INCORPORATING LIBERAL EDUCATION CONCEPTS INTO ENGINEERING TECHNOLOGY SENIOR DESIGN COURSE AT MIAMI UNIVERSITY

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INTRODUCTION

The LEC (Liberal education council) at Miami University monitors and guides the incorporation of liberal education component in capstone course in the engineering technology department. Specifically, the focus points of the liberal education outlined in Miami bulletin[1] are critical thinking, understanding contexts, engaging with others, reflecting and acting. The senior design course is embedded with these attributes so that the student graduates with a well-rounded education.

This paper describes how the engineering technology capstone course (senior design project) at Miami University has been structured to facilitate Liberal education council's guidelines. The four components of liberal education are explained in this paper and a discussion of how each of these attributes is enhanced in the course is presented. For example, the capstone course offers a unique opportunity to learn about ethics (understanding contexts attribute). Because the department does not have a separate ethics course, a guest speaker lecture on ethics is arranged in the senior design course. Students apply this concept to a hypothetical scenario specific to their project and present it in their reflective essay (reflecting and acting attribute).

Capstone design courses are now widely incorporated into senior year undergraduate engineering curriculum at most universities. Many papers are published on the need to integrate issues such as 'ethical, environmental, service awareness', into capstone design courses. The focus is to enable engineering students to understand and appreciate, respect and possibly even value perspectives other than core engineering discipline. For example, the electrical and computer engineering department at Boston University uses the capstone course to introduce social awareness to their senior design teams.[2] Oregon Institute of Technology (OIT) uses EAC (ethics across the curriculum) to integrate ethics into technical classes. OIT provides an opportunity to participate in EAC seminars to increase their expertise for integrating ethics in technical courses.[3] The First National survey of seminars/capstone courses (707 institutions across the United States participated) reveals the following:

- 50.9% uses the capstone course/seminar to foster integration and synthesis within the academic major,
- 22.1% uses it to either promote integration and connections between the academic major and the work world or to improve senior career preparation and pre professional development.
- 5.7% uses it to promote integration and connections between general education and the academic major.
- 5% uses to promote the coherence and relevance of general education. (http://www.sc.edu/fye/resources/surveys/survey_r.htm).

At the engineering technology department at Miami University, the senior design project as a capstone course assimilates engineering design, analysis, and liberal education concepts such as cost/benefit analysis, environmental issues, and ethics. The capstone course presents an excellent opportunity to bring together the student's entire undergraduate program. The capstone experience, usually completed at the end of baccalaureate studies, integrates liberal learning with specialized knowledge. Each capstone emphasizes sharing, synthesis of ideas and critical, informed reflection as significant precursors to action. Student initiative in defining and investigating problems or projects is encouraged.

LIBERAL EDUCATION & ENGINEERING TECHNOLOGY

Liberal education has found a significant base in most baccalaureate engineering technology programs [4-11]. Traditionally, engineering technology has focused on troubleshooting and helping engineers design products. Companies recognize the importance of knowledge of non-engineering skills such as writing, speaking and effective communication, as well as ethics, and environmental consciousness. It is important that the engineering technology curriculum incorporates various technical solutions and resolution of conflicts that extend beyond classical engineering analysis and design. Such problems often involve humanistic considerations that are not always addressed by a technical solution alone.

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 to several constraints. Engineering technology students are often not sure of the need for the liberal education component in a senior design course. Today most engineering technology students take communication, history, math, and science courses as part of their college experience; but traditionally this has not been the case. Engineering technology has customarily focused on technical subjects in a certain discipline. There was often considerable hesitation to include non-technical courses. The reluctance to add liberal education to engineering technology curriculum stems from the concern that there would be little room left for courses in the concentration.

It is important for today's engineer to ask why a product is designed, where is it produced-, and not just how to make it. In the fast changing business world, companies now are building more and more plants in other countries, due to legislation such as NAFTA. They also need help addressing environmental concerns.

By including liberal education as part of the senior design course, students begin to take into account all aspects of designing, manufacturing, and selling a product. At Miami University, students are encouraged to have an industrial sponsor for each senior design project. This helps student's see the value of their project to society. The company will require them to perform a cost/benefit analysis on their project, and defend the viability of their design to the company.

THE MIAMI PLAN

At Miami University, all students must complete courses identified as parts of the Miami Plan as well as courses in their major[1, 4-10.] The Miami Plan for liberal education is ambitious and complex. It took over ten years to develop. The plan emphasizes four foundation principles, thinking critically, engaging with other learners, understanding contexts, and reflecting and acting.

- 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].

In addition, the plan provides breadth through foundation courses, depth through a thematic sequence,and integration through a capstone experience.[6] These are not novel ideas in liberal education program design, but what makes the Miami plan unique is that it emphasizes varying forms of inquiry and pedagogy. Often schools allow students to get liberal education requirements "out of the way" in the first or second year. As a result of implementing the Miami plan, liberal education is integrated into the engineering technology curriculum all through four years..

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, Appendix B).

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).

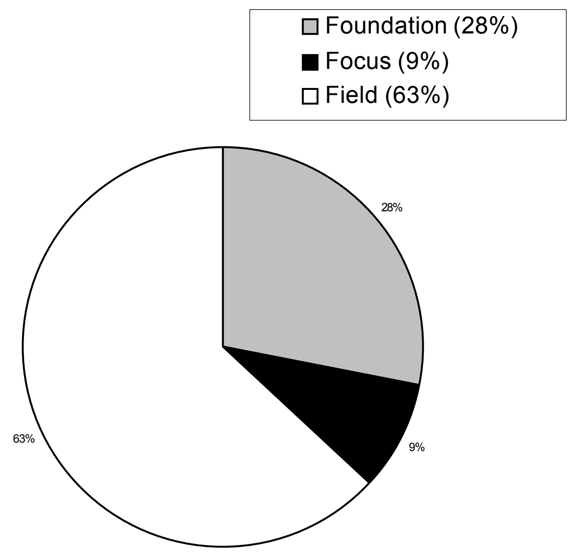

Figure.1: Distribution of course work

BASIC ELEMENTS OF THE SENIOR DESIGN PROJECT COURSE

In 1996, the department of Engineering Technology at Miami University, OH, developed a capstone course entitled 'Senior Design Project' in its Electromechanical Engineering Technology concentration. Engineering technology senior design project course sequence consists of two-semester long courses: ENT 497 and ENT 498. The students conduct major open-ended research and design projects utilizing their knowledge and skills acquired in earlier course work, work in teams, and incorporate engineering standards and real world constraints such as economical and social factors, marketability, ergonomics, safety, aesthetics and ethics into the project.

The fundamental elements of the design process are considered in this course through continuous interaction with faculty and bi-weekly seminars by outside professionals. The seminar topics include Miami Plan, ethics, cost analysis, liberal education component, U.S. patents, and design alternatives.

Students and the faculty meet regularly to discuss the status of the project. 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. These minutes are kept in a weekly journal. The faculty mentor uses the weekly journal to find out each student's participation in the project, which weighs 10% of total grade.

Design projects include the establishment of objectives and design criteria, procedural synthesis, engineering 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 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, Appendix B) 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.

The following assessment tools are used in the course by the instructors to facilitate student evaluation:

- Presentation Evaluation (a panel of judges evaluate student projects and presentation at the end of each semester) (Appendix-B)
- Liberal Education Survey (Appendix-C)

The assessment tools used by the course instructors to assess the success of the course:

- Student Evaluation (divisional student evaluation done at the end of the course)
- Two Minute Survey (usually done after each guest speaker)

I. Critical Thinking in Liberal Education

All senior design projects require a component of engineering analysis. Critical thinking in engineering technology is most often 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. For example last year 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. 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 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.

II. Engaging With Other Learners

Design teams are required to meet at least once a week outside of class, and keep the meeting minutes in a journal. The instructor regularly reviews the journal to evaluate how well the projects are progressing and students are working together. Communication problem are quickly identified and resolved. All students within a design team are strongly encouraged to contribute equally. To facilitate this teams are kept to a maximum number of three to include electrical as well as mechanical majors.

For two consecutive years, our senior design teams have chosen F.I.R.S.T. Robotics competition as their senior design project. In this project the senior design teams had an opportunity to engage and work with high school students, and engineers from industry to produce the final design, a robot .In the first semester, students are involved in fund raising, forming the groups, training the high school students on how to operate lathe, and machining etc and teaching computer software. The second semester, the design teams with the high school students, and engineers, design and construct a robot and participate in FIRST robotic competition. 200-2001, the team is placed first in the region and runner up nationally. 2001-2001, the team is placed first in the region and third nationally. This year the team is aiming at first national place. The ability to work so well together in a short time frame is tribute to the communication skills of Miami students.

III. Understanding Contexts

Rather than rush to build the project, students must first create a timetable for completing the project. Creating objectives and 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 design teams envision and possibly predict the outcomes of their design projects.

The central focus of each project 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. Students see the context that the project will be used in, not just the engineering analysis. Rather than rush to build the project, students must first create a timetable for completing the project. Creating objectives and planning are the focus in the early part of ENT 497. Later, literature research and brain storming sessions help the student to consider all aspects of the project. Feasibility studies help design teams envision and possibly predict the outcomes of their design projects. The engineering design process, which can be viewed as a particular type of problem solving, is an orderly, systematic approach involving iteration and decision making at each step. There are ten steps involved in this model. Design teams are encouraged to follow these steps all through the project. Though design alternatives is a part of engineering design process, a separate session is held to emphasize decision making capability in design teams. Design teams make up alternative approaches to their design needs, and decide the best solution.

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. As mentioned earlier, guest speakers are scheduled during the first semester of the academic year. Attendance is mandatory. Some of the guest speakers are members of industrial advisory council. Speaker topics are partly determined from the feed back of the members of this council. Some of the guest speakers conduct two-minute surveys after the lecture. An example of a question from an ethics survey is given below.
Q: What was the most useful or meaningful thing(s) you learned?
A samples of answers from students is given below:

1) " I learned about due care in product design and manufacturing. I knew about liability but did not know about magnitude"
2) "The true purpose of engineering is not quality/ productivity of the product (though those are important) but it is the safety of the user/consumer"
3) "A failure in design is not necessarily a bad situation. Failures drive innovation."

Engineering technology curriculum does not have a course on cost analysis. Design teams are given an opportunity to learn and develop a simple cost estimation project of constructing a bridge during the cost analysis lecture. It is mandatory to add the cost analysis of their projects in the proposal.

Reflecting and Acting

Reflecting and Acting is demonstrated by requiring students to think about 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 guidelines to write the reflective essay are in Appendix A. Shown below are student comments from selected Reflective Essays.

- "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. Some of the professors from University of Cincinnati (UC) are invited to judge our senior design projects. Some of our professors are invited to evaluate their senior design presentations.

Input from industrial representatives and the other colleges helped us identify and act upon suggestions for improvement. Diversity among the judges is implemented as result of a suggestion. Today the judge list consists of professors from academia (statistics, mechanical and electrical), and industrial representatives (A.K steel, Hamilton Caster, GE and UBE automotive, SOS, Sensotec, VP Engineering). Another 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.

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. As stated earlier, the Reflective Essay and weekly journal entries help students observe their contribution to the course. This data is combined with judges' comments, professor comments, and student evaluations to provide feedback.

Evaluation of Liberal Education Components

The assessment tools used in the course are an aid to the faculty and students. Students, faculty and judges evaluations help ensure that ENT 497/498 is meeting the needs of the department and Liberal Education. The Liberal Education survey is developed to help the faculty determine if students understand and appreciate this component of the course in their perception. The Liberal Education Survey began in the 2000-2001 school year. Appendix-C contains the questions asked and a summary of the responses.

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 2000-2001, the response was 3.31, but in 2001-2002, the response was 2.97. 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

Historically engineering programs have included few liberal education courses. Their senior design experience focused purely on mathematical design and analysis. It has been a challenge for most of the faculty to incorporate liberal education concepts into engineering education programs. 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 to develop the course. The guidance provided by the LEC (Liberal Education Council at Miami University) helped the department achieve its goals of providing a well-rounded education through the Senior Design Course. Some of the faculty has attended lectures to improve their understanding and appreciation of liberal education.

Overall, the department believes it has successfully integrated the Miami plan for Liberal Education into the course. The course coordinator uses the feedback from the faculty mentors of the design teams to continuously improve the course. For example, the faculty is looking into improving the liberal component assessment area.

References

1. "The Miami Bulletin of program requirements and course descriptions, 2000-2002"
2. Horenstein.M and Ruane.M. "Teaching social awareness through the senior capstone design experience", Proc. Of 32nd ASEE/IEEE Frontiers in Education Conference, Nov 6-9, 2002, Boston, MA.
3. Dyrud.M " Ethics Education for the third millennium", Proc. Of ASEE annual conference, June 1999

4. Mark Van Doren; “Liberal Education”, New York, 1943, The Columbia University Press
5. AAC& U, Board approved statement on Liberal learning, published by AAC&U, www.aacu.edu.org/issues/liberaleducation
6. Carol Geary Schneider and Robert Shoenberg. “Contemporary understanding of Liberal education,” Published by AAC&U, 1998
7. “Challenge of connecting learning; Liberal learning and the arts and sciences major”, Vol 1, published by AAC&U, 1991
8. Holstein E J, Mcgrath E J, “Liberal Education and Engineering”, publications of institute of higher education, 1960
9. Boyer. E., et al, “Integrity in the college curriculum”, published by the Association of American Colleges, 1985
10. Narayan M, “Liberal education component”, 22nd Annual Lilly conference, Nov, 2002
11. Ferren A S, Margolin C, “Review of Liberal education at Miami University”, April 25, 2000, www.miami.mu.ohio.edu/provost/reports.cfm

12. 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-I
Foundation and Focus Semester Hours

Foundation Courses (36 Sem. Hrs.)		
English (6 hours)	Fine Arts (3 hours)	Humanities (6 hours)
Social Sciences (3 hours)	US cultures (3 hours)	World Cultures (3 hours)
Biological Sciences (3 hours)	Physical Sciences (6 hours)	Mathematics/Technology/Reasoning (3 hours)
THEMATIC SEQUENCE (9 hours): Typically a Three Course Sequence outside the department of major	CAPSTONE EXPERIENCE (3 hours): Integrates Liberal Learning with specialized knowledge	

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 & Recommendations.
(2 points) References
(7 points) Appendices
(15 points) Quality of Participation
(30 points) Presentation
(15 points) Use of Engineering Analysis
(30 points)

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