Session 2253

The Evolution of an Introductory Freshman Engineering Course: From Curriculum Sampler to Integrated Design Application

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I. Introduction

This paper discusses the experiences at Lake Superior State University (LSSU) with an Introductory Engineering course. In previous years, this course has been team-taught as a sequence of one-week topics covering principle areas of Electrical and Mechanical Engineering, Engineering Design and computer skills. This Introductory course has been offered in order to educate students about engineering degree choices, to increase student retention and to provide basic computer skills. Recognizing the need to integrate design into engineering programs as early as possible, and the value of project-based, multi-disciplinary team experiences, significant changes were implemented in the course in the Fall 1999 semester. Many of the one-week discipline topics were removed in order to introduce a team-based project that the students performed over one third of the course. We have gathered anecdotal information from student surveys at the conclusion of each semester and analyzed student retention data to assess the success of this course as a method of teaching design and as a student retention aid.

There are two aspects to student retention: keeping the students at the university as well as keeping them in that university's engineering program. One way to increase student retention is to provide students with "validating experiences." A validating experience is one that confirms to the student that he or she can succeed and is worthy of being at the college level and in a particular curriculum.[1] Early integration of a design project in the engineering student's college experience can provide such validation. A freshman level design project also provides the opportunity for personal involvement and interest shown by the instructor, which also aids student retention.

Enhancing student retention is not the only reason for early incorporation of an engineering design project. Prospective employers of engineering graduates desire students that have experience solving real-life problems. Students must be able to solve problems without being provided with a complete set of constraints, as in a textbook homework problem. Most incoming college students, however, have never had the opportunity to solve open-ended, poorly defined problems. Instead, students have had twelve years of highly structured education that focuses on precisely defined problems. Exposing students to engineering design at the freshman level aids in the transition from student to productive, problem-solving employee.

Moreover, it is well documented that "students learn by becoming involved."[2] Student effort and involvement positively influence attainment of a large number of educational outcomes, from development of higher-order cognitive skills to enhanced verbal, quantitative and subject matter competence.[1]

This paper discusses LSSU's experience with a Freshman Introductory Engineering course, its success in providing students with validating experiences, and its ongoing efforts to improve retention of freshmen engineering students.

II. LSSU's Introductory Engineering Course

Lake Superior State University is Michigan's smallest public institution of higher learning, with an overall enrollment of approximately 3200 students. Until recently, LSSU offered Electrical Engineering Technology and Mechanical Engineering Technology Bachelor of Science degrees. In 1996, LSSU made the decision to phase out its BSEET and BSMET degrees. Now, LSSU offers Electrical Engineering, Mechanical Engineering, and Manufacturing Engineering Technology Bachelor of Science degrees to a relatively small undergraduate population of 300. The new EE and ME programs will be evaluated by ABET in Fall 2000. The cornerstone of the Lake Superior State University engineering program lies in a very strong senior design experience that involves inter-disciplinary student teams.[3,4]

With the small number of students enrolled in the engineering curricula, LSSU is able to provide an environment conducive to the development of student/instructor relationships. Class size is generally 15-30 students and enrollment in laboratories is limited to 12-16 students. LSSU's ongoing mission places heavy emphasis on a hands-on education in keeping with its history. Hands-on learning is a proven validation technique in education and has always been emphasized at LSSU.

LSSU's Introductory Engineering course is a two-credit lecture/lab offered to the combined freshman class (EE, ME and MfgET), with an average enrollment of 75. The goal of the course is to provide incoming students with an improved understanding of both engineering in general and their chosen engineering discipline, to show students the opportunities available for engineers at LSSU, and to provide some basic technical skills. The course is intended as a retention tool, a means to educate our customers, a vehicle for the introduction of the design process, a way to stimulate creativity, and an introduction to the team setting.

Table 1 shows a comparison of the weekly topics covered in the Introductory Engineering Course in the last two years. As shown, the course spans a 15-week semester. Previously, the course covered basic computer skills early in the semester, introduced a one-week design exercise referred to as Imagineering[5], acquainted students with engineering organizations on campus through presentations by student group leaders, and culminated with a sequence of one-week topics on various engineering subjects. During weeks 6 - 10, a variety of topics were presented to the entire class, but during weeks 11 – 14 the class was divided into two groups, depending on the students' intended field of study, and more specific EE or ME topics were presented. Each week would consist of a 1-hour lecture to the entire class, followed by a 2-hour lab with groups of approximately 12 students.

Week	1998 Course Schedule	1999 Course Schedule
1	Introduction	Introduction
2	Imagineering	Imagineering
3	Computers – Word Processing	Computers – Word Processing
4	Computers – Spreadsheets	Computers – Spreadsheets
5	Student Groups	Robotics I
6	Robotics I	Robotics II
7	Robotics II	Student Groups; Presentation by Sr. Design Project Student Team
8	Data Acquisition	Engineering Design – Pugh Method
9	Fluid Dynamics	EE/ME Option
10	Energy & Efficiency	Disassembly of Drills
11	Signals/ Forces and Stresses	Logbooks
12	Electronics/ Material Science	Project work in labs
13	Digital Electronics/ Dynamics	Academic Success
14	Micro-Controllers/ Thermodynamics	Project Assembly/Construction
15	Assessment	Design Project Demonstrations

Table 1 - Previous and Current Course Outlines

In 1999, however, many of the weekly discipline topics were removed and replaced with a series of topics pertaining to engineering design (8 weeks of the total 15). This provided a common thread in the class and added continuity to the course. Instruction in computer skills remained, as well as a brief (1 or 2 week) introduction to electrical engineering, mechanical engineering, or robotics. Most importantly, a team-based, multi-disciplinary project was introduced that the student teams executed over the last five weeks of the course.

Early in the course, the students were surveyed using a simplified thinking-preference questionnaire patterned after the Hermann Brain Dominance Instrument.[6] The purpose of administering the questionnaire was to ascertain the students' propensity for the following four thinking styles: (1) analytical and logical, (2) planning and organizational, (3) interpersonal and intuitive, and (4) conceptual and holistic. In week 8, the students were divided into teams based upon the results of the questionnaire, with the intention of creating "whole-brain" teams (teams of students that exhibited all four thinking styles). These teams then worked to redesign a travel cup, an exercise developed during a recent NSF design workshop.[7] As part of the redesign, the teams brainstormed and performed a Pugh Method[6] analysis of different designs. This gave the students some design experience and a tool to use for their final design project.

Two-thirds of the way into the course, student teams were again assembled using the thinking-preference data and were given their final design project. The final design project required the student teams to build a vehicle capable of climbing barriers, picking up and relocating a rock. This exercise was based on the 1999 ASME student design competition, modified to reduce some of the difficulty. After team formation, a preliminary team-building exercise occurred, in week 10. This preliminary exercise was the disassembly and reassembly of an electric hand drill.[8] After this exercise, the teams began work on the final design project - creating logbooks of their design process, brainstorming, performing an objective evaluation of their potential designs, and finally, constructing and testing their vehicles. The course culminated with the entire class gathered for the demonstration and competition of all of the teams' vehicles.

In addition to providing continuity and a common thread to the course, the introduction of a design problem enabled other improvements to the course. During 1998, a student saw 7 or 8 different professors during the semester, depending on whether the student chose electrical engineering or mechanical engineering topics in weeks 11 through 14. Student course evaluations (Fall 1998) revealed that many students were unhappy with the large number of different instructors for the course. In 1999, a student saw only 6 different professors and had a pair of designated professors as lab supervisors during the last six weeks. By reducing the number of instructors in the class, the students and instructors were able to begin to forge closer relationships.

The changes to LSSU's introductory engineering course provided students with the opportunity to participate in a multi-week, team-based engineering design project. Despite the addition of the design project, the course continued to provide instruction in basic computer skills, a sampling of electrical and mechanical engineering topics, and an introduction to engineering society activities at LSSU. As revised, the course emphasized the following skills: the ability to design an actual system to meet a desired need, the ability to function on a multi-disciplinary team, and the ability to create and objectively evaluate alternative designs. These are the skills that are becoming well recognized as important for coverage in First-Year Engineering initiatives.[9]

III. Student Retention

As mentioned, a significant justification for the creation of LSSU's Introductory Engineering course has been to improve student retention. National averages indicate that only half of the students who begin studying engineering actually earn an engineering degree. In the freshman year, 25% of the students typically leave the study of engineering.[10] The attrition rates for engineering freshman at LSSU have been even greater, averaging 43% for all disciplines since 1996. A partial explanation for our low retention lies in the transition status of our Electrical and Mechanical programs from Technology to Engineering from 1996 to the present. Some of the students contemplating our engineering program in 1996 and 1997 were better suited for technology programs, and many in fact did switch to the Manufacturing Engineering Technology program. With the transition period ending, the students coming to LSSU for engineering are more capable of becoming engineers, and we are committed to helping them succeed.

To improve student retention, the Freshman Introductory course aims to provide our students with basic skills needed as engineers and, more importantly, to direct them to a meaningful career by giving them a better appreciation for what engineers do. We have begun to administer a number of surveys to the students to gauge the effectiveness of the course goal as a retention tool. We administer typical end-of-course surveys to obtain feedback from the students, the Study Behavior Inventory[11] (SBI), and an Academic Success Skill Survey.[12]

Results from the end-of-course student surveys taken last year (Fall 1998) were generally favorable toward the material covered – though there was some dissatisfaction with the number of different faculty members involved. A few of the topics (such as the more difficult computer assignments) were rated lower, and in general, the week 11 – 14 topics (one-week electrical and mechanical topics) were the highest rated topics. However, despite the good reviews by our students, the most recent freshman attrition rates (for students taking the 1998 Introduction to Engineering course) were improved by only 1%. We were providing the students with an appreciation for engineering, but perhaps not with the skills needed to succeed as engineers. Consequently in 1999 we modified the course to attempt to improve the retention by adding the design component (described above), and we also increased our efforts to both monitor students and to help the students help themselves.

The Study Behavior Inventory [11] (SBI) has been adopted by LSSU and implemented for all of the students in the Introductory Engineering course, as well as other university students. The SBI is a computerized, forty-six item, diagnostic/prescriptive survey that looks to measure:

- Academic Confidence – factors influencing a student's perceived self-esteem.
- Short-term Study Behaviors – preparation for day-to-day routine study tasks.
- Long-term Study Behaviors – preparation to carrying out specific long-range tasks such as projects or writing papers.

Academic preparation habits and skills, coupled with student self-esteem, are considered to be key indicators of academic achievement. All LSSU freshmen engineering students took the self-diagnostic survey. The results indicate that our freshman class is definitely average. The LSSU student average for all three SBI factors shown in Table 2 are within 7 percent of the national average score of 50 (first data column). A score of less than 40 is identified as the range where students are more likely to be unsuccessful academically. For our freshman engineering class, approximately 30 percent fell below a score of 40 for their short and long-term study behaviors, while approximately 40 percent were less than this score for their academic confidence (middle data column of Table 2).

In addition to the SBI survey, an in-class Academic Success Skill Survey[12] was administered to gauge the students' perception of similar areas considered by the SBI. This survey was also used as an in-class forum for discussing study areas that should be addressed and possible ways to make improvements. With the Academic Success Skill Survey, Academic Confidence statements ("I feel good about myself", "I feel good about LSSU", "I am motivated") received slightly higher average scores of 3.8 to 3.9 on a 5 point scale from Strongly Agree (5) to Strongly Disagree (1). Short-term Study statements ("I keep up in my classes", "I devote the appropriate amount of time") received lower average scores of 3.0 to 3.2. Long-term Study statements ("I schedule my time", "I practice good study skills") received average scores of 3.5 to 3.7. In Table 2, the students' self-assessment scores from the Academic Success Skills Survey have been converted from a 5-point scale to better correlate against the SBI results (last data column).

SBI Category	**Average SBI[11] Score**	**Percent of Students Scoring Below 40**	**Academic Success Skills Survey[10] Results**
Academic Confidence	56.4	39.0%	77%
Short-term Study Behaviors	51.9	29.3%	62%
Long-term Study Behaviors	50.0	29.3%	72%

Table 2 – Student Behavior and Skills Survey Results

The results from the two survey instruments should not be directly compared. The SBI Scores are determined from student responses to their activities, and the scores are scaled so that a 50 represents the average student. The Academic Success Results are a measure of students' self-appraisal of their own behavior. Unlike the SBI (50 is average), for the Academic Success survey students will grade themselves using a more traditional point system, where a score in the 70's would reflect an average assessment. The results from Table 2 do offer some insight into the comparison between the categories. Overall Academic Confidence is the highest of the three areas. Students are more critical of their Short-term Study Behaviors, compared to Long-term, although the SBI results indicate less of a difference. Students are more aware of the ongoing pressures and demands discussed in the Short-term Study questions, and therefore were probably more pessimistic about their behavior there.

We intend to continue to gather this data each year that the Introductory Engineering course is taught, with the goal of analyzing the actual success of our students to the survey results as freshmen. Currently this data is also being used in two ways: (1) for the students to help themselves and (2) to guide faculty advisors. The students are given their SBI results together with an interpretation of the results with suggestions for improvements. To augment this information, we have offered a lecture on academic success topics such as goal setting, study strategies, use of campus resources, [12] as well as tips for being effective with note taking, test preparation, and time management.[13]

The SBI data is also being used by the LSSU faculty to assist our advising efforts. All engineering students are assigned a faculty member as an academic advisor as freshman. Copies of the SBI results are given to the students' advisors. At the beginning of the semester, the Coordinator for LSSU's Learning Center, who is directing the campus-wide use of the SBI instrument, provided a seminar on interpreting the SBI data and guiding the students based on the results. Particular attention is given to the students scoring below the 40-point cutoff, and these students are encouraged to take lighter loads, directed to the Learning Center for tutors and study skills classes offered by LSSU.

We believe that the retention data indicates that 60 to 70% of our engineering freshmen are presently in a position to succeed at LSSU. Recognizing that academic preparedness and confidence are only several of the factors leading to actual success,[10] we hope to raise our freshmen retention rate from the current 58% to 70%. We plan to do this by continuing to aid our students in their preparation for an engineering career, by more proactive advisement, and by some of the initiatives described below.

IV. Student Skills and Connection to LSSU Engineering

Study skills are not the only skills that can influence a student's chances of success in college. One of the specific skill areas targeted by LSSU's Introductory Engineering course is computer proficiency. The computer aspect of the course, a 2-week sequence of instruction on basic computer skills, has remained virtually unchanged since the course's inception. Due to the varied backgrounds of the students entering LSSU, a large disparity in the level of computer skills has been observed. Some students have not had instruction in word processing; others have limited experience but have used different software; still others are very competent. A similar trend is observed with spreadsheet skills. By introducing all freshmen students to the same software for both word processing and spreadsheets, and by teaching them basic skills in the software, LSSU aims to "even the playing field", since our experience has been that the weaker students tend to fall further behind if unassisted. These exercises are linked to the remainder of the course, since the students are then expected to provide higher quality lab write-ups for the various written assignments required during the remainder of the course.

A new component in LSSU's Introductory Engineering course is a presentation to the freshmen by one of the senior design teams enrolled in LSSU's capstone senior design course. All graduating engineers at LSSU are required to take a year-long capstone Senior Project design course sequence. In the Senior Projects course, multi-disciplinary teams of Electrical, Mechanical and Manufacturing students are assigned an industrial-based project with a budget of $10,000 to $100,000. The projects typically involve research, design, construction, implementation, testing and documentation. Each team must complete a significant oral presentation of their perceived scope of their project in mid-October. We selected one of the better Senior Project teams ("better" in the sense of the quality of the presentation and the interest it would hold for freshmen) to repeat their presentation to the Introductory Engineering students. The intention was to provide a connection for students starting their engineering education at LSSU to those finishing. This aspect of the course received favorable feedback from the freshmen and seemed to solidify or generate interest in continuing in the engineering curricula. It is hoped that this aspect of the Introductory Engineering course will instill confidence in the freshmen students, provide excitement for the engineering programs at LSSU, and give students additional impetus for staying enrolled in the engineering curricula. Finally, this engineering presentation adds to the design theme running through the course.

One final aspect of the course that bears mentioning is our inclusion of brief presentations by leaders of the various student engineering groups on campus. Introducing the students to these organizations provide them with opportunities for meaningful extra-curricular activities. As mentioned earlier, many students may need validation that they "belong" at college. In-class validation is only one mechanism to provide a student with a meaningful college experience. Providing students with out-of-classroom validating experiences can also give them the confidence to remain at the university, and in the engineering curriculum. Particularly when a student is already successful academically, providing social validation (acceptance by their peers) is important.[1] By promoting and encouraging students to become involved in organizations such as ASME, IEEE, and SME, LSSU hopes to contribute to early social relationships and friendships that will aid students in their academic careers[12] and will prevent attrition of otherwise academically capable students.

V. Integration of Engineering Design

The final course goal that was implemented for the Fall 1999 Introductory Engineering course was to increase the design emphasis. To complement the design aspects of its Senior Projects course, LSSU aimed to add a design component to the Introductory Engineering course, recognizing the following:[7]

- Design should simulate open-ended real world problems
- Introductory design activity provides students good career decision-making skills early
- Design activity provides beginning students high motivation and favorable impressions about engineering
- Creativity and the design process need to be developed early
- Students need to become accustomed to poorly defined realistic problems versus the single-problem, single-solution concept.

In addition to the benefits of student motivation and the value of graduates possessing useful professional skills, we were also seeking to address the ABET Criteria 2000 requirements, which emphasize the need for design. To add this design flavor to the course we have integrated a sequence of three lab exercises (Imagineering,[5] Travel Cup Redesign[14] and Drill Dissection[8]) together with a final project based on the 1999 ASME Rock Retriever student design competition.[15] The Imagineering exercise was used in previous Introductory Engineering classes, but the other exercises were new for the Fall 1999 course.

The Imagineering lab required small groups of students (2 or 3) to take a package of materials (paper clips, screws, rubber bands, sandpaper, etc.) and “create” something to serve “an engineering purpose”. The lecture preceding the lab covered the iterative nature of the design process, form vs. function, and a function structure analysis of design. The goal of the Imagineering lab was to encourage creativity and to begin to convey the form-function concept.

The Travel Cup Redesign lab was the second design activity, and again used small groups of students (3 or 4), working in assigned teams to consider and improve upon an existing design. We used the Herman Brain Dominance thinking preferences to form “whole brain” teams and the students were instructed in the concepts of different thinking preferences (structured versus free-form, detailed versus holistic), and how the various thinking preferences are important in the overall design process. First the students in each lab section set design criteria. Next, each team brainstormed design ideas and formalized a preliminary design with a sketch. Each team presented their improved design to the lab, and then the entire lab section performed a Pugh Method comparison of all of the designs, led by the instructor. The groups later submitted a written report that summarized the lab activities and incorporated the final Pugh Method results.

The formation of the teams for the final design projects was guided by the same thinking preferences method, and in fact a reasonable number of the teams were either identical or nearly the same as for the Travel Cup lab. The final design project teams were groups of 3 to 5 students. These design teams completed a reverse engineering exercise on a hand-held electric drill. The Drill Dissection lab gave the students some appreciation of the components of an electro-mechanical device, which they would be designing themselves for their final projects. The lab reinforced the concepts of form and function and applying design criteria. In the lecture preceding the lab, the concept of manufacturability was introduced. Because the students had to buy and build their own devices, the idea of creating a device that was cost effective and could be readily constructed had immediate relevance to the teams.

We decided to lessen the documentation that accompanied the final projects, and did not assign a final written report. Instead we provided the student teams with bound logbooks and some instruction about commonly accepted design documentation practices. The only documentation required from the teams was their final logbook, which they maintained throughout the final design project. The logbooks also provided us with a means for checking the progress of teams, their plans for the upcoming week, and the individual contributions of team members. More importantly, it gave us some insight into the thinking process as the teams worked to define a solution to the design problem.

The final design project, based on the 1999 ASME student competition, was to design and build a vehicle that would go to a location, retrieve a rock and bring it to a designated spot. The vehicle was required to return to its starting location, ready for another run. To realistically perform this task on a rough surface, the vehicle had to be able to surmount small obstacles (simulated by lengths of wood boards) to get to the rock and to bring the rock back to the designated deposit area. A total of 18 student teams were formed to build vehicles, and the teams worked on their vehicles both in lab and on their own for about 5 weeks. At each design project lab session, 6 design teams and two faculty members were present in a common room with large tables. The labs were very informal, with teams working on their projects, discussing the project with the faculty, seeing what the other teams were doing, and testing the designs on the course which was set out for them. We found that the larger size environment of these labs was effective in creating a positive and productive environment.

Another useful resource for this project was a group of 4 sophomores who had taken the course the previous year. These students worked together to construct several different design solutions for the ASME contest, and recommended changes based on their experiences. This helped the faculty to modify the contest rules to improve the likelihood of freshman student success on the project. For example, the course was modified to make it possible to push, rather than pick up the rock, to the final target area. We were able to give the freshman class suggestions or guidance, based on some of the successful or unsuccessful efforts of the sophomore students. LSSU is located in a small town, and the sophomore students also found local stores that stocked supplies and materials for the vehicles, and obtained web addresses to give the students.

The use of sophomores (versus juniors or seniors) was intentional, in that we wanted students who were not too far removed from the freshman experience to give us a calibration on the project. We also used these sophomores to assist in the design labs. They did an excellent job of wandering around and talking to the teams as peers, rather than as "experts" which the faculty are often perceived to be. Other universities have recognized this strategy of having a "guide on the side" rather than a "sage on the stage."[16]

The Finals Week activity for the Introductory Engineering course was the demonstration and evaluation of the vehicles. All 18 teams did bring functioning vehicles to the final session, although only 9 of the 18 design teams were able to successfully negotiate the course within the time constraints for the project. At many levels the activity was a success. There was tremendous energy in the room (applause for successful runs, collective groans for some of the near misses). The team members demonstrated ownership in their designs ranging from anxiety about looking foolish to fierce competitiveness to "win." Representative pictures of a few of the designs are shown in Figure 1.

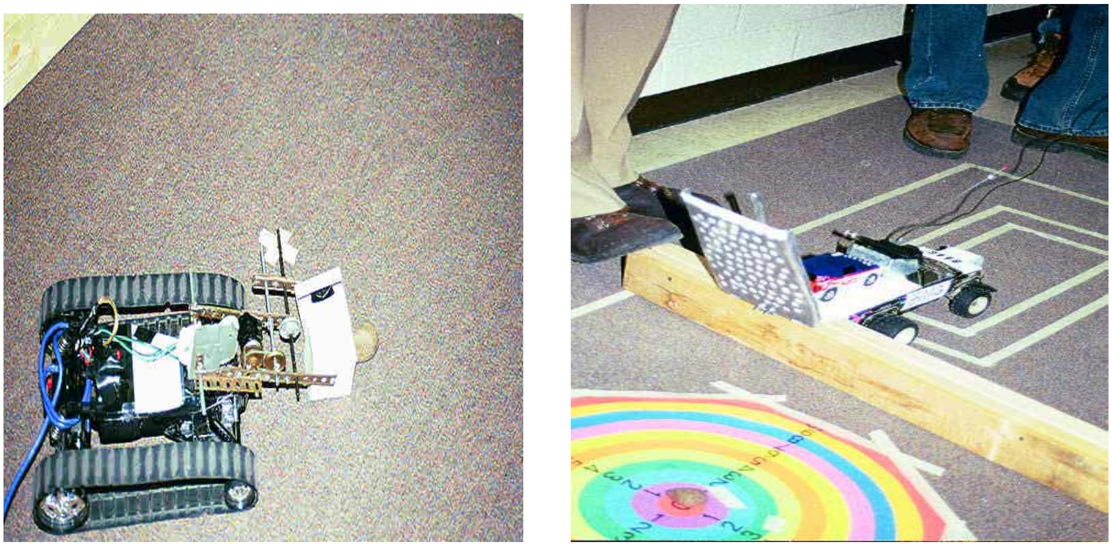

Figure 1 – Typical Student Design Vehicles

An Engineering Design student survey performed at the end of the class indicated that the students felt confident that they understood the engineering design process, and were strongly in agreement that the hands-on learning experience was valuable to their education. They indicated that they entered the course with a somewhat neutral opinion of their abilities to perform engineering design, but that the Introductory Engineering course was helpful in providing design skills early in their academic careers.

VI. Conclusion

LSSU offers an Introductory Engineering course to freshmen designed to educate students about engineering degree choices, to increase student retention and to provide basic computer skills. The course has been modified in Fall 1999 to integrate project-based engineering design and multi-disciplinary team experiences into the course. This was a significant change from previous years, when this course was team-taught as a curriculum sampler - a sequence of one-week topics covering principle areas of Electrical and Mechanical Engineering, Engineering Design and computer skills. Now that the course has been modified to include engineering design, we have started to gather information from students and to analyze student retention data to assess the success of this course as a method of teaching design and as a student retention aid.

The course changes have been favorably received by the freshmen. The course provides a good overview of the entire program and of all three majors offered in the engineering program at LSSU. It enables freshmen students to have an early "validating experience" by working on a hands-on, team-oriented design project. While it remains to be seen how the modifications to the course will affect student retention at LSSU, the present structure at least addresses some of the deficiencies in the previous course outline.

We still have some concern about the number of instructors involved with the course. Not only do students react negatively to a large number of faculty members involved with the course, but it also becomes very difficult logistically to coordinate the activities of all of these instructors. For instance, the course has 3 laboratory sections and each section had a pair of designated faculty (six different instructors in all) for the final five weeks of the course. Next year, we plan to have two designated faculty members that will be involved with each of the sections.

The change from 1998 to 1999 attempted to keep the worthwhile aspects of the "curriculum sampler" while removing or modifying the negative aspects. We believe that we have been successful in doing so. With our continuing efforts to provide students with academic success skills and to monitor their academic behavior, we expect to see positive changes in our student retention rates.

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