INTEGRATING LIBERAL EDUCATION INTO ENGINEERING TECHNOLOGY SENIOR DESIGN COURSE AT MIAMI UNIVERSITY

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Abstract *— At Miami University, the senior design course in the baccalaureate Electromechanical Engineering Technology (EMET) Concentration takes the form of a yearlong liberal education capstone course. In addition to conducting engineering analysis, students are encouraged to integrate ethics, environmental issues, cost/benefit analysis, safety, and aesthetics into their project. Miami emphasizes critical thinking, sharing of ideas, synthesis, and informed reflection as significant precursors to action while focusing on student initiative to define and investigate the problems or projects.*

The inclusion of the liberal education component has proven to be an exciting challenge to the students. Alongside the project design work, the students have to reflect on personal and societal benefits while considering the reality of costing of the projects and the impact in terms of safety, environmental, or ethical issues related to producing the item. The integration of liberal education into the curriculum has generated an implicit understanding of the role of humanities and social science courses in enhancing engineering education.

Index Terms — Miami University, Liberal Education, Senior Design Course

INTRODUCTION

In 1996, the department of Engineering Technology at Miami University, OH, developed a capstone course 'Senior Design Project' in its Electromechanical Engineering Technology degree program. This capstone course is required in the final year for all students graduating with electrical/computer concentration or mechanical concentration[1]. The primary objective of this course is to make the students work in teams to conduct major open-ended research and design projects. This allows the students to be striong team player, utilize their knowledge and skills acquired in earlier course work, and incorporate engineering standards and real world constraints such as economical and social factors, marketability, ergonomics, safety, aesthetics and ethics.

To date, the senior design course has been successful as a Capstone course, meeting the requirements of Liberal Education component. After a brief backgtound on Liberal Education at Miami, the paper outlines the senior design course. The philosophy of embedding the liberal education component in the course is presented later. Finally, the paper shows the assessment techniques employed for continuous improvement of the course.

LIBERAL EDUCATION

Unambiguously a well-rounded education of engineering graduates must include a considerable liberal education component[2]-[9]. Although an engineer's job is to make things better, more efficient, and cheaper, other non-engineering skills such as writing, speaking and effective communication, as well as social and societal awareness, environmental consciousness are involved. It is important that engineering curriculum is comprised of considerations of the appropriateness of various technical solutions and resolution of conflicts that extend beyond classical engineering optimization. Such conflicts involve humanistic considerations that a technical solution must address conscientiously with careful thought.

Albeit the idea to plant the seeds of a social conscience in every graduate is an old one, its implementation at universities is complex and is subject several constraints. In order to estimate the current thinking among academia, a question was posted on the ENT Listserv with regard to if and how liberal education is incorporated in enginnering technology curriculum. The data collecetd from that inquiry indicated a strong support for including Liberal Education component. It appears that most of the engineering students are engaged in takling communication, history,math and science courses in their freshmen to senior level. Some of the postings on the listserv suggest that liberal education concepts should be introduced early on at grade school level (K-12).

The reluctance to add liberal education courses to engineering curriculam stems from the concern that there may be little room left for engineering courses. There is no doubt that introducing liberal education component by including liberal arts in an engineering can be only minimal at best to maximize the time to teach engineering subjects.

One of the ways to overcome this limitation is to embed liberal arts components in one or many senior design courses, in particular, any Capstone engineering design or project course.

THE MIAMI PLAN

At Miami University, all students must complete courses identified as parts of the Miami Plan as well as courses in Major[1],[8]. The Miami Plan for liberal education is an ambitious and complex plan. Based on some of the best thinking at the time of its development, the plan emphasizes four foundation principles. In addition, the plan aims to provide breadth through foundation courses, engagement through seminars, depth through the thematic sequence, integration through the capstone experience, and options for all disciplines to create courses based on the principles of the plan[4]. These are not novel ideas in liberal education program design. What makes the Miami plan unique, and also complex, is that it includes all of these ideas, emphasizing forms of inquiry and pedagogy, allowing overlap among requirements, and operating in an unresolved alliance with college and major requirements.

The Miami plan has two parts; Foundation and Focus. The 'Foundation' requirement is met by taking 36 semester hours of courses (Table-I). The 'Focus' requirement, is met by taking a minimum of 9 hours in a Thematic Sequence outside the major and a minimum of 3 hours in a senior Capstone Experience taken in the final year of study (Table-I).

Typically, a student registered at Miami University would fulfill 28% Foundation requirement, 9% Focus requirement and 63% in the field requirement as shown in the Pie chart.

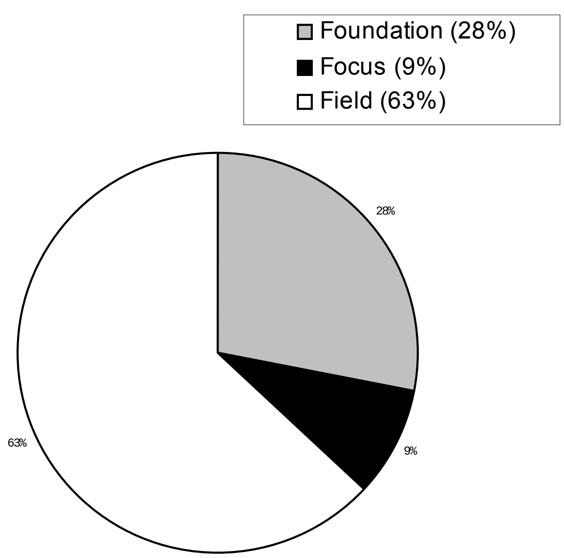

FIGURE. 1
DISTRIBUTION OF COURSE WORK

The Capstone presents an excellent opportunity to bring together the student's entire undergraduate program. The Capstone Experience, usually completed near the end of baccalaureate studies, integrates liberal learning with specialized knowledge. Each Capstone emphasizes sharing of ideas, synthesis, and critical, informed reflection as significant precursors to action, and each includes student initiative in defining and investigating problems or projects.

Capstones may be completed in or outside the major; in some departments, the Capstone Experience will be a requirement of the major. For students not majoring in the department where a Capstone is offered, prerequisites often may be met by completing a related thematic sequence. All Capstones presume a significant scholarly background of specialized study in a major as well as in liberal education course work.

At Miami University, the senior design project assimilates engineering design, analysis, and liberal education concepts such as cost/benefit analysis, environmental issues, and ethics. The Department of Engineering Technology developed the Senior Design Course in 1996. The Liberal Education Council later approved this sequence as a Capstone course. The department has seen the liberal education component in ENT 497/498 as a valuable asset. By focusing on the principles of liberal education at Miami, students learn to ask why they are designing a project, not just how to design it.[1],[9],[10].

TABLE-I
FOUNDATION AND FOCUS SEMESTER HOURS

Foundation Courses (36 Sem. Hrs.)		
English	Fine Arts	Humanities
Social Sciences	US cultures	World Cultures
Biological Sciences	Physical Sciences	Mathematics/Technology/ Reasoning
Focus (9+3 = 12 Seem. Hrs.)		
THEMATIC SEQUENCE: 9 hours Typically a Three Course Sequence outside the department of major	CAPSTONE EXPERIENCE: Integrates Liberal Learning with specialized knowledge	

BASIC ELEMENTS OF SENIOR DESIGN COURSE

The senior design course is divided into two semesters: ENT 497 and ENT 498. The course addresses the application of the knowledge of senior Engineering Technology students to perform a major open-ended design project. This allows students to work in design teams that utilize their combined expertise and skills to achieve a successful design. Each group of students has a faculty mentor.

The fundamental elements of the design process are considered in this course through continuous interaction with faculty and bi-weekly seminars by outside professionals. In this course, a variety of methods is offered to the students to enable them to develop their designs. As appropriate, seminars on topics relevant to the projects and design are conducted by the faculty, students, and guest speakers from industry and other institutions. These topics include Miami Plan, Ethics, Cost Analysis, Liberal Education Component, U.S. Patents, Engineering Design Project, and Design Alternatives.

Along with Guest speaker's seminars, the students and the faculty meet regularly. In each of these meetings, students generate minutes that describe the discussions, activities to be conducted in the future, progress to date, and persons responsible for future tasks.

The design projects include the establishment of objectives and criteria, synthesis, analysis, and evaluation. In all designs, students will consider realistic constraints, such as economic factors, marketability, human factors, safety, reliability, aesthetics, ethics, and social impacts.

The projects offered in this course are chosen from real-world problems. This is intended to enable students to recognize current needs and trends in industry and society. The first part of the project (ENT 497) deals with feasibility studies or proposals. The second part (ENT 498) is the actual implementation, testing, and production or simulation of the prototype. Because design is an iterative process, the students may find it necessary to adjust their proposals from that in ENT 497.

At the end of the second part (ENT 498), the students are required to give a demonstration of their developed design. This is done by using computer simulation or by physical testing. The format for the final report is similar to that of ENT 497 but contains more information about the final design: analysis, mathematical model, cost, and operational procedures.

In general, students are graded (Table-II) and evaluated according to their performance in four areas: 1) finishing the proposed design, 2) reports, which include final report, minutes, and other progress reports; 3) participation, which includes meeting attendance, discussions, active involvement, and leadership in carrying on one's responsibility; and 4) midterm and final presentations.

It should be noted that the students are working in groups to emphasize the importance of teamwork in real life situations. Each group is responsible for dividing the different tasks among its members, writing reports, and presentations. Individuals within a group may receive different grades. Grades are determined by regular evaluations taken during the semester by the instructor and by the students for each individual. While the student input will be given considerable consideration, in the event of conflicting opinions or other such problems, the ultimate grade determination will be by the instructor.

Students submit written assignments in ENT 497/498.

- Mid-Term Report
- Final Report
- Weekly Journal Entries
- Reflective Essay (Appendix-A)
- Presentations

TABLE-II
ENT 497 COURSE GRADE SHEET

Date: _____________

Maximum Points Possible	Graded Item		Points Earned
(15 points)	Project Proposal		
(45 Points)	Final report		
	(2 points)	Title	
	(2 points)	Statement of Purpose	
	(10 points)	Scope & Methodology	
	(10 points)	Expected Findings	
	(10 points)	Conclusions & Rec.	
	(2 points)	References	
	(7 points)	Appendices	
(15 points)	Quality of Participation		
(30 points)	Presentation		
(15 points)	Use of Engineering Analysis		
(30 points)	Weekly Journal & Reflective Essay		
		150 points Total	

The following assessment tools are used in the course.

- Presentation Evaluation (a panel of judges evaluate student projects and presentation at the end of each semester) (Appendix-B)
- Liberal Education Survey (Appendix-C)
- Student Evaluation (divisional student evaluation done at the end of the course)
- Two Minute Survey (usually done after each guest speaker)

EMBEDDING LIBERAL EDUCATION CONCEPTS

All engineering colleges require engineering design from their Senior Design students. In order to foster the consideration of social context and other non-technical issues when designing, building, and implanting engineering projects, liberal education concepts are introduced into the senior design course. These are 'critical thinking', 'understanding contexts', 'engaging with other learners' and 'reflecting and acting'.[1]

- Critical thinking: Critical thinking is to involve imagination, intuition, reasoning, and evaluation in such a way to analyze systematically and solve complex problems. [1]
- Understanding Contexts: The relevance of the problem and the solutions to the society, environment, and the well being of people is as important as the problem and the proposed solution.

Knowledge of the conceptual framework and character of the society are essential inputs. [1]

- Engaging with Others: Only through open and honest exchange of ideas with piers and teachers and colleagues does one accomplish a balanced solution. Active listening, exchange of ideas, reevaluation of established views and critique through actively seeking other's opinions are corner stones to achieve a proper result. [1]
- Reflecting And Acting: Practice decision-making and evaluation of the repercussions thoughtfully. The idea is to enhance personal moral commitment, enrich ethical understanding, and strengthen civic participation. [1]

Students in ENT 497 are required to first establish who is in their group, and then choose a project. Often students have more than one alternative, so they can choose a project that best fits their ability and interest. Groups are altered if there is little diversity in terms of background.

Next is the planning stage, where students discuss the design, establish objectives, prepare a Gantt chart, and assign tasks. Literature research and preliminary reports make up the rest of the semester. All areas of critical thinking (analyzing, formulating alternatives, implementation, and documentation) are done in this class. The mid-term report gives the instructor a clear understanding of the progress of the group.

Following is an analysis of how the department meets the four principles of liberal education at Miami.

Critical Thinking In Liberal Education

All senior design projects require a component of engineering analysis. Critical thinking in engineering technology is most often is centered on analysis and design. The principles learned in prior courses are used as a guide for conceptualizing a complex project, designing the system using engineering analysis to mathematically model the system, then building it. Critical thinking skills are used in analyzing problems, formulating alternative solutions, implementing solutions, and documenting the results. [10]

Here are a few examples:

- A group of students designed a fiber optic multiplexer that allowed a computer to be connected to a matrix of cables. The project was complex and yet quite successful. The company that sponsored this project later patented the final system. To design the mechanical part of the system, students used principles of Statics, Strength of Materials, and Machine Design learned in their engineering technology courses. The accuracy and repeatability of the alignment was crucial to communication being established. Students spent most of the year determining the type of electrical control to be used (i.e. open or closed loop) and designing the mechanical apparatus. They also evaluated a wide variety of designs to best move the platform for proper alignment of the cables. The final decision was that the control system had to be closed loop because of the precision involved. The students designed the control system using differential equations and other modeling techniques taught in their control course.
- A group of students designed a PCB electrical board etching system that allowed schematics to be drawn on a computer, and then downloaded to a robotic arm that etched the board. All aspects of the system (including the robot) were designed and built by students. The students used the knowledge they gained from their mechanical courses, digital design, and programming courses to build this system. The software was written in Visual C++; I/O ports were used to control the machine. The machine entirely built by the students required a tolerance better than a thousandth of an inch. This would normally take months to design and build. Owing to the time spent in planning and preliminary design, the team was able to successfully build, program, and test this complex machine in one weekend.

Engaging With Other Learners

All groups have two or three students in them. Students are required to meet at least once a week outside of class, and keep the minutes in a journal. The instructor regularly reviews the journal to see how well the students are working together. If there is a communication problem, the instructor resolves it quickly, rather than let it fester throughout the course. [10]

An example of engaging with other learners follows:

- For two different years, a group of ENT 497/498 students served as advisors for the F.I.R.S.T. Robotics competition. This national competition has students design a robot in a 6-week period to perform a task. Over 800 colleges and high schools participate in the national event. Our group advised Northwest High School students on all aspects of the robot design. They were also involved in raising funds for the national competition in Florida. In 2000-2001, Miami/Northwest placed first in the region and runner up nationally. In 2001-2002 our students placed first in the region and third nationally. This project had a combination of high school students, college students, and engineers from industry working together to produce the final design. The ability to work so well together in a short time frame is tribute to the communication skills of Miami students.

Not all students communicate well though. Sometimes one student will control the project while others watch. This becomes obvious from the journal entries, and students are informed that group responsibilities must change. All students should contribute equally, depending on their interest and talents. Limiting the maximum number of students to three has also helped with this problem.

Understanding Contexts

Understanding Contexts includes adding a conceptual framework, cost/benefit, and cultural implication to a student's knowledge base. [10]

Rather than rush to build the project, students planning are the focus in the early part of ENT 497. Later, literature research and brainstorming sessions help the student to consider all aspects of the project. Feasibility studies help students envision the effect their product will have once it is designed and produced.

The central focus of the projects is engineering design; so all projects are required to have a significant component of engineering analysis. Students generally find an industry sponsor to fund and mentor the project. This way, students gain a perspective outside the classroom.

Understanding contexts includes other factors besides mathematical analysis. Students are required to include in their design such topics as cost/benefit analysis, safety, ethics, environmental issues, and aesthetics. The company sponsoring the project also mandates these components. Students see the context that the project will be used in, not just engineering analysis.

During ENT 497, guest speakers visit often. Attendance is mandatory on these evenings. A list of subjects presented by guest speakers for Fall 2002 is:

- Miami Plan – August 29
- Ethics – September 12
- Cost Analysis – September 26
- Liberal Education Component – October 10
- U.S. Patents – October 24
- Engineering Design Project – November 7
- Design Alternatives – November 21

Speaker topics are partly determined from student and industrial feedback in previous years. These topics help students step back and look at the project as a whole, rather than designing for the sake of design. A couple of examples of understanding contexts are given below:

- A group of students had a preliminary design for a robotic system that sprayed a fiberglass coating evenly on a tank. They took into account cost/benefit analysis, but not safety. After the instructor required them to look at all aspects of the design, they discovered that the project, if built, would not meet OSHA standards. They redesigned it, and the company is now using the robotic system.
- A group of students designed on paper a brake caliper for an automotive manufacturing plant. They did six different designs. They determined that some of the designs, even though more cost effective, could lead to carpal tunnel syndrome in the company employees. They chose not to go with this type of design when building the final project.

Reflecting And Acting

Reflecting and Acting is demonstrated by requiring students to think what they are designing before building it. The Reflective Essay is due at the end of each semester. It encourages students to evaluate their Senior Design experience with regard to the four goals of liberal education. The report guidelines are in Appendix A. Shown below are student comments from selected Reflective Essays. [10]

- "The goals of the Miami Plan for Liberal Education, in particular the goals of critical thinking and reflecting and acting have been instrumental in the preparation of this project."
- "Communication was one of the most important aspects of this project…because we had clear and concise communication, everyone felt they had a part in the final design."
- "In closing I would like to say that ENT 498 was the most difficult course to date. Not the project itself, but trying to complete the project in such a short amount of time. If I had to do it all over again, I would have insisted on a project that could be completed in a third of the time. By not speaking up, I allowed us to take on a project as complex and involved as this, and open ourselves for potential failure."
- "The communication that Tim and I had… was critical in the development of the project as a whole."

This essay has helped students observe their performance in the course. It helps them see how the breadth and depth of subjects they learned at Miami, including engineering technology, speech, English, philosophy, etc., helped shape their talents as they prepare to work in industry.

EVALUATION OF THE COURSE

At the end of ENT 497, students judge each other's projects and presentations (Appendix-B). While one group is giving the presentation, the remaining students observe and evaluate. The same evaluation form is given to outside judges in ENT 498. The outside judges consist of industrial representatives and faculty from other universities. For the past two years, some of the Miami faculty judge University of Cincinnati (UC) senior design projects and professors from UC evaluate ENT 498 presentations. Input from other colleges has helped us see areas for improvement in the sequence.

For example, in 2000-2001 the presentation day was somewhat disorganized because students wanted to change the time of their presentation at the last minute.

This confused the judges. Now, all students agree to a presentation time weeks in advance. This time schedule is strictly followed.

Students performing the presentation evaluation in ENT 497 tend to be quite honest in their critique. This helps students revise their presentation for ENT 498 the following semester.

The department also uses presentation evaluations to help evaluate the course. For example, the judges from ENT 498 last year made note that some groups had trouble with their speaking ability. They seemed unsure of themselves. To help correct this problem, the faculty is now requiring students to do more practice presentations before being must first create a timetable for completion. Creating objectives and judged. The presentation evaluations will be checked this year to see if the oral presentation is improving.

As stated earlier, the Reflective Essay and weekly journal entries help students observe their contribution to the course.

EVALUATION OF LIBERAL EDUCATION COMPONENTS

The assessment tools used in the course are an aid to the faculty and students. Student evaluations help ensure that ENT 497/498 is meeting the needs of the department and Liberal Education. The Liberal Education survey helps the faculty determine if students understand and appreciate this component of the course.

The Liberal Education Survey began in the 2000-2001 school year. Appendix-C contains the questions asked and a summary of the responses. As can be seen, students in general understand and appreciate the liberal education component of the course.

At the beginning of the school year, faculty meet to discuss ways of implementing improvements based on the survey results from the previous year. For example, Question 7 on the survey asks if the course has helped the student understand ethical issues related to engineering technology. In 2001-2000, the response was 2.97, but in 2001-2002, the response was 3.31. In the 2000, we showed a film on ethics relating to the Challenger disaster. This film generated much discussion in the class. Last year, we had only a short discussion on ethics. To improve on the 2.97 score from last year, we invited an engineer to discuss ethics both from both a moral and legal aspect. The survey will again be used to see if this helped the score.

As for the writing assignments, both years show that while students complain about the amount of written assignments, they do understand the value of journaling, reflecting, and reporting on their project.

CONCLUSION

All engineering colleges require engineering design from their Senior Design students. Most also require cost/benefit analysis, environmental issues, ethics, etc, although these topics are often seen as a minor component of the course. In the Engineering Technology department, these issues cannot be pushed to the background. By focusing on the four principles of liberal education at Miami, students learn to ask why they are designing a project, not just how to design it.

Some of the faculty in the department was initially skeptical of including liberal education in the course. Students take a number of engineering technology courses before enrolling in ENT 497/498, so why not focus on assimilating engineering design and analysis into their project? The thinking was that including liberal education provided little value to engineering analysis and design. Indeed, the quantity of liberal education in the required foundation courses was sometimes seen as a handicap, rather than strength.

Partly by co-teaching ENT 497/498 with other instructors, partly from seeing the effects of including liberal education on the final projects, and partly from listening to guest lecturers, most of the faculty have come to see the value of including all aspects of student learning in the course.

The department, while initially skeptical, has made a valiant attempt to integrate liberal education into the ENT 497/498 sequence. It has been a challenge for most of the faculty, because the engineering programs they were in included few, if any, liberal education courses. Their senior design experience focused purely on mathematical design and analysis.

In the beginning, at times the faculty felt unsure of what they were doing. Communicating with other departments that have a senior design course (such as Manufacturing Engineering) has helped the department develop the course. Having more guidance from the Liberal Education Council would have helped the ENT department understand what was expected. Input from LEC was especially necessary because the department has no other Miami Plan courses to use as a guideline. Overall, the department believes it has successfully integrated the Miami Plan for Liberal Education in the course, but is not sure if this is what the council is looking for.

Some of the faculty believe that ENT 497/498 is the strongest course in our department. The course is being reviewed for continuous improvement. The faculty is contemplating to utilize the course across varied disciplines to supply liberal education component in their curriculaum at senior level..

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APPENDIX A

INDIVIDUAL REFLECTIVE ESSAY

Write a 2-3-page essay on your experience in the senior design project. In your essay, address the issues discussed below. Please remember that a reflective essay is more about self-assessment, performance, and lessons learned than just giving oneself a letter grade**.**

The objective of the individual reflective essay is to allow you to reflect on your experience in conducting your senior design projects. One way to define reflection is to self-assess one's performance in achieving a certain task. The question is how well did you perform in this course? How did you arrive at this conclusion? Another way to define reflection is to compare and contrast the course objectives to what actually happened. For example, the main objective of the course is to *utilize the application of the senior students' knowledge in science, mathematics, and engineering to perform a major open-ended design project.* The question now is: were you able to do that? Why or why not?

Another course objective is integrating liberal education goals (i.e. critical thinking, understanding contexts, and engaging with other learners) and professional engineering goals. These may be found in the principles of engineering science, manufacturing process and methods, and engineering design. See the text for more information. Again, how do you evaluate your experience with regard to this objective? In your opinion, did the course achieve the Miami Plan' requirement for a capstone experience? Why or why not?

Thus, one thing we would like you to do is to read the course syllabus, one more time, and reflect on your experience in the course. Other aspects of the course and the whole experience that you should to reflect on are:

A group of students had a preliminary design for a robotic system that sprayed a fiberglass coating

- Team work: you and your partners' ability to perform in a team.
- Communication: your ability to document your research, to present your results, and to communicate with your advisor, team members, and customer.
- Design: your ability to perform an open-ended design problem. How do you evaluate this experience versus other engineering courses? Explain.
- General skills and knowledge, such as AutoCAD, computers, theory, electronics, machining, etc. How do you evaluate your abilities to apply such skills in your project?
- Learning to learn on your own: how do evaluate this aspect of your performance in this course?
- Your performance, in general: how do you evaluate your own performance? What did you do well and what can be improved? What are the lessons you learned in this experience?

APPENDIX B

TABLE-III

ENT 497 Presentation Evaluation

Group Name ________________

Objective of Project Clearly Stated	Very Good	Good	Fair	Poor
This includes problem statement, customer, and given constraints.				
Synthesis of Group	Very Good	Good	Fair	Poor
This includes brainstorming ideas, using constraints to bring together different components, ideation, and creating schematics and graphical representation of ideas.				
Quality of Analysis:	Very Good	Good	Fair	Poor
Did the group demonstrate the use of engineering science, science, mathematics, statistics, and other modeling techniques to evaluate their solution?				
Testing and evaluation:	Very Good	Good	Fair	Poor
They discussed the approach they used to test and evaluate their hypothesis, model, or solution. Explained clearly the constraints used to achieve that.				
Literature Research	Very Good	Good	Fair	Poor
Includes library research as well as company literature, web surfing, etc.				
Progress of Project	Very Good	Good	Fair	Poor
They used schematics, Gantt chart, narrative, cost, and advantages and disadvantages each approach to the design.				
Future Work	Very Good	Good	Fair	Poor
They discussed their plans for the future, including after the year is over.				
Vocal Quality	Very Good	Good	Fair	Poor
This includes speaking to the audience, holding a level of interest, using connective sentences.				
Appearance of Group Members	Very Good	Good	Fair	Poor
Equal Time for Each Member of Team	Very Good	Good	Fair	Poor

Time of Presentation (minutes) ___________________________

APPENDIX C

TABLE-IV

ENT 497/498 Survey Results, 2000-2001 & 2001-2002

SA = Strongly Agree, A = Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree.
Critical Thinking
1. I believe my critical thinking skills have been enhanced by this course. **SA A N D SD**
2. I believe that my critical thinking skills have been enhanced the work. I have done on my project. **SA A N D SD**
3. I believe this course stressed thinking and not memorizing. **SA A N D SD**
4. I believe this course provided many opportunities for critical thinking about problem solving, program design, and solutions **SA A N D SD**
5. I believe my critical thinking skills have been enhanced by the writing **SA A N D SD**
Understanding Contexts
6. I believe this course helped me understand the positive and negative consequences of the design process. **SA A N D SD**
7. I believe this course helped me understand some of the ethical issues related to engineering technology. **SA A N D SD**
8. I believe this course helped me understand the cost/benefit to a design project. **SA A N D SD**
9. I believe this course helped me understand the manner is which design engineers think and act. **SA A N D SD**
10. I believe this course helped me become sensitive to the consequences of implementing a design. **SA A N D SD**
Engaging With Other Learners
11. I believe the class activities have allowed me to engage with other learners in an effective way. **SA A N D SD**
12. I believe this course has improved my ability to work and solve problems with others. **SA A N D SD**
13. I understand the importance of group work for engineering technology professionals. **SA A N D SD**
14. I learned some things I did not know by working with others. **SA A N D SD**
15. Working with others has helped improve my communication and listening skills. **SA A N D SD**
Reflecting and Acting
16. I believe that the structure of the course has provided opportunities for me to reflect upon the concepts I have learned and apply them in an effective way. **SA A N D SD**
17. I believe that my design will help me reflect upon the concepts I have learned and apply them in an effective way. **SA A N D SD**
18. I believe this course helped me understand the need to reflect before implementing an engineering design. **SA A N D SD**
19. I believe this course helped me to take into account all aspects of an engineering design **SA A N D SD**
20. I believe this course helped me to reflect before acting in other area of my life **SA A N D SD**
Characteristic Ways of Knowing
21. I believe this course helped me to understand the importance of understanding a problem before trying to solve it. **SA A N D SD**
22. I believe this course helped me to understand the importance of designing a solution before trying to solve a problem. **SA A N D SD**
23. I believe this course helped me understand the importance of meeting a users needs when designing a project. **SA A N D SD**
24. I believe this course helped me understand the importance of safety in design practice. **SA A N D SD**
25. I believe this course helped me understand the importance of logic when solving a problem. **SA A N D SD**

The questions are summarized based on the following numerical assignments:

Opinion	Number
Strongly Agree	4
Agree	3
Neutral	2
Disagree	1
Strongly Disagree	0

The survey results for the past two years are shown below:

Question	2000-01 Average	2000-01 Standard Deviation	2001-02 Average	2001-02 Standard Deviation
1	3.47	0.52	3.38	0.62
2	3.33	0.72	3.50	0.63
3	3.80	0.41	3.81	0.40
4	3.80	0.41	3.71	0.60
5	3.13	1.13	3.15	0.93
6	3.53	0.52	3.50	0.52
7	3.31	1.13	2.97	0.87
8	3.53	0.52	3.35	0.48
9	3.67	0.49	3.67	0.50
10	3.40	0.83	3.00	0.63
11	3.60	0.51	3.69	0.48
12	3.53	0.99	3.50	0.73
13	3.47	0.83	3.69	0.48
14	3.40	0.83	3.50	0.52
15	3.47	0.92	3.63	0.62
16	3.60	0.83	3.81	0.40
17	3.33	0.90	3.56	0.63
18	3.60	0.51	3.56	0.51
19	3.27	0.96	3.44	0.73
20	3.40	0.83	3.56	0.51
21	3.57	0.85	3.80	0.41
22	3.57	0.85	3.73	0.46
23	3.36	1.01	3.47	0.74
24	3.43	0.85	3.67	0.49
25	3.29	0.91	3.53	0.64