You have to go out there and talk to a friend. That's extremely important.

2. Instructor Roles

The instructor team consists of the faculty and senior assistants. Virtually all faculty learned valuable lessons about their roles. First, although students generally work well in their teams by themselves, faculty and SAs need to be available at all times. Second, women instructors have a unique role as women students and senior assistants seek out women faculty. Third, industrial visitors can play a significant role as instructors.

Data point 2a: Be there when and only when they need you, but *be* there. Instructors are guides-on-the-side and mentors to students.

Virtually all faculty recognized that students notice if faculty do not have a lot "vested" in them, as this representative comment illustrates.

R: And I think also the senior assistants in our lab, or one of them -- maybe just because there were so many of us -- didn't feel like he had to show up every time. He was absent a few times,... And students notice if you don't- if you're not there. They certainly notice if you don't appear to be, you know- have a lot vested in them.

Another faculty explained that a key faculty role is unobtrusively to provide structure for team-building skills and creative problem-solving; although they are not the central point of attention, but rather guides-on-the-side, their constant presence is important.

R: ...in the first semester when I went to lab, I was there for three hours. And I think there are some faculty who went there a little while and then disappeared to their *offices* and then came back an hour later kind of thing. And, [there were] those complaints and problems associated with that...

Well, with a faculty member not just being there to prompt and observe, [you get a problem]. I mean, you don't have to intervene very much, but you have to be there at the right time to intervene and summarize and point in a new direction, particularly in the beginning of the course. After awhile the students learn to do that for themselves, or, the SAs learn to do that and then the students learn to do that for themselves. So there is a mentoring that goes on there. The beginning of the course I think, it is essential that the faculty kind of prime the pump and get things started....I was there all of the time. I assumed that it was my responsibility to be there.

I: And you feel strongly that that's helpful during the first half of the semester in your mentoring role?

R: Yes.

Data point 2b: The role of women instructors is important to the team balance.

Women students seek out women instructors: an indicator of the reality of "gender issues." This comment is used with permission since only one female faculty person was on the instructor team.

R: Well, I learned things about gender issues when I actually saw how pronounced they were. I had no doubt that the literature was accurate, but I guess I never expected the women to seek me out, and they did. And that was shocking. But I was glad they did.

...I would have expected that if I had a female senior assistant she and I would be quite close. I guess it could be an age thing, too--I'm closer in age to some of the senior assistants. They probably feel more comfortable [because I] don't have that professorial title, either, so I'm probably more approachable than some of the guys are.

Data point 2c: Senior assistants provide guidance. The faculty role is to provide mentoring and to "prime the pump" for both SAs and students, especially at the beginning of the semester.

R: They're (SAs are) very helpful, in fact, I think the students would rather work with a senior assistant then with a faculty member. They're more approachable, and the senior assistants certainly got *into* it after awhile and... helped and found out information whenever they could. (pause) I don't know that the senior assistants could've handled it themselves. (pause) I would say after the first half of the course the senior assistants probably could've taken over... they knew what to do then... But in the beginning they really didn't know what to do. They needed prompting.

I: So as far as the design for next year and the scaling up, the faculty-student ratio would be, what, greater?

R: Yes

I: And so do you feel comfortable with the SAs having the kinds of responsibilities they will have next year, maybe less faculty...

R: It will probably work better

Data point 2d: A role for industrial visitors in the labs is emerging.

Reflecting on experiences during spring semester with industry people, some faculty voiced a desire to have similar industrial involvement in the future. One faculty member explained that industry representatives should visit the labs, not present lectures:

R: This semester we had some really good experiences with that. I was kind of skeptical at first because the students get off task so much that I really hate to divert their attention from whatever it is they're supposed to be doing. I hate to draw them off task. I particularly didn't want somebody to come in and lecture about stuff that the students are so far removed from. I mean, they feel kind of removed from their own *project*, you know? [So they'll feel even more] removed from what's going to happen five years from now when they get out into industry. I think some of that is good, but they can't really make the connection right now. I mean, if you listen to the level of [some students'] questions..., they're not the level of questions I think the industrial people are expecting.... the industrial people are talking about integration of different parts of manufacturing systems, and all sorts of things that seniors would maybe be able to relate to, but these students don't even know what goes into manufacturing to begin with. They don't even know what a chemical engineer *does*, much less how you integrate this with what mechanical engineers do. So the more that the industrial people lectured, the less value it was to the students.

What was neat was that we had a guy from industry visit in lab, and I think that's where the visits need to take place. They need to take place in these small groups of twelve students. And the industrial person needs to have some kind of connection with what the students are doing, [rather than] the students having a connection with what the industrial person does in their job as vice president of something. I mean that's so far removed from these kids. But when the industrial person walks around and sees them brainstorming and says, "You're editing while you're brainstorming, and you know when we brainstorm in our company we have hundreds of ideas before we stop." You know? And the students go, "Gee, you mean [the faculty person] is not just making us do stupid things?" I mean, you know, it was neat, because they reinforced the way that we were teaching, and they added some reality to what the students were already doing.

And then when the industrial people asked, "How much will this cost? If I were the customer I would care about accuracy...," *that* has value. As long as the industrial people focus their attentions on the students' activity, it has a lot of value. And that happened this semester -- it didn't happen last fall. And so that was different. So I would prefer the industrial people to come into each individual lab, and that way we could actually--I think both sides win. We could have a variety of industrial visitors, which would make ERC happy, and yet not distract the students from their task, and the industrial people get an idea of what the class is really like. And so I think everybody wins in that situation.

Data point 2e: A significant connection with high school teachers is emerging.

Observations indicated that faculty are beginning to take steps to identify how they can give forge connections with high schools to give students earlier opportunities to experience engineering. One faculty person expressed the thought that high school students need to recognize that we're all "part of the same big team."

R: One thing that I recognize is that we went out to West High, and watched the young people out there, and they were confident, not quite arrogant, but really confident seniors ready to graduate. And then they come down here and they are so humble. And we have got to break it, we have got to get them thinking that we are no better than they are. We are just more people and part of the same big team.

Data point 2f: Key qualities of faculty include caring for students, giving value to application of math, science and engineering theory, and having tenure.

A discussion of the instructor role would not be complete without identifying characteristics that make a good instructor. Design course faculty believe that the appropriate people to attract as new design course faculty are those who care for students, see value in application of math, science, and engineering theory to real problems, and have tenure. The following representative comment makes these points.

R: We care for the students and we want to do the best for them, even though they don't think of it as being best, in the sense that they see it. We have a little bit more experience than they do. We think it is engineering experience... Most of the guys I work with are engineers, [but] there are a lot of people in our College who are mathematicians. And they are not very good at application. They just want to push the mathematics, not really use it like others.

I: What implication does that have for getting faculty to teach this on a continuing basis?

R: That is a serious problem. You have got to really want to do it, so the students benefit. If you don't want to do it the students won't appreciate it. And then, I think you have got to have an interest in applications. And... that's the thing is our department, most of our colleagues wouldn't even think it was worthwhile to take this course. They don't see the value. It would be better to take one more math course. It would be better to [fill up the students'] toolbox with tools. But it is up to industry [to communicate how important this course is], and that's where I have tried. [Some of] my colleagues--not many of them--ignore this kind of stuff. [They aren't so interested in seeing] more sociology, philosophy, psychology, and how to really use this stuff.

This interviewee later conveyed the idea that design course faculty should be tenured.

R: This is not a place to get tenure...too much teaching, not enough research.

3. The Role of the Design Project

Project selection is a critical process since a balance between too complex and too simple, too broad or too narrow, is essential for both teaching and learning.

Data point 3a: The project selection process should have specified criteria to limit the complexity of the project.

R: I think the second semester project was a little too complex. It was a little too complicated or freshman. If (a specific faculty person) hadn't been there, the damn thing wouldn't have worked. So that's a little too much hands-on in my view.

I: For the faculty to have to be that involved.

R: For the faculty. Yeah, I think so.

Data point 3b: Real customers play a significant role in the value of the project for both

students and faculty.

A real-world, customer-driven design project plays a significant role in the design course. Virtually all of the faculty indicated that real customers are an essential ingredient. However, insistence on real customers is somewhat problematic and a few feel that real customers may not be necessary. Representative comments follow.

I: How important is the real customer to you in this?

R: Exceptionally so.

I: Exceptionally so. Because

R: I want them to have the real experience. So many times in our classroom we ramble on and say, "It is something like this. We feel it is like this." But it is not the real world. You have to really have contact. I was surprised at how well both of our audiences responded to this thing this semester.

R: It's ended up certainly a different course. It's probably different than any course taught anywhere else.

I: Do you think it's comparable, better, or worse then the other courses, in terms of the experience that the freshman have?

R: I don't know. Some members of the team, for example, have an insistence that there will be a customer that the students can talk to. I mean that's certainly admirable. It's nice to have. But at Maryland, why they have artificial projects, build a windmill that will pump so much water... there's no customer but it's a project in which the students, I believe, get very enthusiastic and learn all the same design skills and all that even though they don't talk to the customer. So I think we have a course that's different because we've insisted that there be a customer... and at the same time we've developed a list of 150 or so possible design projects for which there are very few customers around. We may run out of customers. I don't know what will happen then... whether we'll go to a project *without* a customer or pick some trivial thing just because there's a customer attached to it...

I: How do you personally feel about this customer component?

R: Well I think it's very nice but (pause) to go back to the windmill case or whatever... after you set down the specifications you can't *talk* to the customer, but the customer really is identified in the specification sheet...and you go from there. So you've lost a little bit in that you haven't developed the specifications yourself... That's nice and maybe you could do it artificially, have your professor pretend he's the customer... but so far, we have had real customers and I certainly *like* that, but I don't know if it can be the case all the time.

4. Organizational and Structural Issues Impacting the Course

Another key feature of the teaching and learning process is related to organizational and structural issues impacting the course. These understandings evolved throughout the year. In fact, without the experience of second semester with fewer students and only two lab groups, it is less likely the faculty would have developed a clear understanding of the importance of their roles and the roles of the senior assistants and the industrial visitors.

Data point 4a. Composition of the teaching/learning group is critical to the student learning experience.

First semester, the seven faculty each had one lab group of up to twelve students; one of seven senior assistants helped each faculty person. First semester, 67 students completed the course; second semester, fifteen students. Unlike first semester, the faculty in the second semester worked in teams of two with two SAs in each lab. Having the right numbers of instructors and students is important. A bigger group makes the class a bit frenetic, crazy, and chaotic; structured well, such a class environment leads to more creative problem solving and friendly competition, as this representative comment demonstrates.

R: I think [the second semester class] was almost too small of a group. They were below the critical mass. They looked dead. I don't know how to put it any other way, but just sometimes they looked dead. And I just think we were below the critical mass. With a course like this you almost need a big group to make it a little bit frenetic. And it was like too small.

I: Frenetic.

R: Crazy.

I: Crazy. Okay, okay.

R: Insane. Like, chaotic. I mean a little chaos isn't bad. With eighty people we had some good chaos in there sometimes. And that's, in a sense, good. Because something pops out of that. Some ideas pop out... I just have this feeling that the numbers in second semester will always be small and we may get the same psychological problem. This is my feeling. I can't prove it.

I: Okay, talk a little bit more about the psychological problems.

R: Well, if you get too small of a group, you don't generate the spontaneity of ideas within the group and you don't get some sort of chemistry. It could drag, the whole course can drag on you. And then I am not sure what you are learning. Right, because if it is team-based, and it is communication, communications is one of the main objectives. Then you have it so that they are sometimes up as a group and sometimes down as a group. Whereas if you have enough people, there is this friendly competition among the groups that kind of keeps the level of competition up a little bit. It is almost like you have got a basketball tournament, and you have enough teams in the basketball tournament versus a small tournament. I mean we only had two teams this time.

I: Second semester.

R: Second semester - whereas we had seven large teams the first semester, so.

I: Do you like this idea of competition? This friendly competition?

R: Me personally, absolutely. Without a doubt.

I: Is it a good ingredient in the course?

R: I think so. But maybe I am too male or something. But I really think good friendly competition helps an awful lot. As long as everybody helps each other and it doesn't get cutthroat, it is very good. It keeps a little bit of action to it.

Another faculty member made a similar point, explaining that the student-instructor configuration in the second semester actually diluted some of the effective communication and connections between students and faculty.

R: And then because there were two instructors and two SAs, I heard [two faculty] say they commonly started talking to each other. Would go outside and talk some more and didn't really interface with the students. And so, while more people were there, there was less interfacing taking place. I think that we got a group that was so small that they couldn't get this critical mass to get going. That was the problem...

We had a little difficulty with that message [that if you want to be an engineer, you can be if you work hard. That message] ...got all caught up in the difficulty of the project, in the ambiguity, the lack of appropriate level of structure at the beginning, it got a little lost... instead of individual responsibility, we had a collective one... You need that personal connection with the students. If you don't have it, some of the messages become just a little bit diluted.

I: Do you see that personal connection being more difficult or less difficult next year, as it gets bigger?

R: I think since I'll have my own lab section again, I'll be alone with my students... I think as long as you know who you're responsible for, it's easier. You know that there's no other faculty member for them to go directly to, so it's you... They certainly notice if you don't appear to have a lot vested in them... I think it's easier when there's one SA, one faculty member, and everybody knows who is calling on them.

Another faculty member analyzed the relationship between having the right number of instructors and students and having a fruitful group interaction process in the following long excerpt:

R: Then there was also the fact that the project, by it's very nature, was different. In the last faculty meetings we've been talking about what worked this semester and what didn't work, and some of the guys are convinced that either the project was really wrong, and couldn't have worked, or it was the fact that we taught it in the spring semester, and for some reason the students maybe had a different attitude because they already survived one semester at the university and for some reason they had been changed by that. I don't think I really understand everything that happened this semester. I think it was just a strange semester, in that we changed so many things, and we had so few students, and so I've been asking [people] to please not jump to big conclusions, like not teaching it in the spring... or something like that.

I: I think that's a good caution, actually. Just describe for me again the kind of structure that you thought maybe did bring out a better result last semester, that you incorporated...

R: Last semester, if a student wasn't on task, I would walk up to the group, that small group, and tell them that they didn't have much time, and they should be doing their work instead of just visiting. We sat down at the beginning and we listed the things to do, and then I made them choose who was going to do what. We tried to do that some this semester, but if they didn't respond there weren't any consequences, it didn't seem to matter. Because [one SA] was with one group of four, and the [other SA] was with the other group of four, I didn't spend much time hovering; I figured they were getting enough attention, so... I couldn't really tell if they were doing what they said they were doing. In fact, the SAs told us that many times, as soon as [a faculty member] left the room, the students were just visiting. And then [an SA] came in and observed, and told us that many times our group was off-task...

Data point 4b. Scale up issues are numerous:
Cautions to "rewind" each semester and be consistent across labs
Course status as an elective that counts
Demands on faculty
Identifying and attracting new faculty
Achieving widespread faculty buy-in.

As the College plans to increase the enrollment to 200 students for 1995-96, the faculty recognize that scale-up issues are numerous and significant. Faculty comment about differences between first and second semesters of the pilot and the implications these might have for 1995-96. Representative comments follow in the order listed above in the data point.

"Rewinding" at the start of each semester...

This first representative comment cautions faculty about their expectations at the beginning of each semester. Faculty should not assume that students beginning in the course are at the point at which the faculty left the students at the end of the previous semester; students definitely are more mature at the end of the semester than at the beginning of the semester.

R: ...we were talking through the structure of the course this semester as compared to last. It was a new course to us last semester. We kind of hand-held the students in the early weeks, and they became quite proficient in the semester. And then we treated the new bunch apparently like they had that semester's experience. We didn't start over with them again. So that is important. That we really start over next fall.

Achieving consistency across labs...

R: And so I worry kind of about consistency between labs, that we're sending the same message to the students. But hopefully the structure of the course will make it so that everyone has a similar experience, if not exactly the same. And so we have some organizational issues. We have fourteen senior assistants, and up until now [a couple different faculty] have assumed responsibility for organizing the senior assistants. Now that's got to change, because as the class grows then you just can't, well it's just a full time job itself. And so we have this [graduate student], I think, who is going to work with us...

Achieving wide-spread faculty buy-in...

I: What do you mean by "political"?

R: How each department is reacting to the course, what the college wants done with it, how best to recruit new faculty to teach it, how best to talk to these certain committees about what the course is so as not to alienate people or make them hostile towards the course.

Making the course an elective that counts toward graduation...

Virtually all faculty agreed that while the design course should not be required, it should be an elective that counts toward graduation. One representative comment makes this point.

R: We decided against (tying EPD 100 to the design course). We couldn't do that job justice if we did our job right. That would be putting just too much in there. We may lose a few people to 100, that's okay. We have to have people in our class who want to be there, not because they are assigned. And that's a worry. We have this idea of everyone required to take the course, and that doesn't sound like the best idea.

Demands on faculty...

Demands on faculty can be stressful. Certainly, teaching design on overload is stressful, but stress levels are expected to lessen as no one in 1995-96 is expected to teach on an overload basis and new faculty will add new skills. Administrators need to recognize the energies that faculty devote to the course, and therefore avoid assigning faculty to teach the course as overload; faculty who teach it on an overload basis cannot "put their heart into it."

R: [who teaches on an overload basis]: It has been an overload. A lot of extra work. I was treated nicely. I didn't get night hours. I got the daytime hours, while I was here. And then, I like to really do things enthusiastically, not as a subordinate and not as a secondary type person... it is just that I couldn't put my heart into it as much as I would have liked to and that bothered me that I can't.

Almost all faculty felt that new faculty rotating into the course will experience less stress than the pilot year faculty.

R: So even though it is stressful, we have enough new people coming into it that I think it will be less of a burden on them.

Data point 4c: Structure for the faculty team was critical for keeping all the people aligned and focused on the tasks; however, it's a time-consuming task.

Virtually all faculty expressed some need for organization and structure in their faculty team, as this representative comment illustrates.

R: This is the most structured team I have been in. But in terms of teams, I have had others.

I: Did the structure work for the team, for the course?

R: You have to have a structure with as big a course as we had. We needed the structure. If it was too unplanned, we would have disassembled too quickly. So the structure is good.

I: And just define the structure briefly.

R: Well, we had weekly meetings of at least an hour. We had half and hour prep before every general meeting to make sure there were no last minute things, and then we had meetings with the SAs. So we had three meetings plus the course and lab. So that is pretty structured.

5. Evolving Assessment Measures to Determine Student Learning

The faculty conveyed the idea that building consensus among themselves about the course goals is essential. They also explained that determining how to measure the goals challenged their efforts to reach consensus. Virtually all recognized that what faculty "test" becomes the focus of the course and that students will learn what faculty test. Following are representative comments:
R: ...when you're working towards the same goals, if you don't agree on the goal, that makes it very difficult, and in a group of eleven if we don't all agree on the goals of the course, the underlying philosophy, then we have difficulty. It kind of grinds to a halt. And so, I don't know how fall is going to go...because...this course goes way beyond what we do in TIP [the Teaching Improvement Program]. It's much more advanced, and much more in process of evolution. And there's nothing like it to model it on. We're kind of just out there on the edge, we're making it up as we go along. And that's gonna be difficult for some people.

R: I think we had quite a few debates in the direction of getting tangled up a little bit in selecting goals versus qualifying what are selectable goals by what are measurable goals, and what are used to measure them, and so on. And I think some of us feel that the questions of if and how goals are measurable... are irrelevant in selecting goals... [Others believe] that if it's difficult to say that the goal has or has not been achieved--if it's not measurable in some realistic way--that makes it suspect as a valid goal.

Discussing the course goals and how to assess student learning helped faculty clarify these issues for themselves and others. The pilot year faculty expressed the idea that this will be a continuing process as new faculty join the teaching team.

R: I wanted to say that the fact that [one professor] kept bringing up the issue [of assessment and goals] over and over and over again ...certainly forced us to clarify ours. And we would have never felt it necessary to write something as explicit as [the "Philosophy" and Goals] if we didn't realize that what we had done before was inadequate. And he pointed that out. There is value in that... In fact, [the "Philosophy" and Goals] probably could use more revision. I'm sure we'll have to go over it again this summer with the new faculty, and hopefully they'll have some ideas too when we have to explain to them we truly understand what we're trying to do. So that's a good thing for us.

R: If we start testing design skills, then design skills becomes the central focus of the class, and I don't think that is the central focus of the class... So if that's the thing we're going to test `cause that's the only thing we know how to test, that will be the thing that they will work hard at learning.

Data point 5a: Current assessment tools include observing and listening, reading journal entries, weekly updates and a final essay, and reviewing student self and peer assessments.

A review of current methods that the faculty used during the 1994-95 pilot year and those that the faculty are considering for 1995-96 will illustrate the seriousness with which the faculty view the assessment issue. Responses to a question about whether or not students had met the course goals and how faculty know if they met the goals provide a review of the current methods. The majority of the faculty explained, as one person put it, that students had met the goals, and that faculty knew this by "watching them, listening to their comments in labs, and reading weekly updates and lab journals and end-of-semester reports."

Assessment by observing and listening...

R: I just know, in terms of watching them, listening to their comments in labs, and then reading their weekly updates and reading their lab journals and their essays at the end. That's the only way I know.

I: How did you come to that understanding, that they valued this [teamwork]?

R: I guess I'd say a variety of ways. There's no single measure that I know of where it's sort of a test that says teamwork is perceived as valuable or is not. So much is the tenor of the comments in journals, in terms of written form, certainly the descriptions we get from students at mid-semester and the end of the evaluation. In terms of evaluating their team members, I think we get somewhat of a picture of not just the team members themselves, but of how the students really view the team as an idea. But I think probably the biggest thing is simply watching them work, so there's kind of an observer, semi-participant, seeing how, hopefully from the beginning of the semester, questions or issues come up from the individuals. Toward the end of the semester those issues are brought up kind of from the team perspective, with students saying, "The team needs this," or, "My responsibility to the team is to do this part of the project, and here's how we need help." So the context of the questions and the context of even activities shifts from individual-oriented to team-oriented. Again, there's no - there isn't a lot of documentation other than sort of observation,

I: Was this one of the goals then that was hard to measure?

R: I'd say so, yeah, again, because there's no mere fact involved here. It's not a specific fact that's learned and repeated, but kind of an experience that has to be had and then something drawn from the experience that hopefully allows students to do things in a way different than what they had done before. So in some ways you could say there was a concrete result. If you see students doing things differently at the end of the semester than at the beginning of the semester, that's sort of an indicator, but it's hardly proof that they have whole-heartedly embraced the team concept.

Assessment by writing in personal journals...

I: Did that feeling come through in your class that there was some result [of the teamwork], something that they couldn't have done on their own?

R: Not until the very end, the last week or two when they started to kind of pull their final presentation together. Then they began to appreciate sort of how far they had come and what they had really done. I think they began to sort of appreciate that, yeah, no one of them really could have done this by themselves, and in the doing it's hard to see that. You're almost too close to really have much perspective on that particular part of the problem. So I don't really think that realization came until they kind of stepped back to do this preparation for their final project. Only then [did they] begin to realize that at first they had thought, well, one person will do the presentation, but now it's pretty clear one person can't do this presentation, and that maybe by connection, one person never could have done this *project*.
That kind of was my impression, was that it came, but it came late in the semester.

I: Yeah, and that's my impression watching the presentations. Did they also reflect that in their journal?

R: I think so. I think particularly the last entry or two. Again, I think there was sort of a bigger recognition of how the team itself kind of impacted the product, or how things happened. In the middle of it, I think they were so busy with doing that there wasn't much time for that kind of reflection. But I think yeah, the journal entries kind of - particularly the last ones, I think, really supported that kind of idea.

Assessment by individual weekly updates...

I: Last semester each team had to write a weekly update, and this semester every individual had to write one every week. Which is better?

R: Oh, definitely individual. We would have never known what was going on with [student's name], there were a couple of the guys who weren't doing anything until the very end. They could have hidden for a long time if their teammates didn't want to write anything about them. So...it works much better to have individual, although when you have more students, then that's a lot of weekly email to read.

I: Did you respond [to the individual weekly updates] individually?

R: In the beginning I responded to all of them all the time; towards the end I just responded occasionally.

I: Was that the role of the instructor, or the SA?

R: [Students sent] all the weekly email to both instructors and both senior assistants. And we didn't tell [the SAs] if they should or should not respond. I left that up to their discretion. If they had something to say then I thought they should say it. And [we faculty] just responded when we thought it was necessary. In the beginning we always responded, and then towards the end most of it was just blanket email to the whole class, either pep-talk things, or updates about whether their equipment had come in, or whatever.

I: This is getting really specific, but did you copy the SAs in your response to the individual students?

R: No... [The other faculty person] and I didn't even necessarily copy each other on our responses, because it was kind of a private response -- when the student tells you that they're having difficulty with their small group of three, and then you want to say something to them about hanging in there. I guess I thought it was more of a personal thing. It had no content other than a personal reassurance, so I didn't copy anyone on it.

Assessment by reading final essays...

Reflecting on a spring semester lab section, one faculty member explained how the final essays functioned to help assess student learning experiences.

R: [the students] had a hard time getting done!

I: ..but at the end...

R: it worked! ...Oh, I was nervous! [laughs]

I: Well how did you discover that the students felt like they had succeeded at the end?

R: They wrote these last essays at the end; we asked them what they learned in the course, what they would change if they could do it all over again...advice for incoming students, and also then how they would use this, what they learned, in their engineering career or any career. ...Actually [the final essays] were quite revealing, because some of the students said that at first they thought they would drop if they could do it all over again, which was... stunning. We didn't understand that they were that ambivalent about it. But then people started talking about what they learned about themselves, and the fact that they really could do some things that they didn't think they could. But still it wasn't quite the real positive atmosphere I had in my lab last semester, and I haven't really sorted out all the reasons why yet. Because my lab last semester wrote things about learning how to trust each other, and depending on other people, and- this lab really didn't ever get to the point where they seemed to trust each other, and depend on each other very much. There were just small pockets of that. Mostly everybody didn't want to do anything more than they absolutely had to do.

Another faculty member described the role of the final essays as follows:

R: They didn't write a report. They were called "essays" instead.

I: Essays. Okay.

R: Yeah, I fought that battle. I didn't want a project report because I didn't want to hear any more about the sensors. I wanted to hear about what they had learned themselves, as people. And that comes from this difference [among us] about where the focus [of the course] is. The professor who suggested the project report is the same professor who thought they should have learned the process of design, and this is the way to test whether they have learned the process of design. The essays we finally asked them to write about didn't ask them what the process of design was--although some students wrote about the process of design [as part of what] they had learned. And then other students didn't write about that at all; they wrote about what had happened to themselves as people. And I actually was more interested in those, instead of regurgitating to me the process of design, which has been beaten to death in there.

Data point 5b: Current assessment methods are undergoing reconsideration.

Faculty continue to reconsider their assessment methods as they investigate better ways to assess the students' learning. Several factors have influenced the faculty's motivations to reconsider their current assessment methods:

- Individual philosophy about assessment
- No obvious way to assess the general "design experience" goal
- Uncertainty about value that assessment adds
- Oral dialogues with outside "assessors"
- Conflating assessment of what students learned with evaluation of the student learning processes

Their philosophical stances affect their ideas about assessment. Representative of several faculty is the following faculty comment that emphasized how faculty members' philosophical foundation affected both their goals and ideas about assessing how well students accomplished these goals.

R: [The level of disagreement about assessing the achievement of goals] was about the only thing that surprised me... I didn't see the point. ...[This matter] is more of an indication to me of how people have to have a [particular] philosophical foundation. And if the course is not somehow legitimizing their philosophical foundation, they feel like, "what's the point?"

I: Is there some implication for that...

R: Yeah, it means that if we rotate a lot of faculty into the course, we could get into some interesting problems if people don't philosophically buy into the way that we are doing it.

I: And what does that mean in terms of curriculum in the college? If you can't say for sure what the students are learning in the course, if you can't point to a test let's say, or some other measure, will that cause a problem?

R: I don't think so, if you can verbalize what [students] do pick up. Because I think a lot--most--of the faculty will say qualitatively that team dynamics and communication skills practiced in the setting of a design projects are worthwhile things to have.

When asked to comment on the matter of individualized versus standardized kinds of learning, several faculty voiced comments similar to the following. This speaker related assessment issues to the value of students learning individualized lessons (as opposed to standardized material). The following quotes from two different interviews indicate how faculty members are beginning to consider how to allow or even encourage students to engage in self-assessment. Note how grading is intimately connected to the assessment issues.

R: What each student takes away from this class is very individualized, and that's the part I care about. I don't particularly care about the standardized part, about the process of design, or whether or not they understand how such and such works, you know. I don't care. I

mean, it would be nice if they did, and I think that would help them in their engineering future. I'm more concerned that they take away some knowledge about themselves and what they're capable of. And that's very individualized. And so how do you assess that and assign it a grade? That's an issue, and it's a real issue.

R: What we've done in the past is... we looked at how they participated in their group, how the other students ranked them as participating, how reflective they were in their lab journals, and how well they documented [in their journals] what they learned. And that's how we assigned a grade. You know, I would be happier if this course didn't have grades.

I: How do you think that's going to evolve?

R: The grading?

I: Mm-hm.

R: When we first talked about this course, in the very beginning, I was an advocate of pass-fail. But you can't have credit in the curriculum if it's pass-fail, and there are some other bureaucratic reasons that it doesn't work. So I understand that. And also, some of these students want the A. They worked really hard and they want the A, and they want it to effect their grade point, and I don't want to cheat them of that either. So I guess we just hang in there with what we decided, which was that the mean grade would be an AB in this class, and to get a BC or even lower you have to really try. You have to just show continuously that you don't care. And we did have a student who got a BC this semester.

The following faculty member conveyed the idea that more structured journal entries can encourage students to more effectively evaluate their *own* learning processes and assess their *own* learning outcomes.

R: The things I would be interested in would be, "Do we see certain kinds of people who choose to leave engineering?" "Are they choosing to leave for reasons like... `I found something that I enjoy better,' or reasons like `I just don't think I can do this--my classmates have managed to convince me that I can't make it, whatever, my parents or whatever say that this is no place for women," things like that. Other than kind of anecdotal evidence or small elements that sometimes come up in journals, I haven't been able to think of a great way to measure that. That might be kind of fun to talk to psychologists, for example, just to get some idea of what are other indicators of confidence...
I: Did you ask both of those questions, and then students reflected on that in the journals?

R: ...we never really [provided] a set of questions... designed specifically to see what has been the change in the students, so I think for fall [semester] we'll try to... have students actually put a particular set of four or five questions in their journals on the first day of class, ask them a few similar questions on the last day, and then perhaps have them kind of go back and assess for themselves whether they think it's changed. You might choose to do the same.

I: That whole refection piece that the journal allows you to investigate seems to be becoming an important component.

R: I think so. I think that the self-awareness will kind of grow and change. I think could be a really valuable thing for students to acquire. I know that usually so many of them hurry to just scribble down what they did today. That isn't a high priority, but again, with a little bit more, how should we say it, guided use of the journals. I guess we would like to make that more of a common thread.

Testing students to determine whether they have learned specific material runs counter to key goals faculty hold for the course, according to virtually all faculty.

R: Well, the faculty are certainly used to giving tests, so in some ways, in my mind, the default of what's the easiest, most comfortable thing to do is give tests. We do that all the time, so people are very comfortable with the idea that that's how you find out if somebody's learned something: you write an exam and if they do well then obviously they've learned it, and if they don't then obviously they haven't. I think in this case I would suggest an argument in the opposite direction. Assuming that all things are done well--it's a great exam and all that--[you] may indeed find out if certain specific... ideas have been adopted by students. That's quite true, but I'm not sure if, from my viewpoint, that's a particularly valuable thing. That's not a strong interest of mine in terms of the class and whether students have or have not adopted certain ideas as their own. To me it is not much of a measure of whether of not they really have gotten something out of this design process and have gathered something in the design process. So I can see it's tempting to say that's the only way you can tell if they know how to design [is to test it], but I guess I also feel at this level it's real easy to make that into the narrow view that there is only one sort of design process, and this is the way you should learn to do it `cause this is the way we will ask you to give it back to us. And that, I think, runs kind of counter to some of the other ideas we'd like to pursue in the class.

I: Are you saying that there are a variety of design processes in the first place?

R: Oh yeah, there are many, many, and we deliberately chose only one.

There's no obvious way to assess the general "design experience" goal. Assessment of the "design experience" goal will remain an issue as more faculty join the team.

R: I think by and large [students got] a general picture of what design is all about and a general notion of how do you come up with designs... In the discussion about measurable, it came up [that] one test would be to say, "Okay, design something different, something we didn't make before." We didn't do that, so we didn't really say, "Gee, can you now take the derived skills you may have learned in this particular design and go apply them to some other thing as kind of a test to see just how much you understand about these design skills and how transportable they are." We didn't do that. I guess we could. Again, I'm a little reluctant to make this too much of a skills kind of class.

As early as the first month of the first semester, several faculty discussed oral dialogues with outside "assessors" as an appropriate assessment method. When asked whether an outsider would be able to tell what the design students had learned, several faculty indicated that an oral discussion would reveal the most accurate information. This relates to the idea that real customers are essential ingredients to the course.

R: By asking them what their experience was, I think [outsiders] would certainly respond positively. Maybe they would learn something wrong too. Like this semester, one fellow decided this is not for me... That's fine if that was what he was finding... So we don't want to look at it in terms of positive or negative for the course but [rather in terms of whether] they benefit, by themselves... I think that is what it is--to sit there in conversation and check on [their] attitude. I know darn well, there will be much different answers than on day one of that course. And then of course there are the themes of customer, project evaluation, safety, and ethics; all of these things have come through... We have got to make people more conscious of ethics in the sense of their daily decisions... Let's do it right instead of doing it shabbily.

B. Key Opportunities for Improvement

Faculty recognize that 1995-96 will bring a variety of challenges. Virtually all the faculty see these challenges as opportunities for improvement. Representative comments regarding these challenges follow within sections similar to the previous section.

1. Opportunities to Address Organizational and Structural Issues Impacting the Course

Establishing an image, maintaining real customers, and integrating new faculty are challenges.

R: First of all, get the image established college wide. Get graduates--graduate all of our students. [Students in all the majors] don't all have it yet. Mech Es don't have it as a credit [course] for graduation. EE does. Nuclear does... That is certainly a bookkeeping challenge. And then this idea of having it be a real customer based project instead of [being based on a text] book all the time is a challenge. And again, it is nice to have these new faculty involved... people that I really respect ...[I'm] worried about how we are going to build it and keep it going now. And we gotta keep transitioning people into the course--time for one to step out and others to come in.

An instructor's manual for both faculty and senior assistants would be a valuable product.

R: Well, one of our faculty volunteered to write an instructor's manual. The problem with the seven that are involved in this is that they have it all in their head. And then a brand new instructor comes aboard. There ought to be some helpful suggestions in written form to help the instructor.

Keeping faculty meetings focused on the important educational goals is a challenge.

Virtually all faculty saw the value in team meetings, but recognized that they seldom had time to discuss important teaching concerns, as these two representative comments describe.

I: Other rewards?

R: Well, I am very interested in education. And certainly the give and take of working with six other faculty helped me to think out what items are important in education... it would be nice to have goals that the students could shoot for and then design the course so that they learn things that are necessary for achieving the goals. Some of our exercises, and homework and lectures that students went through weren't aimed toward these goals. And the students perceived that and commented on that. You know, "Why did you have us do this? It never [fit in]. It is a side street." So I think the faculty sort of struggled with some of these questions. [Despite our many meetings] we didn't spend much time on what I think are the fundamental issues, and we spent so much time on scheduling and getting money and all these other issues that aren't really educational.

I: So a challenge would be to perhaps balance the timing that you spend on the fundamental issues as well as the mundane issues?

R: The meetings have to cover not only the content of the course and what's going to happen that week in lab; they also have to cover the political aspects of the course. And then many times we get people coming in with a guest to these meetings, and they have their own agenda, something that they need to tell us, in our one hour per week. And so we end up not having a whole lot of time to talk about what we're doing. We talk about mostly things that need to be done, not what's being done

Another faculty person's suggestion that the team meetings be more structured may answer the concerns mentioned above.

R: I think [our faculty meetings] would work better if we set an agenda a couple of days before, but, you know, things come up all of the sudden, and people have things they want to share, like something really neat happened in lab and we want to spend some time talking about it. I don't know how we can make it more structured.

I: But you think that there should be a little more structure?

R: I think maybe there should be some prioritization, you know? If there's something- maybe there's some way that things having to do with the teaching of that week, you know, take precedence over, just, other little tidbits when we get everybody in the same room.

Connections among course components, especially lecture, lab, and homework, can be stronger.

R: We really need to tighten up those [lecture and homework] activities so that they land directly into lab; we're still having some disconnect between that. I think it got better this semester, but certain topics need to be expanded and certain topics need to be compressed. And we need to have more things on ethics and societal impact. We've been stuffing that into fifty minutes, and that just doesn't make sense. We can't even have a discussion so... certain things need to be refined in there, and we need to have the students write in their lab journals and things like that.

Transitioning from a pilot course with third-party evaluation to an institutionalized course without third-party evaluator must be planned.

R: ... what will we do when the LEAD Center is no longer paid to interview these students at the end of the semester? We've been counting on you guys to do that for us, and then you have a record of what's been learned. And I don't know what the answer to that is. I guess we could require of ourselves and all of the SAs to write a reflective essay at the end of each semester about what we learned and what we think we should change. I think that would be good to put in a book somewhere. But if we don't do something with it then it's not really realistic. I mean, we can make the students do it, it's part of their grade, but for the rest of us, it's more of an artificial exercise. So I don't know; if there's no third party involved, I don't know how we do that.

2. Opportunities to Address the Emerging Goals for the Course

Improvements in helping students use and learn engineering and business tools

Almost all the faculty felt that the pilot year students had achieved the primary goals for student learning in the course. However, virtually all of them recognized that the goal of ensuring that students learned how to use engineering tools and resources was achieved least well. They realized that students often were not able to see the connections among the project, homework, and lecture. This faculty comment is representative.

I: Okay. Do you think that the students met these goals throughout the year? [referring to the list of goals]

R: Well, they definitely met the team interaction [goal]. They definitely met the communication [goal], both verbally and written. Where we fell down to some extent is... [with] the engineering tools... the students don't see the connection between practicing engineering tools and the course.... being forced to do a problem set in EXCEL seems irrelevant to them. Personally, I don't care if it irrelevant, I will still make them do it. But that connection, you know. That thing where you interviewed them and they said the homework had a very minimal connection to the rest of it? That's true, yet how do you learn anything except by practice? So, that's one area where I think we fell down. We [have] this objective of getting them to practice using engineering tools. And I think that we fell down there because there wasn't enough of a connection between what they were doing and the design product.

...So I think that we easily met the objectives. We did a good job on the two biggest objectives, which are team interaction and communication, both verbal and written. I don't think we did as good a job as we could have on the engineering tools and the product.

Improvements in managing and improving group dynamics

Managing the social dynamics affecting student work groups presents a continuing challenge in courses that emphasize learning through teamwork. This representative comment illustrates the problem of how to facilitate groups that include a very shy person.

R: We had, in my group, an extremely shy student--[shy] to the point where other students in their email messages will complain and wonder what they should do. And every time I got an email message, I always responded and I always made suggestions as to how they can encourage this person to participate. I mean the person became less shy as time went on, a little bit. Whether it was a result of anything I did or not, or just time in teamwork, I am not sure.

Student and faculty teams benefit from activities designed to help team members understand each other as unique people.

R: I think some element of common experience at the beginning of the teamwork is really helpful... what I'm thinking of is trying to kind of learn a little bit more about each other as other than caricatures of faculty or caricatures of other students. I'm sure students are like faculty: when you meet someone, you start to imagine what they're like and what they think and what their office looks like, and then all kinds of things, with little to back that up. The one thing that seemed to be sort of effective with students was to try as quickly as we could to introduce some activities which... forced students to see each other in a little bit different way... You might call them ice breakers or something like that - some way of forcing students to have some interaction. These aren't necessarily related to class work per se. They kind of [help students] see each other as not this collection of characteristic features, but as someone with a personality, and then perhaps you're a little bit more prepared... once you begin to recognize at least there's a personality... what they have to say relative to the [design] problems.

I: What were some of the ice breakers that you included in this course?

R: Well, the first semester I thought we did more than we did the second semester, but wearing headbands I thought was a pretty good one, and then just the little ones where we'd pair students off and then ask them to introduce themselves to each other, and then each pair would introduce their partner to the rest of the group. It's just a way of making the mechanical introduction part... a little bit more personal... I think the second week we had another similar activity with four-person groups.

Improvements in the racial and gender diversity of the instructor team

Improvements in responding to student self-confidence issues, especially for female students could be made, in part, by having more female faculty role models. Several faculty mentioned the importance of having more racial and gender diversity in the group of faculty teaching the course. For example, the apparent lack of tenured, female faculty in the College prompted this representative comment.

R: I'm also a little bit sad that when we were having a discussion about what female faculty might be involved in the course... there was no one! And so that is surprising to me, that we can't find someone that would volunteer to do it, [although] I do realize all the women are overloaded, and many of them are assistant professors. But you don't have any [women faculty] with tenure who really expresses an interest in teaching this class... at this point. And that says something about the College itself.

In order to send the message to women that "there's a place for you here," the strategy of having an all female lab surfaced. Several faculty mentioned this strategy during the end-of-semester interviews. One long conversation, used with permission and confirmed by comments from several faculty, describes typical observations of female students' experiences.

R: Somebody brought [an all female lab] up, and at first I didn't know if I liked it or not, but now after talking to the [female] senior assistants enough this semester, I think maybe we need that.

I: Tell me more about that; what did you learn from them?

R: I learned that they really don't have a lot of confidence even at their level, and that they need a lot of reassurance, and in fact, [they lose confidence] if you don't go out of your way to tell them they're doing a good job... And you realize none of these senior assistants was *my* senior assistant, ...but they would seek me out and ask me if they were doing okay, and I would try to tell the rest of the faculty [that their SAs needed reassurance]. I guess guys [the male faculty] think in terms of, "If I don't tell you something, that means you're doing fine." But I've noticed that... for these women, it appeared that if you didn't say anything that means they weren't doing fine... [One of the female SAs] actually wasn't going to apply for the fall. She didn't think she was qualified. So that was kind of shocking. It was surprising to me that she didn't know she was doing a good job, and in fact she was afraid to read her own student evaluations from last year. And they were fine!

I: Last semester?

R: Last semester. We had read everybody's and we knew that everybody had done fine. We wouldn't invite them back if there'd been a big problem. So, that was surprising to me... At that same time in TIP we were giving the guys some gender articles, on teaching and learning. And it was quite consistent with the literature...I didn't realize that it would be so marked... to know something intellectually, and yet to make it happen is a little bit different. So we need to spend more time with that.

We had one female student this semester [who in her essays] wrote really about her life in terms of what she learned about herself and that she could do things that she didn't think she could, and ... she was much more connected to her whole life experience than any of the guys' essays that I have read. Not that the guys weren't insightful, or introspective, but they always would get to course work.

She told [a male faculty] and me [female faculty] a number of times that she was having difficulty in the lab communicating with the guys in the lab, and that they didn't seem to be listening to her, and that nobody seemed to care about the project. [A male faculty person] and I would write back to her. We wrote back to her about different communication styles and that we had witnessed it happening in the lab, and she wasn't imagining it. [We encouraged her to] just hang in there and keep saying what she thought because eventually somebody would hear her.

I: So you provided that support.

R: On her weekly email reports she would tell us, and after that we started watching for it, and it was easy to see. When we'd sit down in the lab and they were supposed to be working on what was going to happen that night, putting things on the board, she would say, "well what about this?" But it was always in terms of a question, something like that. Then there would be silence, and then a couple of minutes later somebody would rephrase exactly what she had said as a *statement*, and then someone would jump up and write it on the board. And I could see why she was very frustrated.

I: So again, it's an example of intellectually kind of knowing some of this or reading about this, and then you actually saw this.

R: Yes, but then unfortunately the literature doesn't really tell you what to do about it. It just tells you that it is there, and then how to fix it is a different thing. I didn't really feel comfortable pulling aside some 17 year old boys and telling them that they weren't listening to her. I felt more comfortable talking to her about the fact that it's different communication styles, and that she was making sense, and that she should just... keep saying her opinion. I don't know if the right thing to do would have been to talk to all the guys about it. But the thing is she was all alone, and I didn't want them to know that she... wasn't happy with them. I think they would have talked to her even less then.

I: Let's just pursue this idea, if we had an all-female lab -- what would be the implications for that, let's say, in diversity on a team?

R: I don't have a problem with diversity. The only problem I would have is that maybe those women would come in thinking that, because there's no men in their class, that their project's not going to be as good as the other labs. So I think we have a big confidence issue at the beginning. But then, it should be even more rewarding as they actually learn to do things by themselves.

Improvements in student assessment methods

The level of disagreement about how to assess student learning was both frustrating and surprising to the faculty. Animated discussions among the faculty took place during team meetings, at local eateries, and on email. The issue of student assessment is critical as faculty prepare to increase the numbers of students and work with newer members on the faculty team. The following representative comments illustrate some of the discussion.

R: ...I think that the issue is going to come up again as the class presumably grows and encompasses more students and as more faculty in the College get involved, the issue will come up again. Is that something that needs to be done or should be done in this class? Is that kind of [assessment] going to give you useful information on the specific things you want to see happen in terms of this goal?

Faculty are uncertain whether the course experience has helped the student develop specific skills or whether they had those skills when they entered the course. They wonder whether the course has added value to the students, as this representative comment illustrates.

R: We noticed student change. One way of doing it is by [comparing] the presentations made in the middle of the semester with those at the end...all of the faculty can certainly observe changes in student interaction and cooperation from the beginning of the course... until the end of the course, where they are able to work in teams very successfully. So the students have learned, certainly, to work on teams in this setting. Whether or not they've done it before in high school or in laboratory courses here, I don't know.

I: Would there be value in finding that out from your what their experience on teams has been?

R: Well, I think so. I'd like to think that, at a minimum, you set some level of accomplishment that you'd like and at the end of the course you test for it. That's what most of us do in most of the courses... What we really don't know is whether the students could have passed the exam on the first day without our intervention--have we *added* anything? We all think that we do, probably do, but we don't really know.

Faculty agreed that the written essays, reports, journals, and presentations remain appropriate indicators of student learning. However, they discussed the merits of other assessment strategies including written and oral examinations.

R: I don't think giving them a test is a step in the right direction. I think requiring them to do more qualitative writing, or quantitative writing on their own that we check over [is the right step]. I mean if I were to do one other thing more, which would be very time consuming, I would think of an oral. Where I would get the team in or one individual in and ask them some questions. And then you get right to the heart if they knew anything or not.

R: ...I don't like written exams in this kind of a setting. If we are going to do anything

different, an oral is definitely different, because people get all "oochy" about that. But, I think that that [oral interviews] are too time consuming with a large class. But, given that, I think that the written, the journal, the presentation are good indicators.

A few faculty appeared to be conflating assessment of what students learned with evaluation of the student learning processes. This merging of assessment and evaluation is easy to understand, as there are many conflicting uses of the terms "assessment" and "evaluation." However, the problem was particularly frustrating for one faculty member. On the one hand, he felt stymied by the faculty group's uncertainty about how to assess what students had learned and, in particular, were they "able to design" upon finishing the course. On the other hand, he felt frustrated upon learning that the LEAD Center researchers focused only on the learning processes that students experience; he had anticipated that LEAD would assess how well students were able to perform engineering design work.

R: Well my expectations were... that we would develop some real objectives for student learning, and that the students would realize that they should learn these things. And the problem is... that right now I have to grade the eight students in my class. And I don't really know if they have accomplished what I have in mind. And it is not just me. I can go back to the writings of other faculty members who think, as I do, that students should be able to design when they have finished this course. So, those are my expectations, and I thought that we would achieve them in the second semester. But it is obvious to me that they will probably never be achieved... Another expectation was that the external evaluator would perhaps comment on the fact that they [the evaluators] were unable to find goals and evaluate whether the students could achieve them. And I haven't seen that.

I: Right...

R: If I could give a metaphor...I could propose a new course that is called wine-tasting 160. And set up objectives that the students would be able to learn to distinguish between red and white wine. Or learn the different root stocks, or the history of wine making or something like this. And then I could advise an external evaluator to attend one of our wine tastings. And the evaluator would go to the student and say, "Well, how's the course?" And the response might be, "Oh, man, the course is a blast. We had such a great party last night drinking all of this wine." And you would say, "But could you tell me something about the difference between American and French wine?" "Well, I don't know, I care about that, but we really had a great party. And we really feel good about this course. We really like this course, it has really set us up for the future and all that stuff." And then you come back and you say, "Can you tell me something about grafting onto root stock?" "Well, I don't know anything about that. But it's a really great course. Really like the instructors. And the teamwork we went through and everything that we went through was just wonderful." I don't think I need to say anymore.

II. Outcomes for Faculty

We present learning outcomes (LO) below. During subsequent analysis, additional outcomes may become apparent.

LO1. Achievement of goals for first-year students and SAs is an outcome by which faculty gauge the value of the course.

Virtually all the faculty found it rewarding when students achieved the course goals. In particular, they felt a sense of accomplishment upon seeing students mature and become part of the engineering system. Two representative comments follow.

R: I enjoy teaching so it is always a joy doing something like this and watching people mature and become part of the system and they are on the inside track a little bit.

R: Well, I enjoyed it very much.

I: Perhaps the most rewarding part of the course could be what?

R: Well, just seeing students develop.

Other faculty members noted how a gratifying outcome of their teaching effort was the opportunity to nurture a sense of confidence and professional direction in students. For example:

R: One day out of nowhere [student name] asked me to please come to a [organization] banquet [because he] was the M.C. for the banquet. He invited me because he liked me, because he felt I brought him to this point [where he could be an M.C.]. And now he is vice-president of the organization--as a sophomore. And again he comes to me and looks me up. So that is something that I value so much. He matured so much in that operation...

Another student, a young woman, wanted to be a chemical engineer when she came into the course. I told her chemical engineering is not chemistry from high school. And before long she changed into geological engineering... in February, I saw a very decent geological engineering book thrown out in the hall, one of the profs threw out. A brand new one. And I called her up on email and said I had this book, would she like it. And again she just spilled the beans. What a wonderful experience that was [in the design course]... with new friends and the professors that she has come to meet. So those were rewarding for me to see that.

Another instructor commented on how the course provides students an opportunity not only to explore engineering but also to evolve as individuals.

R: It [the course] is an exploration and what you're exploring is engineering, but mostly it's your reaction and your abilities to cope in an ambiguous situation. It's more an exploration of yourself than of engineering. So hopefully [students feel] challenged in a positive way and then see how they feel about how that works out. And I'm not so certain the students are certain when they leave here. They feel like they learned something, learned a lot about themselves, and they don't know exactly what impact that's going to have.

I: Was it clear to you at the end of the semester that they were or were not still interested in engineering, and did that matter to you?

R: Some were not interested in being engineers anymore... I still think the course is a success if they feel that they're leaving because they want to leave, versus they don't understand what it is they're leaving. I mean, [one young woman] is trying to decide between a dance career and an engineering career... Whatever she's happy doing is fine with us. So she knows what this is now, and she knows that if she leaves it's not because she couldn't do it.

Several faculty shared comments from senior assistants who described how teaching this course changed their lives!

R: The rewarding parts of this course are getting to know seventeen year old pre-engineering students. And hearing about life through their eyes. And a surprisingly rewarding part is hearing about not only getting to know the one senior assistant you work with closely, but hearing them talk about what they learned from teaching this class; hearing [them] talk about how teaching this class changed their *life*! That's surprisingly rewarding. So this class- teaching this class I think has a huge effect on those students, and hopefully a huge positive effect.

LO2. Faculty develop their own learning community, but find it may be more difficult for faculty to function as members of a team than for first-year students.

R: I was really pleased to say that I learned to know these "foreign" people--these mechanical engineers, industrial engineers. I knew them as names, but now I know them as people. Now I know them as friends. And that is a real benefit that I've had. I really value that. Before, I just didn't know these people well enough to know what their interests were, but what I see is interest in the students. That is where we stand out pretty highly, more so then many of my [other] colleagues. And we all care about that. We want to remedy the situation in different ways and yet our [shared] goal is to improve the student. We listen to each other.

Faculty bring their own baggage and assumptions to a faculty team; reaching consensus is difficult; it may be easier for students than for faculty to function effectively as members of a team.

R: ... teamwork wasn't as successful with the faculty when there seemed to be not just strong difference of opinion, but... let's say, a lack of recognition that we're coming at a problem from very, very different perspectives. Too many assumptions made before we'd begin the discussion made it very difficult to find a common ground. I think the faculty is really awkward `cause they're not used to kind of backing up and asking themselves, "Now what assumptions did I make to get to the statement I just made, and what assumptions did this person make to get to the statement they just made, and how are those sets of assumptions consistent or inconsistent?" It's a little easier, I think, for students, because we're constantly asking them to do that. They're a little more accustomed to second guessing themselves and saying, "Oh gee, maybe I shouldn't have made that assumption." But faculty, I think, are less used to that, so it's a little more difficult for them to... recognize how much baggage they're bringing with them... It's sort of a consideration with the freshmen and with the faculty too. It can be an impediment that affects people.

LO3. Faculty develop as individuals .

One faculty member observed that new personal skills were developed by some members of the faculty design team.

R: ...over the three years that I've known [faculty name], I've seem him change from somebody who was extremely introverted and quiet... [to someone who is] in a leadership role. I've watched him become increasingly progressive and wanting to learn. And that's really neat. And then I watched myself. I've transformed from somebody who--I'm still idealistic, but I'm more tolerant now of that things won't always be immediately the way I want them to be. I don't know if it causes me any less stress, but at least I realize it... that even if things aren't going quite right, that doesn't mean that you can't turn them around. So, maybe I'm maturing. I think I'm also becoming more confident, too...

Another faculty member noted that he had developed more political awareness of how to foster change within the College.

R: ...it's an education in the politics of - "politics" not used in a negative way, but referring to the way in which large organizations work - organizations. [It helped me] as a person looking for resources for one little element of a large organization [to learn] what strategies are helpful and which ones are not, in terms of getting resources for your little piece of the organization.

I: So what did you learn there? What strategies are helpful?

R: ... recognition of personalities involved in this college, for example. The things that have - how should we put it? - big public relations impact or have impact and look good are a lot more attractive than maybe equally valuable things that the general public or the public outside of the teaching faculty can't quite relate to. So if you count your interests in a way that is likely to appeal to non-engineering faculty, it's a lot easier to convince the Dean that this is an attractive proposition, [in contrast to how you go about] convincing the faculty.

Faculty became more acutely aware of the need to prioritize their own activities, and of their need to develop more effective time management skills.

I: Okay, things that aren't helpful...

R: Failure to recognize [that when] you take on additional tasks, you can't do some of the things you used to do. There's a finite amount of time and effort that one can devote to stuff, and while getting involved in new activities is great, that means some of the things that you used to be doing, you're either now doing a really crummy job at or you're not doing them at all...

I: How does one monitor that? Have you come up with any suggestions?

R: Not that I've been very successful at it, but you sort of monitor yourself, I guess. A lot of it, I think, is you probably see more faculty here [who respond] to being told "You ought to be doing." But then there's also a lot of self-directed stuff, so it's generally your own set of priorities. The external inputs are so many as to be ludicrous, in the sense that no one can do all the things that the Dean says the faculty members should do - which is okay in a way because once it becomes ludicrous then you're free to choose whatever you want. If the load was reasonable then it would be a lot harder to say, "Well, I'm only doing half of that." Because it's ridiculous, I think it sort of ends up, for most faculty, as your own priority system of what has to get done and what I would like to get done if there's time. ...I haven't really figured out how to do this yet.

LO4. Departments/administrators affect and are affected by the course

Several design faculty emphasized that there is a certain dynamic element about the course: it affects all individuals involved with it, and in turn, is changed by those it affects.

I: You just made a statement about it has an effect on everything. Can you just kind of summarize the "everything" again?

R: Well it [the course] had an effect on student expectations--[students] appeared to be voicing these expectations in certain classes. It had an effect on faculty expectations, which is more powerful because the faculty have more power [laugh]. It had an effect on the administration as they see people willing to devote time and energy to something that they don't get an obvious direct benefit from--I think that must make an impression. And it changes other courses as other faculty hear and learn and change their own expectations of teaching. So it affects everything that surrounds it or is involved with it, I think. And it is changed by those things as well. So, it's a very dynamic thing. I mean, I would be ashamed of us if a description [of the course] stayed exactly the same for a year.

Several faculty commented that their experiences in the first-year design course are having an effect on the upper-division courses they teach in their departments and on the COE curriculum overall. They tended to view the design course as a laboratory that provides a "rapid feedback mode." As one faculty member explained, those who experience innovative approaches first-hand notice significant differences in students' learning and thus understand the value of these approaches. Accordingly, they are motivated to change their other courses and the engineering curriculum.

R: I think it has been really interesting and a great learning experience from the teaching viewpoint, seeing in a sort of rapid feedback mode what things seem to work, what things don't seem to work. [We can] find out pretty quickly what ideas seem to really get students interested and what ones don't, so that's pretty nice. I guess also that another feature of having a class that's sufficiently open-ended is you really can do a lot with it if you choose to. It's not constrained like many of the other required classes that we teach, where certain material really has to be covered. So that's been kind of fun. You feel like you have a little more flexibility than with many other classes.

Another faculty explained how they apply lessons learned in teaching the design course to upper division courses they teach.

R: As far as the department, I think there aren't any huge changes other than that they gave me kind of a mixed response to it... You could say we've got a lot of enthusiasts. On the other hand, department chairs and the department as a whole have... a minor inconvenience. We have to find people to teach our regular classes `cause a lot of faculty are off teaching the design course. In that sense it's been a bit of a challenge for the departments... On the other hand, the exposure of lots of new faculty - I think, they are having a similar experience to mine - [provides them] a chance to be a little bit more experimental than they might be in a regular class. They are not just observers, but [are getting] experience as doers in a course that really has a lot of big differences from the regular ones. As I said, it's got these vague goals that aren't easily tested, and some ways to accomplish the goals that aren't commonplace in engineering classes. So in that sense, I think, people who are participating have kind of found it interesting to be so different and take some of those different ideas back with them to regular classes... So I guess it's sort of a laboratory for trying out new ideas... What most of the faculty who have volunteered to teach this next fall have told me is that they're hoping to take away some of the structure of the course and put it in their courses. They're hoping to learn something in this course about teaching that they can't learn any other way. Because hearing about the course, watching student presentations is very different than having your own lab section of twelve, fifteen students. And so I think it can only help the departments that participate.

As the two interview excerpts below indicate, the design faculty found that support from department chairs and colleagues was not only an outcome but also a necessary condition of their participation in the course. The second quote shows that another outcome was some hostility from departmental colleagues.

I: In your own department, how did you find people to cover your other classes? Were they other faculty, or did you bring in people?

R: Well, to the extent that we've been successful they would have to have done that. It's been both, some faculty, some post-docs. We usually don't like to have TAs teach classes, but some post-docs, for example, graduates who are stuck here for an extra six months or a year, are teaching a course for us. So we kind of made due in that regard. I guess as department policy we were reluctant to have anyone who's not a faculty member, like one of these post-docs that we know pretty well, teach a regular lecture type class. So... then a few faculty taught more classes than they would normally.

R: Quite frankly I'm surprised at some of the open hostility towards the course from some of the departments... I thought some departments might be ambivalent, but I never thought they would be openly hostile. I'm always surprised at that, and at people's resistance to new ideas, even if they don't fully understand what they are...

LO5. Awareness of the value of shifting teaching into a collaborative mode in a public arena

Faculty explained that an effect of their understanding of the teaching/learning process was a new understanding of the "public" nature of their teaching.

I: Okay. Has this experience made a difference for you in your life?

R: Yeah! Big difference. It's the first class I've ever put together from nothing. Always before I taught a class that already existed, and I would take a syllabus and modify it or something. So this is the first time I've ever been involved in the development of a brand new class, so that was very educational. And [I did it] with experienced people who know a lot, and are willing to teach me. I would say it's kind of been a life-changing experience for me to be able to teach with people from different departments...it's been a great opportunity.

...And the fact that the class attracts attention [is important] too. We get so much input from outside, which is really unique. Because usually when you teach a class it's within a department and no one ever comes in. Nobody looks at it, and you're just alone with your students... and this class is not like that at all. It's a totally different experience. It's very visible, and a lot of people are interested in what happens. I think that's good.

LO6. Excitement, pride, and anticipation of an even better course in future years.

Several faculty expressed a strong positive overall feeling about their participation in the course.

I: The course has had what effects on you?

R: I'm really proud of it, I'm really happy that it exists, and that it is the way it is, I think it's quite unique. I feel very honored that I was part of it this year, and got to play a role in it. And I'm really hopeful about the future of it because the new faculty who are coming are really neat. I think it's going to be even more fun. The course is going to be even more creative and fun to teach, and hopefully fun to be in, than it is now. I mean, the people coming in are so constructive, that I think it's really going to change the course in a good way. And it's also good for the seven of us who have been together now for three years to have some new blood in here...

III. Analytic Generalizations: From the Researchers' Point of View

We structure our analytic generalizations (AG) about the learning processes under the following headings:

AG1. Approach to teaching and learning: Collaborative teamwork engenders creative, cooperative approaches to teaching and learning.

Faculty demonstrated a collaborative, creative team approach to teaching and learning. Their approach was collaborative in the sense that they worked together to establish goals; define roles for themselves and the senior assistants; establish the projects and maintain contact with the real clients; organize the content and methodology; arrange for rooms, equipment, timetable designations, and other structural needs; assess student learning; and revise the course. In addition, they worked with their colleagues to discuss the merits of the course in meeting the needs of the students and the College of Engineering. It engendered creativity because both faculty and students - separately and together with their colleagues - were open to one another's ideas and were not limited by their individual capacities. Finally, relying primarily on their faculty colleagues and secondarily on senior assistants, they used the team approach to create a better course. (Data points 1 - 5)

AG2. Attitude toward teaching and learning: Faculty demonstrated positive attitudes toward teaching and learning and pleasure in connecting their TIP study of cooperative, collaborative teaching to a freshman engineering design course where they were both teachers of student teams and learners in a faculty team.

Faculty demonstrated a positive attitude toward teaching and learning. They recognized their unique role as both teachers and learners in a new cross-disciplinary team within the College of Engineering. Their experience reflected the experience of their students in many ways; the team teaching, with both its benefits and frustrations, created a positive, valued experience for the faculty. (Data points 2, 4)

AG3. Sources of affirmation: Interaction with colleagues helps faculty develop their self-confidence in designing a curriculum that meets the needs of students and other stakeholders.

Interaction with colleagues, particularly those with more experience, helps faculty discuss teaching and learning strategies, apply new methodologies in their classrooms, interact with industrial representatives, and feel more comfortable sharing their teaching stories with colleagues and interested others. (Data point 2)

AG4. An "island" of connected understanding and cross-disciplinary teaching and learning: The course needs to gain buy-in from other faculty for acceptance within the College of Engineering.

The process of having time to work together with colleagues from different disciplines to design a course from beginning to end is in marked contrast to the traditional course proposal process in the College of Engineering and in higher education in general. The design course is an island of connected understanding and real learning in marked contrast to traditional, isolated freshmen courses that offer little or no real engineering connections. Likewise, for the faculty, the design course is an island of connected understanding and real learning as contrasted to traditional, "mine-shaft"-like departmental courses that offer little or no interaction with colleagues in terms of integrating and avoiding duplication of engineering principles, skills, and applications. One impact of the course may be that it will affect the engineering curriculum over time, expanding this "island of connected understanding" to encompass a much larger portion of COE students' experiences.

AG5. Early connections with high schools: The "before" connection is as important as the

"after" connection with business and industry.

Faculty recognize that early connections with students and teachers in high schools will help students and faculty understand that "we're all one big team" working on the same skills and attitudes. The teaching and learning processes that teachers and students experience "before" they enter higher education are as important as the teaching and learning processes that they experience "after" they leave the College of Engineering and enter the world of work. The design faculty are beginning to help facilitate these connections. (Data point 4)

AG6. Assessment of student learning and evaluation of the learning process

Assessment of what students learn and evaluation of their learning processes are two significant issues that faculty are addressing. They "experimented" with new ways of addressing both issues: instead of giving traditional exams, they asked students to assess themselves and others, to write in journals, and write an end-of-semester essay. They relied on the LEAD Center for formative feedback evaluation of student - and instructor - the learning processes. They recognize that some colleagues question the reliability of their tools to asses what students have learned in the course. Furthermore, they recognize that they will need to develop an evaluation process (replacing LEAD Center contributions) that works for them. (Data point 5)

AG7. Project with real customers: This essential feature captures the "spirit" of the course.

By viewing real-world projects and real customers as central to the "spirit" of the course, the faculty tapped into a significant factor that motivates students. Students' concern about contributing to society appears to be genuine. Such projects should remain the center of the course even though observations reveal that project selection is time-consuming and difficult. In much the same way, by viewing the need to meet students' learning needs as central to the "spirit" of the College of Engineering, the College taps into a significant factor that motivates faculty, and that meets the needs of employers and society overall. (Data points 2, 3)

Principal Investigator Perspectives

Principal Investigator Perspectives

The principal investigator for the TRP ARPA "Diversity and Cultural Change: Manufacturing Engineering Education for the Future" (MEEF) grant is J. Leon Shohet, Professor and Director of the Engineering Research Center for Plasma-Aided Manufacturing. Denice Denton, Associate Professor, Electrical and Computer Engineering is the grant manager and leader of the Education Thrust Area of the ERC for PAM.[2] They are clients of the LEAD Center and worked closely with its director, Susan Millar, in the early stages of writing the MEEF proposal and conceptualizing the LEAD Center. As such, the "Introduction to Engineering" is one of the first third-party evaluations conducted by the LEAD Center.

This report summarizes interviews with Professors Shohet and Denton. The ERC's Associate Director, Marlene Barmish, also participated in one of the interviews. The interviews were conducted at the beginning and end of fall 1994. This summary presents their perspectives on the course and will help interested others understand the context in which "Introduction to Engineering" came to be and the role that they see for the course. For example, one principal investigator (PI) talked about the course being one part of a bigger picture or puzzle:

R: Well, this course is one piece of a puzzle... [The course] is not an entity that stands alone for me because I think all these different things have to be happening. It is a nice lever to get the college to really think through what it is trying to do. And it is precipitating all of this discussion on the part of the Dean and other people about what we should really be doing. So I think that is good.

Before proceeding to this review, it is important to state that "Introduction to Engineering" is one part of the curricular reform efforts within the College of Engineering and throughout the physical sciences. The course is one of five curricular and pedagogical reforms funded through the TRP ARPA grant: 1) cross-disciplinary introductory design course; 2) workshop-based pre-requisite courses in physics, chemistry, calculus, linear algebra, and differential equations; 3) science, mathematics, and engineering (SME) bonding groups; 4) advanced manufacturing design course; 5) cross-disciplinary course cluster on manufacturing. In addition to the curricular and pedagogical reform component are two other components. An additional outreach and undergraduate recruitment component consists of a summer internship program in manufacturing technology, K-12 manufacturing kits, and a SWE/ERC K-12 plasma road show. The evaluation, assessment, and dissemination component consists of formative evaluation, assessment of the curricular and pedagogical reform activities, and guidance for the production of innovative and effective dissemination materials.

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[2] Because the PI and the grant manager work very closely together on the administration of the MEEF grant, and to avoid excessive wordiness, we refer to them collectively in this report as "the PIs."

1. Recognizing the Cross-Functional Role of the Engineering Research Center

The Engineering Research Center, funded initially by NSF in 1988 for eleven years or until 1999, is a cross-disciplinary center with both a research and an education component. Its image in the College is evolving from a source of money to a source of curricular innovation. Its mission encompasses places other than the University of Wisconsin-Madison including: University of Minnesota, UCLA, Stanford, University of Illinois, University of Michigan, and Drexel. Its multi-campus structure may facilitate the dissemination of the learnings to others. The ERC for PAM consists of four research thrust areas, an education thrust area, and three support groups (diagnostics, theory in modelling, and engineering statistics).

R: The Center that really funds this has been in existence since 1988. So we are just ending our sixth year of operation, beginning our seventh year in October. And one of the reasons that I think the proposal went the way it did is that the Center had in addition to a research mandate a very strong education mandate. That is really a parcel of the mission of the Engineering Research Center as defined by the National Science Foundation. To some extent the infrastructure of the Center is really set up to do many of the sorts of things that were in this TRP proposal including the cross-disciplinary design course. I think that when the request for proposals came out it seemed like a natural fit to be able to extend the educational activity of the Center itself beyond engineering. Again, another reason why it works for a center like this is that it is inherently cross-disciplinary by definition. One of the things is that the [ERCs] must be is cross-disciplinary; they must have a research component and an educational component. I must say that the NSF has always felt that our particular Center's educational component was really good. And because of that, I think we were fortunate to be able to be provided with the type of funding for this activity...

...Now there is another aspect of our Center that you may not be aware of and that is that part of it is in other places. Some of our activities are in Minnesota. We also support work at UCLA and Stanford, at University of Illinois, and I think we are going to be starting a new program in Michigan. And presently we are still supporting some work at Drexel [and Stanford]. So there is an opportunity. It is a good thing to get this kind of a course operational at other places and I would hope that if the D of LEAD is what I think it is, "dissemination"

I: Yes, it is.

R: Then there is sort of a built-in mechanism by which we could do that through the Center, which I think would really be terrific.

Data point 1a: Education, not just research, matters: ERC has established an

infrastructure and is building an attitude among the faculty and researchers that education matters.

When asked to describe a vision for the ERC Thrust Area Five, one PI described these components.

I: So basically I would like you to describe your vision for the ERC Thrust Area Five.

R: The ERC has an education mandate... NSF has really insisted that we become involved in activities beyond the research laboratory. And that means new courses, new undergraduate instructional laboratories, outreach programs, and precollege programs. In many ways, I often view the Engineering Research Center as a miniature College of Engineering because we have these extra facets that you don't normally have in research activities. And so what we have actually been able to do is to really set up not only an infrastructure but also an attitude among the faculty and researchers that education matters. It's taken a good number of years to do it. The Center is now in its 7th year of operation, and I would say after the first couple of years people have really begun to take this education activity much more seriously than they did in the past.

I: Could you explain what you mean by attitude with your faculty and the ERC?

R: I would say that when we got started, everybody had sort of a different view of what the ERC was all about, and that in many cases, faculty viewed the ERC as a place where they could get money to do research that they wanted to. And over the first few years of the Center's operation I think we found that that changed.

I: How do you know it changed?

R: I will give you a real tangible example, and it's one I always use because I think it's very indicative of what happened. Whenever we have a sight visit from NSF we always go around the room and ask people to introduce themselves. And the first year the students would say, "I'm so and so, I work for professor so and so." But the second year, they would say, "I'm so and so, I'm in Thrust Area Three." That says something. It says that it really does become an entity in the minds of the people. But more than that, I think that when the educational activities began to impact the students and the faculty directly, they began to think of things like this. We have, for example, developed an undergraduate laboratory based on a lot of experimental work that we did in the Center. And the students really got involved in doing this. It's a terrific laboratory. It's really good. It teaches a lot of the activities not only in the field of our Center itself, but also manufacturing techniques, statistical experimental design, and so forth. I think it's really been just terrific.

I: You talked about the effect you've already seen in Thrust Area Five on faculty attitude. I wonder if you could explore a little bit the anticipated effects you'd like to see on the administration and on students.

R: Now, when you say administration, you mean the college and university administration?

I: Uh huh.

R: There are a couple of things that I think are very helpful to us in this regard. I think that it certainly makes the Center--we hope at least--much more visible. I think that this is very important for the future of the Center because a lot of times people view our Engineering Research Center the same as another center and another center, and they're not. This one, more than most, is very unique and very different. And the fact that the Center really takes a very strong role in educational activities is something that probably most people don't know and don't understand. And I think here is an opportunity for us to do that. But secondly, and I think this is even more important, we have some very talented people that are involved in the research activities in the ERC. To get them to start thinking about education and become involved with a number of these aspects is something that I think ordinarily would never happen without the Center, and is, in that respect, terrific.

I: Ok, and you want to make that visible to the administration?

R: I think the administration knows it. I think that you can never get too little exposure to what goes on. Because in many ways, education is where it's at. Here's a case where we can actually show [the link between research and education]. I testified at the Board of Regents last week. They were asking me about some issues regarding research and education, and I went into a whole discussion about the TRP Program. I have a feeling that more and more research grants are going to have more and more education components in them.

Data point 1b: The COE and ERC are companions: Cross-college and within-college education reform activities of both infrastructures are synergistic. With a dollar for dollar match, the ERC is a seedbed.

The relationship between the College of Engineering and the Engineering Research Center is important in terms of understanding how "Introduction to Engineering" came to be and what its future may be. Financially, the ARPA-TRP grants work on a "dollar for dollar" match premise. Therefore, the PIs use the analogy of ERC as a seedbed to describe the beginning of "Introduction to Engineering."

I: Where does the ARPA-TRP grant that is funding the Design and WES programs and so forth come into the history of the Thrust Area Five?

R: A couple of years ago, we were specifically requested by NSF to submit a proposal because they really felt that the education program that we developed before this TRP project was the best one of all the engineering research centers

R2: I think it is, I don't think there is any question.

R: And so they said, "This is an opportunity for you to extend what you're doing beyond the confines of the field and maybe even just the College of Engineering." And so they really encouraged us to develop this and they said, "But we want to preserve the relationship of the ERC to the projects," and so that's why they came up with the idea of making it as a separate thrust area.

I: I'm beginning to understand some of the relationship between the Dean and his interest in cross-college and within-college education reform activity and the ERC's. I mean, it's a pretty complex picture. Professors Corradini and Denton and Dean Bollinger are trying to think through a new way of structuring the first two years--what they call the "T diagram." They certainly support one another because Professor Denton seems to have a foot in each place, so she's acting as a kind of mediator between the two Centers or infrastructures.

R: I think that's one of the things that I hope we can continue to do, that is, to really stimulate people who aren't necessarily part of ERC to start thinking about this because they can see some real tangible results that occur. Number one, you get funded; and number two, you can really see some results. So I think that NSF would really be pleased to know about all these, let's say, companion activities. I think it's terrific. And I think that it's just what NSF wants to do. Because they obviously can't fund the entire College of Engineering to do this, but what they hope they can do is get enough people aware of it and excited about some of these changes that people can develop things on their own.

I: So it's like the ERC is seedbed, almost?

R: I think that's how they view it.
R2: Although everything's matched. Everything's dollar for dollar.

A little later:

R2: Your word "seed-money" is a really good term... as far as the interactions with NSF go, I think that's precisely their mission here--to provide these bits of seed money. But I believe that when we talk [about] going ahead in the next year or two and beginning to think about what's going to go into [the ERC continuation proposal], I think they're not going to view favorably [providing continuation funding for those activities] which they feel the university should take up. I mean, it comes back to the whole issue, with [Chancellor start-up funding for LEAD],and the whole history over the past year and a half.

Regarding the financial support and the role of the PI, we heard these comments:

I: Any other concerns?

R: The fiscal issue is important and plus we are not a cash cow, although a lot of people sometimes think we are. Are there going to be sufficient resources so that this course can be expanded to the entire curriculum? I think that is an issue as to what the future is when the money is gone and the course is so large that it really will need a lot of resources. I think it would be a shame if we got all this enthusiasm but then there was no way to keep it going. That means space. It means money for equipment. It means money for personnel. All of these things -- I don't know where the money is going to come from. Thank God we have got it now.

A different way in which the MEEF grant functions as a "seedbed" was expressed as follows:

R: [The faculty] are going to have to decide if they want to do it a different way. And it is interesting to me.... [the faculty need to learn] some crucial, fundamental issues about how you really do student-centered education...

I: Could this be a laboratory in which they are learning?

R: I hope so... They have to figure that out.

2. Setting Goals

Both PIs articulated the following goals throughout their interviews:

- prepare first-year students to become engineers working in industry
- provide students a real engineering experience by working in teams to make, test, and sell something
- provide students a context for other courses, such as calculus
- integrate manufacturing into the curriculum

- involve industry representatives in the curriculum
- get students excited about the potential of what can be done as an engineer
- help find students meaningful jobs
- help students make informed-decisions about whether to stay or leave engineering, which will result in improved retention rates
- help students learn early to be independent thinkers and students, thereby helping them make the transition from high school to college
- expose students to software and tools in an enjoyable manner
- expose students to economics and business strategies.

Data point 2a: Goals articulated by the PIs appear to be aligned with goals stated by both faculty and students.

I: What are your expectations of this course?

R: I think we need to do a better job of educating people to work as engineers. We all do a really great job of teaching our students to become professors and not such a good job of teaching them to work in industry. And I think the National Science Foundation and ARPA probably recognize that a lot of the training that we give undergraduate engineering students is really not to prepare them for the role they would have in industry. The purpose of industry is to make money. We don't teach that, especially when they are freshmen. . We teach them calculus, chemistry, physics. But we don't say that the purpose of, let's say IBM, is not to make computers but to make money. And what does that mean and how do you mix them? We don't do a very good job of that. I think that this cross-disciplinary design course, if it is really going to be effective, ought to give students a sense of, "OK, this is what it really takes to make something. This is really what it takes to think about how to build it, how to put it together, will it sell, where do we get the resources to do it?" And to work in a team operation which is what you do in industry all the time. I think that if it is done right, the excitement and the potential for this thing ought to really get the students sold on having a career in engineering. And that is what I hope will come out of it.

I: So that is your expectation. And that is different than other courses you see happening here? You kind of alluded to that.

R: Oh, very much so. Very much so. And it is especially important in the freshman year because so many times we hear students say, "I don't know what engineers do and why do I want to take calculus? What good is it?" ...You don't have to study for three semesters and then try and figure out where you are going to fit it in the future.

[With this new course, they] are doing it in week one.

I: You mentioned the word "fit." How do you see this course fitting into the whole engineering curriculum?

R: What I hope will happen is that this will set the stage for the entire engineering curriculum to be more oriented towards the industrial and manufacturing applications. For example, in my own Department, which is Electrical and Computer Engineering, there is no course in manufacturing. There is nothing. One of the things that is really critical for today

is the use of modern statistical methods for doing experiments for manufacturing. We teach nothing like that. The industrial engineers get it, but not the electrical engineers. Why is that? Again, partly from our experience in setting up the Center where we do have a lot of this activity, [w learn] that people teaching electrical engineering don't recognize that that is what is really needed these days. Here is an opportunity to get things like that going in the curriculum...

...I think in addition to the money that we have gotten to run this one particular course there are a number of other activities that are designed to try and bring more of the manufacturing back into the entire curriculum of engineering. And the other thing that is really important about these courses is to keep the industrial involvement. For example, we have like 33 companies that are members of the Center. We would really like them to be involved in the cross-disciplinary design course not only to help us with topics, but also to come to these classes and really explain to the students what it is that engineers do. Not only in this course but with other activities as well, including the work we do with calculus, with chemistry, with physics, to get people really excited about the potential of what can be done as an engineer...

...I want to add that just because you can do it, doesn't mean that somebody is going to buy it. And I would hope that that economic issue could somehow get put into the course... I think [the design faculty] are saying right now, "Let's just see if they can do it." But I think the whole issue about marketing, sales, all of these things, ought to be part of this thing. Because if it is really going to work and industry is really going to pick up on something like this, all of that has to be looked at. And students need to know about that. So do the faculty, for that matter.

R2: I think being able to work in a team is one of the most fun aspects of this whole proposal... we are already cross-disciplinary, but know you've got the education component. ...the engineers who are doing their plasma aided manufacturing... are also seeing this aspect of working with a team--knowing how to talk to chemists, mathematicians, and now even education people. I've just seen the changes in the last few months. I think that has really made a difference.

I: Why did you get involved in the introductory design course?

R: I think it was because nationally it looked like there were a number of these efforts underway and we didn't have anything at Madison in the first year. One of my big motivations is the retention issue, to try and keep students in engineering--the ones that should stay but who are leaving because they just don't like the calculus class or whatever. So to give them a better choice, a better way to make the decision about whether to stay or leave.

I: Is there anything else you would say you are trying to accomplish?

R: Probably getting them to learn early on how to be independent studiers and thinkers. Give them creative assignments that make them realize that they have to do a lot of the work themselves in college. No one is going to do it for them. So it is the transition from high school to college.

Giving students a real engineering experience and having them make something that society can benefit from appear to be among the most important goals that PIs have for students. They appear to believe that if the course incorporates these two aspects, then students will make informed career decisions and more will choose to stay in engineering.

I: What do you see as the ideal effect on students for this whole program?

R: Well, the students that actually participate in the courses, you would hope get a very good idea of what engineering is all about. I think that's really critical. I am so appalled that so few American students enroll in engineering. It's just terrible...

I: So you see this as a recruiting...

R: Recruiting and retention... And what's even more important, and this I hope will eventually percolate into the faculty, is that people have to realize that when you're an engineer, you have to make something. And I don't think most faculty members realize that... what's the difference, then, between engineering and physics, or engineering and chemistry? If you make no distinction, I think the country is in trouble. So what you have to say is, "We are going to do just as good science as people in the Physics Department do, but the science has to be such that if we're successful, things will happen that will result in new products, in something that this society can benefit from.

I: OK, so that awareness of the actual production of objects...

R: It's a pragmatic approach... we need to train engineering students to realize that when they go to work, they're probably not going to be professors, they're going to be working in industry. And what is the purpose of industry? It's not to do research. It's to make money. And I don't think most students realize it. I think they are beginning to now. And I think the presence of the ERC with the constant industrial involvement [will help students recognize the significance of the course goals].

With respect to the role of business and industry in the course, the PI goals are not entirely aligned with those articulated by the faculty.

I: OK. Do you feel that the course goals and objectives as stated here are the right ones? Things like problem-solving, team work.

R: The only thing that is not there is the economics.

R2: I think that is what they meant by the business.

R: And another one that maybe ought to be spelled out a little bit more is active involvement of industry.

Data point 2b: 1994-95 pilot is the year to debug the course.

The pilot year is a debugging year, as one PI responded while presenting expectations for the course this year. Actually, the results at the end of the pilot year show that more students remain in engineering after one year than this PI had projected.

R: I think what we have to learn is how to make something like this work in our college. To me, this first year is just the debugging year to find out what is going to work or not work and what we might have to do to either get the curriculum or content just right, get the level right, and make sure we are achieving our goals. It is just a test run, really. So I don't have great expectations. My hope would be that a few of the students would stay and not all drop the class. I will be happy if half of them by the end were still with it and into it. I think there are going to be a lot of mistakes made... because [most of the faculty] have never taught freshmen... Most of us don't see students until they are juniors and are oblivious to where an eighteen-year-old is in their life. So to me, it is a learning experience for the faculty...

R: I would like the students to leave the course with some inkling of what engineering is about, with a picture that complements what they are given when they sit through these big boring calculus lectures. So that they get the clue that, "No, that is not engineering. This over here, this is something like engineering." Maybe they will learn something about the different branches in engineering, although probably not a whole lot. And [would hope] that they can be intelligently deciding whether or not to stay in engineering based on their experience... [the course] should be something they will enjoy... the faculty need to think what can an eighteen-year-old really do [in this course] while they are trying to learn calculus and chemistry and econ and whatever. They should be exposed to some new things, like some software and some tools and things they would use in whatever field they end up in and have some idea about teams and study groups. So all of those could be ideal outcomes.

I: OK. Do you feel that these goals were articulated in the brochure, for example, and the SOAR Program?

R: I think to some degree. I think that is pretty much what they were telling these students. "You are going to have a real engineering experience; you are going to work in teams. You are going to learn a little engineering in this"

3. Creating a Student-Centered Course: A Challenge to Teaching

PIs recognized that a challenge was to take the talk about teaching improvement to a real course. The following representative comment demonstrates their understanding of the difference between talking about making a course "student-centered" and actually doing it.

Data point 3a: Understanding first-year students is critical to developing a student-centered course.

Several times throughout interviews with PIs, researchers noted the concern about the faculty's knowledge of how to work with first-year students.

R: I didn't quite anticipate how hard it would be for [the faculty] to understand freshmen and what they can really do and ought to be doing. We don't want to be taking away from their other courses that they have to do well in. I think it is just going to be a real challenge to... be able to pull this off... Not physically being there, I don't know what is really happening. But my interpretation is that [they haven't acquired] ...that much perspective really about what "student-centered" means, about how you take into account the needs of the students, the abilities of the students, what are the best things for the students to learn to have a good learning experience.

At another time, one PI commented on the same issue but expressed hope when observing how students were so involved with the fall, 1994 project.

R: ...during the summer had students sitting around the table while they were developing the course...

I: Rewards. What has been the most rewarding thing that you have observed related

to this?
R: I think just seeing the students in their teams when they were going around the first week with the wheelchairs and trying to understand what it meant. That was a real vision of it actually happening, that they were going around doing all of that stuff. So that is good.

In addition, one PI commented this way about the course itself.

I: You have not personally been involved with the nitty-gritty design. But are there some things that you would like to share with us that you would keep for sure and things that you would change?

R: I think the format is probably reasonable. A lecture a week and then they have their labs. And then I would just really soft pedal homework. I would keep it real low key. If any, I would have some tiny amount, like a pre-lab, something that would help them understand the lab better if they did it the week before. I would emphasize lab notebooks, primarily in the

context of what they did while they were physically in the lab room. [Students need to] learn how to keep a notebook in the lab, not to go off and do some huge report in the lab notebook later. So I would want them to be learning how to keep a lab notebook, maybe give them a few sets of pre-lab questions or pre-designs to work on before they come that they would then be using when they got there.

Data point 3b: The project topic and industrial involvement are critical components in creating a customer-focused course.

The PIs agreed that the project is important in creating a student-centered course. The project must be at the right level, involve real clients, and link industrial representatives with the course.

I: Are there other challenges you care to mention before we close?

R: Well, frankly I think the choice of the topics of the project is very critical and I think again we really need to get people with enough interest and understanding of what [first-year] students can do. And creativity as well. I am talking about what they are capable of. If you tell them to design a computer, they probably can't do it. Or make a chip. But if you tell them to build a ramp, maybe they can. And so the level of the product is really important and that is going to be a challenge for the future. You want to have different projects. You want to have something that is exciting so they can all get into it. It's not easy...

...I have explicitly chosen not to micromanage this project because the faculty have to buy into what they are doing. When I think something is really important, [I let them know.] Like I was really concerned when they were [thinking of having students] design a battery for the semester... that is when I suggested if they would just inject some people into it... and they got into the wheelchair thing.

When asked about the role industrial people might play, ideas such as guest lectures, donation of equipment, brainstorming ideas with faculty, and project possibilities surfaced. A new approach of getting industry involved with assessment of learning also appeared to have possibilities.

I: What I am wondering is whether or not [industry representatives] would like to be involved in the assessment. Are there certain questions that they see as very important?

R: I think some of them would [like to be involved], actually... But this is the very way they could do it. They could say we need to get you guys to impart this message to the students and we don't see that it is there but if you do this it would really be terrific...

...I think it's really critical that the industrial partners have something to contribute, and we point to some tangible things where they're really involved in what goes on.

R2: [Many] of the industrial partners who are active, let's say a core of 25, maybe more companies, ...provided letters of support. There were some pretty strong industrial letters attached to this at the end, and even sent in the follow-up phase the month after it was submitted... We said come along with us, but we sort of laid back on getting them involved until things were rolling... It really behooves us to get people involved in a much bigger way. And I don't know how easy it's going to be to really get the involvement in the design course...

R: I don't think most students realize [how important industrial sponsors are.] I think they are beginning to now. And I think the presence of the ERC with the constant industrial involvement is helpful.

I: OK, I hear you.

R: It really makes a difference. And we've actually had to shut down projects because the industrial people said, "We don't think it's going any place." Not because it isn't good science.

I: So in some sense you have accountability to your industry sponsors that you don't see elsewhere in college?

R: You bet. Because if the companies don't like what we do, they walk. And that's not good for us.

I: So you have accountability to industry built right into your structure.

R: Absolutely. Industry is intimately involved in all the projects. They have a say in how we spend the Center's money, and we have to convince them that what we do is good stuff.

4. Assessing Student Learning and Evaluating the Course

When asked to comment on the assessment component of the course, PIs agreed with faculty in recognizing the importance of the assessment of student learning, the need to stress process rather than one "right way" to solve problems, and the role of observation in determining whether students meet the goals of the course. PIs mentioned the "spirit" of the process involved with the course.

Data point 4a: Observation plays an important role in assessing student learning in a course that focuses on process.

I: Let's talk about how you will know that the students understand. How will you know when students have reached the goals of the course?

R: So if they did it [create access to the buildings], and it works in a pragmatic sense, they have done it... I think what I would really hate to have happen is for somebody to say, "Well, the students didn't meet the goal because even though they built the ramp or whatever, they didn't use the right methodology." And I think that is not something that you want to teach people about working in industry. That is [the approach] for working in a mature bureaucracy, but it is not for working in industry especially if you talk about start-up companies and so forth. You have to be really flexible. You have to figure out a new way to get the job done.
R2: So I would hope that some of that spirit would be in part of this thing so people aren't locked into one way of doing things.

PIs reviewed the interview protocol that the researchers used for students and faculty at the end of semester and urged us to ask questions about what did and didn't work, especially regarding group work, reliance on SAs and faculty, student growth toward independence, and student interest in staying in engineering.

I: OK. Alright, in closing, are there any other questions we should be asking faculty or students related to this course such that the answers to those questions would be important to your industrial people or to you?

R: Certainly we want to ask them what sort of problems they have had. What some of the good and bad points are. If people feel left out because the group dynamics are such that somebody gets shut out. That can happen. It certainly happens in industry all the time, anyway. So how to deal with that. There may be some people issues--this might be a good opportunity for students to learn about... "This is the real world, guys. You are in team and you compete. And sometimes some people are a little more competitive than others and how to deal with it." Maybe there are gender issues that ought to be touched on, too. One of the things that always concerns me is that I often find that women students, especially in an environment like this, tend to be reticent about getting involved. Maybe you want to think about some experiments where you have all-women teams to see if that makes a difference. That might be very interesting, a direction to go to.

I: Right. Let's focus on assessment for a little bit. You have mentioned the goals for the course. How will you know when the students have reached the goals? Now, you are not the instructor, but do you care to think about that?

R: I think I would probably mainly watch how they behave in the lab... I would watch: Do the teams work effectively? Do they seem to set goals and sort of work together, maybe divide up tasks and get back together and do things together? Are they making progress week to week? Do they seem to know what they are doing? How much are they relying on the SAs or the faculty member and are they becoming more independent with time? And how do they seem toward the end of the semester? If you asked them toward the beginning and toward the end, "What is engineering?" or "What are your thoughts about engineering?

What are your thoughts about staying in engineering or leaving?" And if they said they were going to leave because they hate working in teams and they don't like building things, and they would rather just lay around and think, then great. Ciao. So in terms of assessment, those are just the sorts of things I would do to see if things were coming along.

Data point 4b: Formative feedback from a third-party evaluator will help debug the course.

I: I'm wondering if you would give me some feedback on what you see the LEAD Center doing?

R: I think that the goals of the LEAD Center are really important. I think that right now, all we rely on for evaluation of things are student grades, and I guess there is a little bit of peer review of instruction, but I think so much more has to be done. In order for us to be effective in what we do, we really do need to know that we're getting some place. If our LEAD Center can assist not only in this work but in other things around the campus, I think it will be better and probably quicker to make changes that I think are really needed--especially in the engineering curriculum--as we approach the year 2000... We really need your help. All we have to do is [be able to] pay for it.

Both PIs indicated that formative feedback will help faculty implement changes and lend support to suggestions that the PIs themselves may have. Both also mentioned the role of senior assistants and the importance of collecting data to help determine the value of the SA role to students, faculty, and the SAs themselves.

I: OK. Frustrations or concerns?...

R: ...[there is] this delicate balance of how much do you try to manipulate what is happening... I think that really the time to do that will be as the feedback starts coming back, and LEAD reports start coming back and we have to be thinking about the second semester. Then I will weigh in with some opinions and it will be backed up, in part, by the surveys and what the students are saying. Because I figure what I say in a vacuum is not going to have as much impact as if I pick and choose among the assessment material and data that comes back and then I can say, "Well, I agree with these three points and I think we really ought to do something about it." I think they will probably want to do that too, so I will just encourage them along to do some of that...

...The other thing I would have liked for them to do differently was ...when they were so adamant about having only twelve kids in a section. I said, "Come on, don't you think you guys could do fifteen, and don't you think we ought to really keep track of the waiting list and as students drop the first week, as they always do, you can immediately replenish?" I tend to drop the ball on logistical things like that.

I: Certainly a lot of these things also fit under the heading "challenges." Did you want to say more about challenges that you see ahead?

R: Well, the big challenge is going to be, (a) Can this team get it together and make mid-course corrections and improve things? and (b) Is it feasible to identify a core of ten percent of COE, which would be about twenty-five faculty rather than just six, who really could do this? And then the other thing is (c) the big debate about whether this course should be taught by faculty at all or be handed off to either the SAs or TAs with a group of faculty as sort of the advisory group. So all of those things are under the category of challenges. How to really do this...

...it may be that a whole bunch of seniors who were properly advised and counseled and given proper guidance could do a better job than the faculty do. And that would depend a lot on quality control and selecting those students... But the question is, could you get enough [capable senior students]? Could you get a core who were sufficiently energetic and motivated that it wouldn't cut into their other business that they need to graduate? Because I think first-year students just interact so much better with peers close to their own age, and a senior would be much more aware of what a freshman can do, what they know, how much time they have, all those kinds of issues.

5. Involving Faculty and Institutionalizing Change

Data point 5a: Faculty need data to help them determine the value of the course and "manufacture a curricular change."

The question of whether "Introduction to Engineering" should be a required course led the PIs to articulate issues associated with teaching freshmen, fitting the course into a tight curriculum, and considering how ABET mandates may impact the situation. There is a consensus that faculty need to "manufacture" engineering education by shifting to a student-centered curriculum.

I: Do you see this as being a required course in the College of Engineering?

R2: Yes, absolutely.

R: Now of course the individual departments will say, "What are we going to take out to substitute for this?" But I think willy-nilly it has got to be in there.

I: What are some of the stumbling blocks that you see?

R: This issue about "what course are we going to give up in a particular department's curriculum?" is very important because everybody will say, "Give up his course; don't give up my course." And they will say, "Gee, we can't give up math, we can't give up humanities.

Therefore there isn't any room in the curriculum." And that is really a big issue... We are having an ABET accreditation visit very soon. If ABET would say, "Thou shalt make this a required course," then we will certainly see to it.

I: That is interesting but what is the likelihood?

R: Oh, I think it is likely. It is likely...I remember this from one of the last ones... They said we must have a capstone design course. Well, capstone is too late, but we had to do it because they said, "You either do this or you are not accredited." So if they say, "You must do this," it will happen for sure. So that is a very good way to do it and do it this year...

...However, if you can't do it that way, then I think the issue comes down to one of whose ox is being gored or which part of the curriculum is going to have to change. The Dean is already pushing to decrease the number of credits for graduation as it is. If they do that plus everything else, it is going to be tricky but I think it has to happen...

...The other problem that you are going to have with a course like this is that it is for freshmen, and there are a lot of faculty members that don't like to teach freshmen. I ran into one faculty member who said to me that, "Everything is good here except for one thing and that is that we have to teach undergraduates." ...The issue is that a lot of faculty members have that perception that they get most of their enjoyment out of teaching graduate courses. This thing is so different and so exciting to me that it seems to me that if it is done right, faculty members ought to be interested in teaching this course. It is really a lot of fun and you get the excitement of the students with it.

Data point 5b: Faculty need to involve other faculty.

Department involvement in and acceptance of the course is critical to its success. Steps in the process include having a certain proportion of the faculty teach freshmen and establishing a core curriculum.

I: Any surprises related to this course, or frustrations and concerns?

R: It would have been nice if we had gotten more faculty members from other departments in the College involved... For example, Chemical Engineering is number 1 or number 2 in the country and it will affect [the course] if they don't participate in something like this. ...I really hope that somehow or other [the Chem E] faculty could become more interested in this thing. Maybe if ABET says that it be required... So I would hope that whatever information is generated from your evaluation and assessment, that you pitch it in such a way that it really gets people interested in getting involved in this course...

...Long range I would like to see the thing scale up and have all the freshmen taking it. If it is successful. I hope we can use the three years of the ARPA program to get the bugs out of the course and get more faculty involved in it so that as ARPA fades out the College is kicking in and it becomes an institutionalized thing. The Dean already wants to do that. [We] are making up plans on how to make all of that happen.

I: What do you see as the major steps in that process?

R: Well, we will have to get a lot of faculty input and input from chairs. I have already been talking to chairs about ..these process issues. It is getting people to buy into it. [The curriculum issues] are zero sum, so they are going to have to have something go away. [One department chair] just thought it through. He decided that about ten percent of his faculty will have to be devoted to teaching freshmen. And so then you have to get ten percent of the COE faculty to buy into teaching freshmen. You have got to get them to learn how to teach freshmen. So it is going to be a long-term process.

I: Which begins to answer the question, "How do you see this course fitting into the whole college engineering curriculum?"

R: I go with that T-diagram that Dean Bollinger always shows: the four credits for two years and then things branch out into the engineering majors. So they are in COE for four, four, four, four. So it is sixteen credits of COE for the first two years. And then the question is what is going to be in those four credits. Some combination of this course, EPD 100, EPD 101, Tech Communication, Statics, Dynamics, whatever. And we will have to get as many departments to buy into that as we can.

Data point 5c: Overcoming hurdles to implementation will take time and strategies.

When asked about hurdles to implementation, the PIs again stressed faculty acceptance and willingness to institutionalize such a course. Representative comments follow:

I: What about the most significant hurdles to implementation of your plans for the TRP thrust?

R: I think the most significant hurdle is to get faculty acceptance of some of these things and to get them integrated into the program. I think that's the hardest part.

R2: Well, I mean, the issue of support... I'm talking about things like space, trying to find a room where we could put a lab together. That issue of space is one that Dean Bollinger is well aware of... and in order for this thing to work, people are going to need to have rooms, offices and all of the things that they need. You get back to dollars and cents and the one-to-one match... And the Graduate School has been a godsend. They have not been able to do enough. I mean, we've gotten RAs, we've gotten PAs...

I: Anything else that you want to say about implementation?

R: Another issue is being able to introduce manufacturing across the entire curriculum, that every course has some aspect of manufacturing to it. That's a very difficult thing.

I: That comes back to what you were saying before about increasing awareness of the fact that students go out and work in industry and don't become clones of the faculty.

R: In fact, we want them to go to work in industry and we want them to make things and make this country competitive and win the economic wars. That's what we really want. And I think it offers a great opportunity to do that, during the educational process that they have... in school here.

I: It sounds to me like you're talking about what I would call cultural change issues...

R: Some departments are more oriented toward manufacturing than others, like Industrial Engineering and also Mechanical Engineering, but for example, my own department has very little.

I: You said earlier that they can't continue to rely on external funding... At some point it has to move past the testbed and into the ongoing, taken-for-granted everyday structure of the College. I'm wondering if you have any comments about this.

R: Well, I think there are two ways that you [build the course into the College]. One of them is that you convince the departments that this has to be integrated into their curriculum, and then you have to convince the administration that if additional resources are needed--more positions, or whatever--that they'll provide for them. I think it's not going to be an easy battle, but I think it's a battle that has to be won, and will happen, if not here, at another place.

I: In other words, do you think COE will make structural changes?

R: Absolutely. That's why it's called "manufacturing engineering education." I mean, we're serious about this.

The Evolution of the Course over the Two 1994-95 Pilot Semesters

While the basic components remained the same over the first two semesters, a process of evolution is clearly underway. For example, in spring semester an end-of-semester essay was added and individual, rather than team, weekly email reports were required to make the learning experience more effective. In this section, changes between first and second semester in each component are described. These changes occurred in line with a faculty effort to strengthen the connections among the components in the spring semester. This effort was stimulated by the faculty's own discussions among themselves and their students as well as by the formative feedback from the LEAD Center. The feedback included results of a fall semester student survey and student interviews that indicated students often did not see the connections, especially among lectures, labs, and homework.

1. Lectures

Virtually all the students noted that being actively involved during the lecture was important in helping them learn. While most of the lecture topics remained the same for both semesters, faculty improved student involvement during second semester by using cooperative learning strategies and incorporating presentations from department representatives throughout the semester rather than just at the end. The following quotes from a first semester (R1) and a second semester (R2) design student who participated in a focus group, held in mid-spring, illustrate the value of the changes the faculty made over the course of the year.

S2: I like it when we are, like, involved. When he sets up a problem and we get into little groups and we actually do stuff.

I: In the lecture?

S2: Yeah. It's sort of like lab. We get into groups and we figure out solutions to the problems. There was this one lecture where it was just a really fun thing, to open up our minds. It was a puzzle, and you had to connect 90 dots in four lines. You had to stack 9 nails on one nail head, and you had to somehow fit some things through something--some objects through other objects. Those things are fun.

I: You remember them. What was the purpose of them? Do you remember?

S2: To expand your mind to eliminate any boundaries, any assumptions we have. I think it was before our brainstorming to show that there were, like, no bounds--the sky's the limit...

S1: We didn't have those puzzles, but they would have been interesting... they obviously added that since last semester so that's something good that they did.

Students described the need for lectures to be stimulating and interactive, connected to the labs, and to be held in rooms conducive to learning. A few students commented that their plain lecture room was not conducive to learning. All the students appreciated the more modern rooms for their final presentations; room 1610 for first semester and 3609 for second semester. Some expressed an interest in having the lectures in a more modern room like 1610 Engineering Hall.

S2: The professors put on a skit for us--

S1: Did they make cookies?! [all laugh]

R2; Yeah. [all laugh] Well, we had a choice!

S1: Yeah, we did too. We took the cookies! (laugh)

S2: Yeah, we took the cookies too. [laugh] And I really liked the skit. It was funny.

I: What are you saying about the lecture with comments like that?

S2: I think lectures can be really fun if they do the right things.

I: And what are the right things? What would make them better?

S1: Well, some of the lectures, like I said before, pertain to the project in some remote way or more... Not like all the lectures were very boring, but I mean, if they found a way to be a little more interesting, I mean, we were involved--a little bit more involved from a students' standpoint. And the room that we were in was just really bad too. I mean, they have to get a nice room. I always walked by and, like, 1610 always seems to be open. If they had it in there, that would make it seem more interesting, too. We were in there once, and that was interesting... I don't know if they are in the same room now, are they?

I: No, but it's a similar room.

S1: Yeah, it's not very conducive to anything.

Spring semester students ranked the lecture as high as the team and project as course components that were helping them learn, whereas first semester students ranked the lectures next to last. See survey summaries dated November 1994 and April 1995.

Fall 1995 students will attend two lectures. Student comments such as those below from a focus group that included both first and second semester students indicate that this change poses a new challenge for the faculty:

I: Ok, now one of you made the comment earlier about the number of times you meet and how you feel kind of connected all week, and we need to follow up on that. There is a possibility that they will be keeping the long lab, but having two lectures per week. How do you feel about that? If they did that what would be important to consider? You're meeting more *often.*

S2: I don't know if that's really the right way to go about it. I would think the other way around would be the better choice. But you have to fully analyze it, I guess, because I was thinking just more work time just in terms of getting things honed down a little better. It's kind of hard to say, but we treated lab a lot more seriously than we treated lecture. Lecture was--we got some useful things out of lecture, but it seems we were shooting 50% I think--

I: In terms of attendance?

S2: Yeah. So then I don't know if we had lecture twice a week, we'd be shooting 25%! (all laugh) So--

I: What about your kind of feedback?

S1: Well, right out from the beginning of the semester we had lecture on Tuesday from 8:30 to 9:30 and then that night I had lab from 7 to 10--that really got tiring! I couldn't handle that. So I changed my lab to Wed. But still I think lecture is way too early in the morning. And lab was too long too late at night. Because usually you feel really, really tired half way through the lab. And lectures in the morning are--you know, you're sleeping through them pretty much. They are there, but. What we learn in lecture is just basic, generally ideas about engineering. Really they don't apply too much after awhile. Well, at first they taught us like processes and stuff, and that was kind of--we utilized that in lab, but now it's just basic engineering liability, stuff like that which really doesn't affect our lab that much. Lecture isn't really as important as lab so I think two lectures a week really wouldn't accomplish much. Rather two labs a week--shortening up the labs to make them two labs a week.

Presentations about the engineering disciplines changed somewhat from first semester; they incorporated more interactive teaching and learning strategies and were distributed more evenly throughout the semester. They helped students with their decision, as the following focus group comments illustrate.

I: You [addressing first-semester student] said at the end of your semester they realized that the students wanted to know about engineering more, and so [the faculty] put all this stuff at the end, right?

S1: Yeah.

I: Ok, [addressing second-semester student] and how are you learning about the other engineering disciplines?

S2: During lectures, lately, they have been kind of having guest speakers come in and giving presentations--like 15 minute presentations--and they give out brochures on their engineering department. This one guy who came in had a whole bunch of problems like bicycle frames...

S1: I didn't see that!

S2: I thought that was real interesting when a guy comes in and does something.

I: So you've appreciated that and it's helped--it has helped with your decision making?

S2: Oh, yeah, yeah.

2. Labs

Students attended one of seven, three-hour labs each week during first semester and one of two evening labs during second semester. In the first semester, two labs were in the evenings and the other five were held during the day. Originally planned to accommodate twelve students each, lab size varied from seven to twelve each semester; only one lab maintained an enrollment of twelve through the end. Faculty and students received an outline of lab activities for each week. Students attended labs regularly; seldom did students miss. Students consistently rated labs with their accompanying teamwork as the most effective component in terms of helping them learn.

3. Homework

Students completed several homework assignments early in the semester. Topics included computer software for word processing and drawing, stress analysis, and a library search at the Kurt F. Wendt Engineering Library. Homework improved for second semester, but students identified it as an important area to improve.

4. Journals

Students kept a personal design journal to track both the design process and class learning throughout the semester. Faculty reviewed the journals periodically and incorporated them into the course grade. Students were guided more specifically second semester regarding their journal entries. Many students signed a release form so faculty could copy their journal entries to share with interested others. The journals may become more reflective and, therefore, even more important learning and assessment tools for both students and faculty, as stated by one faculty person.

Some of us are hoping to introduce some narrative, personal storytelling into this class. And I'm not exactly sure what context yet, but I think it has to be more pronounced and more formal than just their weekly update, and I'm not exactly sure how to do that, so over the summer I'm going to think about that. [Another faculty member] and I are writing a paper about potential directions for engineering education and use of reflection and narrative, and so... so the journal is going to become even more important, and in fact, [yet another faculty member] and I were thinking that we have two large class sessions a week going to add this
fall, we're going to use one of them to give students [time] to write in their lab journal. Because we had a big problem getting them to write anything down- certainly no reflecting of any deep nature.

5. Notes

For fall semester, a handbook that the faculty had prepared during the summer constituted the textbook. Additional notes were often distributed during lectures and labs throughout the semester. For spring, the handbook was more extensive since handouts in the previous semester were incorporated into the handbook. More second-semester students indicated that they used the notes than did first-semester students. Random observations showed that faculty had made a more conscious effort to refer students to the notes.

6. Presentations

Students prepared and delivered two presentations throughout the semester. The first was within their own lab when each team of three or four students presented their team design. The second was presented to all students, all instructors, some real-customers, COE faculty, and COE dean. Each lab group of up to twelve students presented their lab's design using the multimedia facilities of room 1610 Engineering Hall for first semester and 3609 for second semester in a variety of creative ways.

7. Assessments

A new assessment second semester was a new end-of-semester essay which students wrote to reflect their engineering experience. This essay accounted for a portion of the grade. Peer and self assessments, reviews of journals and presentations, and observations of teamwork continued to be effective assessments of student learning.

8. Office hours and Email Dialog and Weekly Updates

During second semester, students submitted weekly individual progress reports by email. This replaced the team reports by email that were part of the first semester course. Faculty responded to each student's weekly update on a regular basis.

Both the content and methodology of the course changed somewhat over the two semesters, but the basic components remained the same. As one faculty person stated, "We're very much aware that where we are is kind of neat but we're probably going to end up in a different place. Not substantially different, philosophically different. What we've got now is a good start, but it's not the finished product yet."

Essential Features: "The Spirit of the Course"

Throughout the evaluation process of the 1994-95 pilot of "Introduction to Engineering," the faculty sought summary statements that would articulate the "spirit of the course." For example, they wanted to know answers to the following questions:

- What are the core components of the course without which the course would no longer be the course that it should be?

- What commonalities and structural organizational processes should the course entail, independent of the faculty who teach the course?

Analysis of data across all sources confirms and extends findings stated in the First Semester Evaluation Report, January, 1995. This section describes essential features of the course in terms of the students, instructors, course structure, "content," teaching and learning methodology, material resources, and a continuous improvement approach. Analysis confirms that students who completed the College of Engineering "Introduction to Engineering" are meeting the goals of the course. Salient among the outcomes is that they are making informed decisions about pursuing an engineering career and are recommending the course to others.

Essential Features for Students

Students remain the center of the course. A critical mass of students is necessary to create the enthusiastic, perhaps frenetic, environment that motivates students to learn. A critical mass is at least 65 students divided into lab groups of eight to twelve students. Almost all students enrolled in the course so that they could determine whether engineering was the right career choice for them. One first-semester student verbalized the importance of determining whether "engineering has a soul."

I: As far as your college experience, did this course make any difference? Are you going to stay in engineering?

S: This entire year I've been sort of thinking about it and contemplating it...There's a guy that's an art major in my computer science class, and from talking with him I found out that he had a year to do whatever he wanted....In Letters and Science, I guess, you get a lot more give in your major, and so he loaded up on the science this year and he is just dead sick of it, and computer science is the worst. He phrased this the best: he said it has no soul. You know. and he's right. And so I've been trying to determine if a field such as mechanical engineering has a soul in it to be found, and I'm still trying to do that.

By the end of the pilot year, a faculty person had picked up on this analogy, whether intentionally or unintentionally. This faculty person viewed the soul or spirit of the first-year design course as setting this course apart for first-year COE students. At the same time, this instructor noted that this spirit will be hard to preserve as new faculty get involved. Virtually all the faculty agreed with this idea, but only one chose these words:

R: We have this specific set of ideas, goals, kind of spirit, of this particular class, which we think is very important. As the class evolves and new people get involved and new people get involved, I'm curious to see if that kind of soul of the class remains, gets picked up by new faculty who embrace it and put their own stamp on it, but nonetheless keep the students and this sense in the real center of the class. Or if it [the course] sort of veers off course. Perhaps one semester with a strong personality who loves designing, it would be a real hard core design class. Another semester, someone may have some other real interest. It would veer from one place to the other without this central set of goals which we all felt were pretty important. So I guess that would probably be my biggest concern. I think it's wonderful to get lots of faculty involved, and I think it's probably a good idea to get lots of us out of there. But I'm not too sure if it's going to remain a consistent and stable class [that preserves the spirit of the course.]

I: You seem to say that with some hesitation. Is it good to get some of you out of there and to bring more people in? Again, the challenge is to keep that soul or that spirit?

R: This soul is a unique aspect of the class, part of what I think makes it valuable. That's what makes it really different from a design class or any other introductory survey class. So we've tried pretty hard to preserve that. It will be interesting to see whether we in a sense can articulate that clearly enough and convincingly enough to the new faculty who want to get involved in the class so that they'll agree that, "Yeah, that's a unique thing that we really need to preserve," or are they not convinced and say, "Ah, it's a waste of time, let's make this a design class."

I: When you say soul, what do you mean exactly?

R: The spirit of the class is a sense that you can say even our goals kind of sprang from. We want students to have an engineering experience. We want them to be engaged in a team experience. We want as broad a range of students as possible to feel like there's opportunity for them in engineering if they choose to take advantage of it. This [series of successful experiences] as opposed to specific learning or specific items we want students to learn. That's not on our list of goals, and I guess we're anxious to keep that kind of an offer.

Completion of the first-year design course helped students discover that engineering does have a soul; it is a profession that most of the students chose to pursue as of the end of their freshman year on campus. Virtually all the students identified the following essential features of the course:

- real-world context with real problems and real clients
- student-centered faculty
- faculty who represent a variety of engineering disciplines
- common team experiences with other freshmen on real projects
- series of successful experiences
- senior assistants who are guides.

Students benefit from student-centered faculty who work as members of a cross-functional team and from experiencing an engineering context that helps them make informed decisions about pursuing an engineering career. Fall 1994 first-year students, including a disproportionately large percentage of women, chose the course based on descriptions of the course and availability. They chose the course because they thought it would meet their personal needs, not because it was required. They thought that it would help answer their questions about whether engineering is for them.

Student interview data support the proposition that experiencing a common engineering design project provides context from which students can decide to pursue an engineering career and understand why they need other math and science courses. The course meets the goals of giving students a common experience and a series of successes as they discover the engineering design process first hand: with a real project, real clients, and real communication situations. The project selection process entails social implications and student involvement.

Senior faculty (those with tenure) and senior undergraduates create an effective team for first-year students. Members of the faculty and senior assistants team represent a variety of engineering disciplines and help students appreciate the different engineering professions. Undergraduates who are seniors are close enough in age to freshmen that they provide a bridge between the faculty and the first-year students. It is optimal that senior assistants be from a variety of engineering disciplines and not be teamed up with a faculty person from the same engineering discipline or department. The cross-functional staffing pattern helps ensure an effective team approach because it sets up a social and professional environment in which individuals from different backgrounds can work together and achieve positive results. Students appreciate faculty who have demonstrated an interest in and understanding of effective teaching and learning strategies which are student-centered. It would be optimal in future offerings of the course, if faculty and SA teams included greater gender and ethnic diversity.

<u>Essential Features for Instructors</u>

Virtually all the instructors identified the following essential features of faculty who teach this course:

- ability to juggle effectively
- genuine interest in students
- willingness to learn how to engage in teamwork in an otherwise individualistic environment
- willingness to "get out of the way" of student learning
- willingness to meet regularly with other course faculty.

The instructor team includes both highly regarded yet "accessible" faculty and seniors assistants who are "senior peers."

<u>Essential Features of Course Structure</u>

Analysis of data from across all sources identifies the following essential features of the course structure:

- complementary combination of lab and lecture
- assignments that are connected and make good use of students' time
- assessment and grading processes that reinforce or even realize for students the primary goals of the course
- appropriate peer and self assessments with timely feedback
- small lab size and instructor/student ratios
- suitable classroom and lab space and facilities
- "fit" within the College of Engineering curriculum.

Lecture and a lab combine to produce an effective structure for the course. Although students experience the design process within their own lab, they were only able to see the faculty work as a team, learn from a faculty team that represents many engineering disciplines, and exchange ideas with other freshmen in the lecture portion of the course. Likewise, faculty working alone, even with a senior assistant, would not experience the rewards and challenges of working as a team without the lecture. As a team, faculty begin to appreciate the pleasures and frustrations that their students experience within the design course. Since university faculty are traditionally autonomous, a structure that includes a faculty team benefits both faculty and students. Faculty meet together to plan and suggest improvements; they attend lectures even though only one takes primary responsibility for each lecture; they facilitate the labs on their own but based on a plan to which they gave consensus; and they share the responsibilities and rewards.

Peer and self assessments are challenging for students and faculty alike. Students are often uncomfortable assessing their own abilities and those of their peers; faculty are not accustomed to designing and using assessment tools that focus on the student learning process. Faculty recognize that the ability to assess oneself is essential for improvement, and that, likewise, the ability to give constructive criticism is essential for improved teamwork, products, and productivity.

Essential Features of "Content"

The primary "content" for students in this course is acquiring knowledge of the engineering design process and the engineering profession. The following are essential features of the content:

- processes involved in solving open-ended engineering design problems and producing actual design prototypes
- products including use engineering and business principles and tools.

The experience of going through the design process constitutes the essential feature of the learning. Designing, building, and testing the specific project itself provides the opportunity for this learning to occur. Open-ended design problems incorporate ambiguity for both faculty and students. Faculty do not know the outcome of the students' designs. Students don't work toward one right answer. Faculty and senior assistants know how to stay out of the students' way and how to respect and nurture their ability to figure things out themselves. The team interaction and the communication that are part of the process help students build confidence and self-esteem. The products students create are not, in and of themselves, important. As stated earlier, this needs to be stated directly to the students at the beginning of the semester.

Essential Features of Teaching and Learning Methodology

Analysis of data across all sources confirms the following essential features of the teaching and learning methods that the faculty articulated:

- collaborative or team activity
- hands-on testing experiences
- multiple perspectives on problems
- "just-in-time" engineering science
- feedback from students
- assessment criteria and tools
- time to build all or part of their design

Through effective team experiences, each student develops the sense that "I belong, I can do it." Through a dynamic team approach, instructors act as facilitators to encourage effective teaching and learning. A team approach for the instructors enables open communication among the instructors and students. A team approach leads to "sifting and winnowing" and results in a better course for students, as one representative faculty quote demonstrates:

R: Well, I think it's a better course as a result. I believe that any single faculty member on the team could run the course with help from the senior assistants. And it would be OK. It might even be good. But it's certainly better when ideas are thrown out and sifted and winnowed, to determine what might be a better idea.

Essential Features of the Facilities and Material Resources

Essential features of the facilities and other resources include:

- state-of-the-art hardware and software
- appropriate room for lecture and lab
- tables and chairs for small group work
- large multi-media auditorium for the final presentations
- money to finance student projects.

Essential Features of Continuous Improvement Approach

Expectations and realities are important to identify and share as students, instructors, and administrators come to understand the teaching and learning process that is part of a freshman engineering course. Essential features of this continuous improvement process include:

- open communication
- formative feedback
- training regarding teaching and learning strategies
- faculty evaluation process based on continuous improvement.

Open communication among all stakeholders in the course is essential for continuous quality improvement. Open communication fosters: coordination and consistency across sections or labs; connections among class assignments and activities and with the rest of the College of Engineering curriculum; and interaction in labs, email, office hours, and faculty/senior assistant weekly meetings.

Formative feedback information is essential for faculty to make any necessary mid-course adjustments and keep their learning curve steep. Finally, training or teaching improvement is essential for both senior assistants and faculty.

These essential features characterize the 1994-95 pilot of the University of Wisconsin-Madison, College of Engineering "Introduction to Engineering" course. As one student put it, these features describe "the heart of the course." As one faculty person viewed it, the essential features capture the "soul" or "spirit" that animates the course. These features make the course genuinely different from other design classes and other introductory survey classes.

History of the Freshman Design Course at UW-Madison

The following account describes the development and scale-up of a freshman design course at the University of Wisconsin-Madison (UW-Madison). It shows how a two-year old project is moving through nine phases that project directors engaged in curricular reform have identified.[1]

Phase 1. Articulate the Need.

In the UW-Madison College of Engineering, a new focus on the undergraduate engineering student emerged from two seemingly separate events between 1991 and 1992: the introduction of strategic planning and the introduction of total quality management (TQM) principles. First, after taking note of successful strategic planning strategies of his counterparts in business and industry, the Dean of Engineering introduced to the College--with varying degrees of success--strategic planning. Second, one hundred faculty from the UW-Madison and Tuskegee University were hosted by Procter & Gamble in Cincinnati, Ohio, to discover TQM and investigate its application to higher education. This opportunity was made possible through a challenge prompted by the Motorola Chief Executive Officer's invitation to introduce TQM to higher education by having businesses "team up" with universities and colleges. UW-Madison and Tuskegee were among the winning universities.

By 1993, the Dean formed the College Curriculum Committee, and charged it to determine whether a gap existed between the educational program that the College offered its students and the expectations of their employers. This committee, which continues today, is different from traditional, department-centered, curriculum committees because it is comprised of one representative from each department. Moreover, it functions with the help of a facilitator who uses TQM strategies. This faculty committee identified a gap and proceeded to consider ways to address the problem. In particular, they articulated as primary the needs to retain more of the students who expressed an interest in engineering and to increase the numbers of women and minorities in engineering.

Simultaneously, a relatively small project to improve teaching methodologies within the College emerged. Enthused by the new focus on undergraduate education and teaching, Sandy Courter attended a weeklong seminar taught by Richard Felder, University of North Carolina State University at Raleigh, and James Stice, University of Texas at Austin, following the 1992 American Society for Engineering Education Conference. Based on material from this seminar, she assisted Katherine Sanders with a teaching improvement study that involved six faculty, who agreed to work with Sanders as part of her doctoral research work. At the time, Sanders was a doctoral student in industrial engineering focusing on investigating the question of whether a participatory learning approach for engineering faculty can lead to improved teaching and learning strategies.

A focus on the "needs of the customer" was an over-arching theme that, in the opinion of the authors, helped COE leaders articulate a need to improve the education of undergraduates. Although debate ensued as to whether students are "customers," these College leaders listened to perspectives from faculty colleagues, business representatives, parents, and government officials and concluded that the College needed to improve its undergraduate education. Moreover, throughout the whole process, faculty and administrators educated themselves about other institutions' efforts to improve undergraduate education. They read with interest about engineering coalitions such as the NSF-sponsored ECSEL. They attended ASEE conferences and discipline conferences. For a core group of COE faculty and administrators, teaching and meeting the needs of students were becoming more valued.

Phase 2. Develop Promising Reform Ideas and Colleagues.

Faculty involved with both the College Curriculum Committee and the Teaching Improvement Program (TIP), which evolved from Sanders' dissertation work, began developing promising reform ideas at about the same time during the 1993-94 academic year. The Curriculum Committee began exploring a core curriculum for freshman and sophomore students.

Meanwhile, the six faculty who worked with Sanders during 1992-93 continued to meet on a weekly basis during 1993-94 to further explore learning strategies and implications for teaching. Results of their brainstorming and collaborative planning were flow charts of the learning process. All involved admitted that the process of creating the flowcharts with the continual dialog necessary to explore the issues was more powerful than the flowcharts themselves. Nonetheless, they shared the flowcharts with other faculty and administrators in an effort to help others improve students' learning experiences. These faculty, who represented mechanical, nuclear, and electrical and computer engineering disciplines, were all male and all but one tenured. Sanders, now a Ph.D.-trained industrial engineer, continued as their facilitator and brought a female perspective to the team. As the six TIP faculty moved back and forth between the first phase of articulating a need to the second phase of developing promising reform ideas, they became an emerging reform team. Their understanding of the need for change was deepening.

The growth of the Teaching Improvement Program merits attention. Sanders worked throughout 1992-93 as a project and teaching assistant with no additional funds. Courter volunteered her time as part of her teaching improvement efforts associated with a new partial appointment in the Dean's Office. However the faculty involved initiated a "grassroots effort" to expand the TIP to include more faculty. They secured funding to continue for 1993-94, a step described in the next phase.

Phase 3. "Get a Plan."

A proposal to create a freshman design course and a proposal for continued support for the Teaching Improvement Program were submitted in summer 1993. While each was submitted by a different group and to different sponsors, they shared a common vision to improve the teaching and learning experience for engineering students, especially freshmen. The first proposal was developed by Professors Leon Shohet, Director, Engineering Research Center for Plasma-Aided Manufacturing (ERC for PAM), and Denice Denton, leader of the ERC for PAM Education Thrust Area. This proposal, submitted to the education reform component of the Advanced

Research Projects Agency Technology Reinvestment Project (ARPA TRP), included a freshman design course as one component. This proposal, which included a substantial plan for evaluating the course, was funded for implementation in summer 1994.

The second proposal, which sought continued support of TIP as noted above, was developed by three senior faculty members from the first TIP team. This proposal, submitted to the Dean's Office, sought monies from an IBM Award to the College. The IBM Award had a research component within which TIP fit. This proposal was convincing in part because it was based on "grassroots" efforts of faculty. The Dean approved an expanded TIP for two years with Sanders coordinating the program in a post-doctoral position. By January, 1994, thirty-four faculty--about 20% of the College of Engineering faculty--were associated with TIP.

Once the ARPA proposal was funded, the first step in implementing the first-year design course was to identify faculty to create this course. The faculty in the original TIP group were the natural choice. They accepted. They were ready to accept the challenges of putting together the new freshman design course that emerged during the summer of 1994. With funds provided through the ARPA proposal, they began to actively "benchmark" similar programs around the nation. Their visits included the University of Maryland, Rose-Hulman, and the 1994 ASEE Annual Meeting. The Dean was supportive during summer 1994 as the faculty planned the course; he helped secure space and promoted the course throughout the College as an "innovation worth exploring."

Phase 4. Engage in Initial Implementation.

Initial implementation occurred during the summer of 1994. The faculty team of six met regularly to develop new materials and teaching methods. They recognized that they had a "laboratory" (the course) in which to "practice" what they had explored the previous year. Together with senior engineering students, they engaged in the time-consuming process of choosing a course project. This process entailed brainstorming, the development of criteria, and testing ideas against the specified criteria. After considering over one-hundred ideas, they selected "access to Old World Wisconsin" (a museum comprised of historical buildings) as the problem. The real problems of helping physically disadvantaged people, who are real clients, gain access to buildings in an historical site became the cornerstone around which the course started to take shape.

Interacting with a range of people to establish the course was a necessary component of the initial implementation. Attracting students meant developing and distributing descriptive brochures and inviting students to enroll. Professor Denton, working with staff at the ERC, designed a brochure that faculty distributed during Summer Orientation and Registration (SOAR) to freshmen interested in engineering and their parents. By the end of the summer, 84 students had enrolled, and 40 were on a waiting list. The faculty, who had planned for six labs of twelve students each, agreed to open another section to accommodate all 84 students. They invited Dr. Sanders, who had been facilitating the team as part of the TIP experience, to lead this seventh section. They also hired seven senior engineering students to work as student assistants (SAs). The final configuration was seven instructors, seven senior assistants, and 84 students.

The "design faculty" and others accomplished myriad tasks in addition to planning their course curriculum and teaching methods. The Dean worked with space management personnel to locate rooms and equipment, including computers. Staff from the Registrar's Office were contacted to list the course in the timetable. Due to the short timeline, they had to use existing course numbers for special project courses in three departments. The design faculty worked with student advisors and administrators to avoid conflict with other reform programs such as the Wisconsin Emerging Scholars (WES) offered by the Mathematics Department. They worked with department chairs to negotiate revised teaching assignments and to ask them to considering how the course might fit into the curriculum of different majors. And they asked departmental curriculum committees to explore how the new course might fit within the curriculum.

Throughout the summer and the pilot year, faculty developed a friendly political awareness. They sustained a "friendly guerilla" orientation by learning about and becoming facile in the politics of organizational change. Indeed, by the second semester of the pilot year (1994-95), one faculty member, Mike Corradini, Professor in Nuclear Engineering and Engineering Physics, was selected as the College's new Associate Dean of Academic Affairs.

Phase 5. Implement and Evaluate the Reform on a Pilot Basis.

On September 6, 1994, the pilot year of the freshman design course, now known as "Introduction to Engineering", began. With implementation underway, the evaluation component also took shape. As presented in the ARPA-TRP proposal, the evaluation plan involved a Learning through Evaluation, Adaptation, and Dissemination (LEAD) program which would conduct evaluation research as an outside third-party. The freshman course was to be one of LEAD's first evaluation projects. The authors, both of LEAD, worked with the design faculty to clarify research questions, acquire baseline data, and provide evaluation data that would be useful to the faculty. Because curriculum denotes both content and method, the evaluation included strategies to examine both content and methodology reforms incorporated in this freshmen engineering design course. The purpose of the LEAD evaluation research was to yield contextualized understanding of a curriculum innovation intended to both enhance and modify the teaching and learning experience. The following excerpts from a LEAD Summary of the Freshman Course Evaluation prepared for the College of Engineering Curriculum Committee help to describe the implementation and the evaluation of the pilot course:

> Characteristics of Qualitative Research: The evaluation is "work in progress" and presents formative evaluation information based primarily on data collected from student interviews. Please note that evaluation is formative when applied researchers give faculty reformers feedback while the program/activity is being planned, piloted, and scaled up, and with the intention of improving the program/activity while it is under development. Qualitative research differs from quantitative research in data collection and analysis methodologies. Individual interviews, focus groups, and classroom observations were used to elicit from participants a range of perceived characteristics of the course. These methodologies do not yield precise, quantitative assessments of the proportion of students with particular opinions. They do, however, provide useful insights about the course to date.

Goals for Course Outcomes: Course outcomes sought by the faculty are increased retention rates for incoming students in engineering and increased numbers of women and minorities in engineering. The faculty also seek to incorporate continuous improvement principles and strategies including creative product teams, interdisciplinary (cross-functional) teams of students and faculty, customer focus, integration of quality concepts and tools, and computer network resources. The primary goal of the formative evaluation undertaken by the LEAD Center team is to support these faculty goals by providing faculty and administrators with empirical information (both negative and positive) about the student learning process and the course implementation process. We therefore implemented the continuous quality improvement process by providing feedback to the design faculty, the ARPA-TRP principal investigators/managers, and (at the request of the former individuals) other stakeholders. That is, formative feedback reports served as a basis from which faculty and others can make informed and appropriate changes during the semester and for second semester.

Key Features of the Learning Process Based on Students' Perspectives: Students' perspectives on the course were complex but patterns or data-points emerged during our preliminary analysis. These themes or data points are listed below, and fit into three categories.

Features almost universally viewed as effective:

- Teamwork is a process that works.
- Hands-on activities develop early intimations of professional identity.
- Cooperative teaching and learning environment fosters peer learning.
- Course helps students recognize context for undergraduate curriculum.
- Course is excellent for "testing the water" before plunging into engineering.
- When instructors act primarily as facilitators rather than primarily as lecturers, they help students learn more and be more creative.

Feature almost universally viewed as problematic:

- Course does not "fit" into the engineering curriculum.

Features about which students opinions were notably diverse:

- Integration, organization, and variety of components help students learn.
- Self and peer assessments are challenging for students.

Due to the effectiveness of the faculty response to students and to evaluation information provided throughout the semester, almost all the evaluation findings fell within "almost uniformly effective."

Generalizations from the Researchers' Point of View: Analytic generalizations about the learning processes from the researchers' point of view fall into four categories, each with one data-point.

- Approach to learning: Systematic teamwork engenders creative, multiple approaches to problem-solving. Students generally experience the course as an "island" of connected understanding and real learning.

- Attitude toward learning: Most students demonstrated a positive attitude toward learning and pleasure in connecting the engineering design process to real-world problems.

- Sources of affirmation: Interaction with peers and "more experienced others" helps students create and build their own design and feel comfortable in both a social and professional engineering environment.

- Fit within COE curriculum: Both male and female students express a concern about "fit." The course needs to count.

The learning outcomes from the researchers' point of view are that students:

- get an early "peek behind the scenes" of engineering
- acquire hands-on knowledge of the engineering design process
- experience the context of, and thus come to understand why they need, math and science
- acquire greater motivation to pursue engineering
- develop real-world appreciation for excellent communication skills.
- develop teamwork skills
- acquire real-world computer and graphics skills

The Summary Report from which the excerpt above comes was one of eight documents that gave formative feedback to the faculty and principal investigators (PI) whose proposals form the base of the course. The evaluators provided real-time formative feedback on student learning experiences. It is expected that formative evaluation information also will be provided by LEAD during the second year.

The design faculty coordinated classroom assessment processes including student self and peer assessments for team problem-solving as well as journals that reflected student's learning throughout the semester.

During second semester, sixteen students enrolled in the class. The smaller enrollment seemed to be due to the facts that the course was not yet listed as satisfying any engineering curriculum and the promotion was less intense than that possible through a summer orientation like SOAR. However, the senior assistants continued to work as "guides" to students throughout both semesters. Faculty continued to meet every week. They interacted with other faculty through the College, describing the merits of the course, often using information from formative feedback reports from the LEAD Center. They continued to provide the "grease" that gets all the steps working together and enables project success. They engaged in genuine two-way conversations with their colleagues, exchanging knowledge and perspectives.

Moreover during the second semester, faculty participated in an informal debate about assessment issues. One faculty person stressed the importance of developing examinations/assessments that "put a measure on" the new kinds of knowledge/skills that the reform seeks to help students develop. He emphasized that to achieve full-scale implementation, colleagues who remain outside the reform effort must come to understand and accept these new assessments. Concern about how best to assess student learning continues. Benchmarking others' best case practices also continues.

Phase 6. Revise and Beta Test the Reform.

During 1995-96 the freshman design course will be offered again. Scale-up and hand-off issues are significant since up to 200 students, four new faculty, and almost all new senior assistants will be involved. Proposed new LEAD Center evaluation strategies include a "post-semester assessment" that would involve faculty outside the teaching team in assessment interviews with students who have completed the design course plus a group of matched comparison students who have not taken the course. Through focus groups discussions with small groups of students, teams of two outsider faculty will attempt to assess the differences, if any, among the students and see for themselves the value of the course. Aware of the "prophet in his/her own land" syndrome, the faculty anticipate encountering more difficulty convincing their own colleagues than people in other disciplines or in engineering schools elsewhere in the country.

In addition, faculty are beginning to investigate how to adapt the course to diverse environments without sacrificing essential features. For example, they have initiated discussions with faculty in UW System four-year colleges and a local high school about how the course might be exported to these other contexts. They also are planning a proposal to the NSF which would make the class available to preservice teachers enrolled at UW-Madison, in order to introduce hands-on technology and science to K-12 teachers.

Throughout the second year, faculty will continue to use formative evaluation information drawn from an evaluation plan designed in collaboration with the LEAD Center. They also will continue to benchmark others' best case practices.

Phase 7. Locate and Work with a "Publisher."

This reform group has only begun this phase. Even so, their experience both with the design course and the TIP will be featured in a PBS Adult Learning Series planned for December, 1995. The National Technological University (NTU) has invited the College to participate in a Faculty Forum on Continuous Improvement in Undergraduate Engineering Education. The design faculty's experience will no doubt be featured again. Faculty continue to write papers for a variety of journals. To date, they declined an invitation to publish their class notes, but may reconsider this option in the future. They also have the option of self-publishing, or having the LEAD Center publish formative feedback reports and other products developed by LEAD, such as a classroom observation protocol designed for use by student assistants.

Phase 8. Handoff to the Publisher.

It is too soon to engage in this phase of full-scale implementation.

Phase 9. Work for Change on the National Level.

Participating in the 1995 ASEE conference, the PBS Series, and potentially the NTU Faculty Forum are specific ways in which the UW-Madison design faculty are working for change in undergraduate engineering education on the national level. One-on-one exchanges that continue to occur among colleagues at national conferences remain effective vectors of change. Sharing their common vision and their various successes and problems with their reform efforts give the faculty and their colleagues the confidence to make a difference.

Conclusion

During the many face-to-face interactions described in this history of the UW-Madison College of Engineering first-year design course, reformers naturally and meaningfully present to interested others their newly developed methods and student outcomes, and their new curricular and teaching materials. Understanding these materials, stories, and data in context, these others are more likely to shift from being merely interested to being active adopters/adapters of education reforms. Moreover, these key "dissemination moments" are valuable to the experienced education reformers themselves. Observing the responses of interested others, the reformers better understand why their new materials and approaches work and how they can help others grasp the essential features of these materials and approaches.

[1] Millar, S. and Courter, S. 1995. "Implementation/Dissemination as an 'Interactive Whole Story': The Case of Freshman Design at UW-Madison."

Philosophy of "Introduction to Engineering"

The goal of the course is to provide an experience in the freshman year that allows incoming students to discover engineering by practicing engineering. Students work in small teams to understand engineering in terms of the design process, to show connections between science, math and engineering courses, to see how they might "fit" into an engineering career, and to develop confidence in their ability to be successful engineers.

Some of the skills that students are expected to learn are: to ask questions; to clarify ambiguous situations; to collect and interpret data; to solve problems as a team; to rely on their own and others' abilities' to question premises; to apply some basic engineering techniques where appropriate; and to work constructively toward a true team solution.

The specific goals of the course are to:

- allow students to learn how to form and work in teams (team dynamics
- provide the opportunity for a sequence of successful experiences for the student
- have students acquire a feeling (hands-on) of what engineering entails and might encompass
- develop design process skills on a "real" design project with "real" customers
- develop skills for hardware and software usage in the projects in an as-needed basis
- develop context for engineering curriculum, so students see connections among math, science and technology classes
- develop confidence in engineering as a career, particularly for students with little prior knowledge or experience in engineering-type activities

To accomplish these goals, there are specific concepts that we wish to see developed. These are divided into "process" and "product" categories.

Process: (focus)

Design methodology: Students learn to work through the design process, including identifying customer needs, translating those needs into engineering specifications, developing multiple alternative solutions, evaluating proposed solutions against existing products, and creating workable and cost-effective designs. Realistic constraints are developed by students and customers.

Why Design?

Because...the design process seems to be one process common to all disciplines of engineering; the design process encompasses most of the important elements we wanted in the class; the design process is real engineering (not an artificial academic exercise), regardless of technical level.

Team interaction: Students learn to work in teams with peers, to plan tasks, to organize activity to accomplish tasks on time, and to interact constructively and effectively with team members.

Why team-based?

Because...team interaction presents students with the opportunity to meet and know other engineers and appreciate the wide range of students interested in engineering; it offers opportunities for peer teaching and learning; it represents a realistic view of what most engineering activity is like.

Communication: Students learn to communicate effectively with peers, with instructors, and with customers.

Why emphasize communication?

Because...clear communication of ideas and understanding of other's ideas is critical in the design process, particularly in teams; many engineers need to begin developing communication skills at an early stage of their careers.

Confidence building: Students develop confidence in their value as members of a team and in their potential for success in engineering.

Why worry about student confidence?

Because...we want to develop a level of confidence in first-year students that they belong in the engineering field and can be successful engineers, should they choose to do so; for some groups currently underrepresented in engineering, this lack of confidence in belonging or seeing connections to personal values may be a significant deterrent to remaining in an engineering career.

Product: (enabling)

Engineering science principles: Students learn some basic concepts in engineering science relevant to the specific project; for example, basic electrical circuit relations or relations for strength of structural members.

Why include engineering science topics?

Because...students need these fundamentals to attack their design problems; knowledge of some engineering science principles builds a context for subsequent math, physics, and chemistry classes; understanding and successfully using these ideas in a design can contribute to a student's confidence.

Engineering tools: Students learn basic calculation and communication skills, including email, spreadsheets, word processors, and graphics programs.

Why learn about engineering tools?

Because...the tools make much of the class work and communications easier (spreadsheets, email); they present a realistic picture of some common engineering tools; they are likely to be of use in many following classes.

Design Course Evaluation Process

1. Who: The LEAD Center

The course evaluation of the First-year Design Course is in partial fulfillment of 1) the assessment component in the Advanced Research Projects Agency (ARPA), Technology Reinvestment Project (TRP) grant to the Engineering Research Center (ERC) for Plasma-Aided Manufacturing, and 2) the proposed research of the IBM-UW Partnership Proposal. Both grants are part of the College of Engineering, University of Wisconsin - Madison. The evaluation project team was directed by Dr. Susan Millar, the Director of the UW-Madison's Learning through Evaluation, Adaptation and Dissemination (LEAD) Center. Sandra Courter, Adjunct Assistant Professor, and during first semester, Andrea Bailey, a political science graduate student, collected data. Courter took major responsibility for data analysis and writing.

2. What: Formative Evaluation Process

Course outcomes sought by the faculty are increased retention rates for incoming students in engineering and increased numbers of women and minorities in engineering. The faculty also seek to incorporate continuous improvement principles and strategies: creative product teams, interdisciplinary (cross-functional) teams of students and faculty, customer focus, integration of quality concepts and tools, and computer network resources. The primary goal of the formative evaluation undertaken by the LEAD Center team is to support these faculty goals by helping faculty and administrators evaluate both the effectiveness of the course and simultaneously the effects of continuous quality improvement efforts in higher education. Please note that evaluation is "formative" when applied researchers give faculty reformers feedback while the program/activity is being planned, piloted, and scaled up, and with the intention of improving the program/activity while it is under development.

As the evaluation proposal explains, the purpose of the research is to yield contextualized understanding of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college. Further, the evaluation research entails a case study of a total quality management (TQM) curriculum innovation. The curriculum innovation is the new freshman design course. This report follows a series of formative evaluation reports and meetings which provided insight to faculty, principal investigators, and senior assistants at intervals during the semester. These formative feedback materials consisted of work-in-progress reports based on individual and focus group interviews, a survey, and classroom/lab observations.

Qualitative and quantitative research methods differ not only with respect to data collection but with respect to analysis. Individual and focus group interviews and classroom observations allow the researchers to "get inside of" the experiences of these diverse participants. Data collection methods are as open-ended and subject-responsive as feasible to ensure that the experiences of the study subjects, not the researchers, are reported. Likewise, analysis processes are fundamentally inductive to ensure that the subjects' experiences shape the findings. In practice, this means that the researchers make every effort to at least temporarily suspend the ideas that structured their interview protocols and classroom observations. Analysis begins by reading transcripts with an eye to what is most important to the participants. Primary analytical categories emerge as the researchers process the transcripts. In contrast to survey methods, these methods do not yield precise, quantitative assessments of the proportion of participants holding pre-specified opinions. However, these methods provide extraordinarily rich information expressing the complexity of the lived experiences of the study subjects.

3. Why: ARPA TRP, NSF grant and IBM grant

The "Introduction to Engineering" is a cross-disciplinary freshman design course that is one of five curricular and pedagogical reforms funded in the TRP ARPA grant. The abstract for the original proposal summarizes the need for these reforms as follows:

> The future success of the U.S. economy requires that some of our best and brightest young people choose to enter the engineering profession. To this end, the NSF Engineering Research Center for Plasma-Aided Manufacturing proposes to implement a cultural change approach to engineering education that will incorporate manufacturing across the engineering curriculum, bring manufacturing experts into the classroom, and broaden the ethnic and gender diversity of the engineering work force. These goals are to be achieved by developing an integrated program of workshops, courses, and learning communities for both first-year and upper division students. Given the high attrition rates in engineering in the early semesters, we focus many of our activities on the needs of the first-year students, particularly those from under-represented groups. Fully aware that our cultural change approach entails a complex and iterative process, our activities will be guided by faculty-initiated evaluation and assessment to insure the highest possible program quality. Together with our partners in industry, we propose a strong and innovative program with three major components: (A) curricular and pedagogical reform: manufacturing across the curriculum, (B) outreach and recruitment of engineering undergraduates, and (C) evaluation, assessment, and dissemination.

4. How: Research Questions, Methods, and Reporting

This section distinguishes between student learning experiences and instructor teaching and learning experiences. It further lists the research questions, methodology, and procedures for analyzing and reporting both student and instructor experiences.

4.1 Student Learning Experiences

4.1.1 Research Questions Based on Instructor Objectives for Student Learning

The purpose of the proposed qualitative research is to yield contextualized understanding of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college. Further, the proposed research centers around a case study of a curriculum innovation. The curriculum innovation is the new freshman design course. The questions are:

1. What is the impact on students of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college?

2. Can qualitative evaluation methods provide insightful answers to the question of how, how well, and what are students learning in this course?

3. Do student assessment procedures (journals, homework, observations) adequately measure what students are learning and foster the learning process?

4. How well is the course achieving the faculty's goals for student learning?

4.1.2 Methodology

From a total population of 67 freshmen students during first semester, we selected two males and two females from each lab whenever possible and from those willing to participate, both at the beginning and the end of the semester. We interviewed twenty-eight students. We also organized two focus groups: one for females and one for males. We listened to the "silent voices" through written survey. Finally, we observed lectures and labs on a rotating basis. We did not videotape any groups in the labs, as originally suggested in the evaluation proposal, because sufficient resources were not available. From a population of 15 freshmen students during second semester, we requested participation of students in two focus groups. Data collection was at a minimum during the second semester.

Students: Information was obtained from first-year design students as follows:

Open-ended interviews. Courter and Bailey individually interviewed students who volunteered to participate. Interviews occurred at the beginning and end of the semester during the fourth and fourteenth weeks of the first semester. With interviewee permission, the interviews were tape recorded. The interview protocols are available upon request.

Focus group discussion. Courter and Bailey facilitated one female and one male focus group with one representative from each lab during first semester and two focus groups with representatives from both first and second semesters during the second semester.

Survey. With faculty assistance, Courter and Bailey designed a two page survey that all students completed in their lab during the tenth week of the course. Most of the questions were open-ended which lead to more qualitative than quantitative data. Students completed the survey both semesters.

Classroom observation. Courter and Bailey observed all lectures, two of the seven lab sections each week on a rotating basis, and the presentations of all lab designs at the end of the semester during the first semester. Courter observed random lectures and labs as well as the final presentations during second semester.

4.2 Instructor Teaching/Learning Experiences

4.2.1 Research Questions Based on Instructor Objectives for the Course

1. What is the impact on instructors (faculty and senior assistants) of a curriculum innovation aimed at enhancing and modifying the teaching and learning experience in an engineering college?

2 What do and how can the faculty who are team-teaching this course learn from each other while investigating the key question, "What and how are the students learning?"

4.2.2 Methodology

Instructors: Information was obtained from first-year design instructors including faculty and senior assistants and the principal investigators.

Open-ended interviews. During first semester, Courter and Bailey conducted open-ended structured interviews with the instructors, including seven faculty and seven senior assistants and two administrators who have direct or indirect experience with the courses and/or have knowledge of the change process by which the course is being developed and piloted within the College. Interviews lasted about 45 minutes each. With interviewee permission, the interviews were tape recorded. Questions focused on issues such as faculty goals for student learning in the course, teaching approaches, observations of student learning patterns and departmental organizational processes. In addition, Courter interviewed the faculty at the second semester and facilitated a focus group discussion with the senior assistants near the end of the year.

Classroom observation. During first semester, Courter and Bailey observed all lectures, two of the seven lab sections each week on a rotating basis, and the presentations of all lab designs at the end of the semester.

4.3 Procedures for Analyzing and Reporting Findings

At intervals during the semester, Courter and Millar held "formative feedback" meetings with faculty, administrators, and senior assistants after each phase of the data collection process: initial interviews, survey, focus group discussions, and end-of-semester interviews. At each of these meetings, "work-in-progress" reports were distributed and discussed. At each meeting the faculty developed a set of "action items" which emerged from their analysis of the feedback. The LEAD Center followed up after each meeting with a summary of the discussion and action ideas. In sum, Courter and Millar provided faculty with feedback in "real-time." Faculty used this feedback to make mid-course corrections and revisions within the semester and for subsequent semesters. They provided evaluation data so that faculty can communicate to others about the processes and outcomes associated with their curricular reform program.

Other Products

Distribution of documents is at the discretion of the clients who are the principal investigators and faculty of the course. Many of the following documents are available upon request from the LEAD Center, University of Wisconsin-Madison, 1402 University Avenue, Madison, WI 53706 (608-265-5920, lead@engr.wisc.edu)

Proposal for Evaluation of "Introduction to Engineering", October 18, 1994

Preliminary Feedback, November 11, 1994

Mid-Semester Feedback, November 22, 1994

Formative Feedback Report on Fall 1994 End-of-Semester Interviews and Observations, January 3, 1995

First Semester Evaluation Report, January 30, 1995

Revision of Spring 1995 Evaluation Plans, February 13, 1995

A Summary of the Freshman Course Evaluation Based on Students' Perspectives prepared for the College of Engineering Curriculum Committee, February 20, 1995

Survey Summary, April 13, 1995

A Summary of the Freshman Course Evaluation Based on Students' Perspectives prepared for the IBM Visiting Team, April 26, 1995

Feedback from Observations of Senior Assistants, May 3, 1995

Interview Protocols

Senior Assistant Observation Protocols

"Implementation/Dissemination as an 'Interactive Whole Story': The Case of Freshman Design at UW-Madison", by Susan Millar and Sandra Courter. Presented at the 1995 ASEE Annual Meeting, June, 1995