

## An Engineering Technology Capstone Course Which Integrates Theory, Design, and Construction in an Open-Ended Project

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### Abstract

The culminating experience in many engineering technology programs is typically a one or two-semester capstone design experience. The underlying premise for this type of senior design course is that at the submission of the final report and/or oral presentation, the students will graduate and be well prepared to enter the workforce. Upon entrance into the technical workforce, the students will be required by their employers to work in an interdisciplinary environment, completing a wide range of tasks, and sharing the results with fellow employees and management. Since the capstone experience serves as the bridge from the role of the student to that of the employee, this culminating experience must prepare the students for this change. The capstone experiences in many engineering technology programs are designed to allow the students to develop open-ended designs in many of the areas within the school's technology programs.

The Engineering Technology programs at Northern Illinois University have developed a model for a two-semester interdisciplinary capstone experience which integrates design, theory, and construction into the completion of an open-ended project. In addition, student teams are required to demonstrate that each project incorporates a subset of knowledge from their major course work. The projects are tracked through a tiered faculty input system, where students report to both a main faculty advisor and a course, or project, director. Each design team is given a minimal budget, and therefore, the teams must interface with both product suppliers and sponsoring companies to obtain parts and meet the project goals and timelines. Both semesters of this capstone experience are considered writing and oral presentation intensive, where the design teams are required to present the project findings, both in oral and written forms numerous times during each semester. Through input from the departmental industrial advisory boards, the faculty members involved are able to develop projects which allow the student teams to work on current topics or topics which lend themselves to industrial settings.

### Introduction

The concept of including a senior design project or experience within an Engineering Technology curriculum is not a novel idea<sup>[1,2,3,4]</sup>. In fact most 4-year engineering technology curricula include a one or two semester senior design project as a culminating experience. The novel idea behind this work is the development of this culminating engineering technology experience which encompasses many desirable programmatic aspects including

theory, design, and construction into an open-ended project. The engineering technology faculty at Northern Illinois University have developed two applied engineering programs, Electrical Engineering Technology and Manufacturing Engineering Technology. Within the development of these two programs, it was decided that students must be introduced to both applications and the underlying theory in the various subjects areas covered. As the technology name applies, the curriculum must introduce the students to the hands-on skills that they will also need upon graduation. Therefore, since the programs have been designed to include the concepts of theory, design, and application, then these must be the basis for the senior capstone experience for the students as well.

In order to develop a unique capstone experience, it was determined through ABET concerns and faculty goals that the course should span two continuous semesters. The goals of this course developed by the chair and engineering technology faculty included,

- Interdisciplinary projects
- Preparation of initial proposals
- Development of significant theory component
- Presentation of designs and construction of design
- Presentation of social impact and ethical considerations
- Development of projects which are relatively inclusive of skills learned in program

In addition to the department faculty, the Departmental Manufacturing and Electrical Industrial Advisory Boards were asked to assist in developing this important course. As the advisory board discussions progressed, some important additional goals started to emerge like requiring the student teams to make many presentations and reports as well as the need to have some industry interaction, application of economic analysis, and goal setting and tracking by all of the teams.

Once the basic goals were developed, the course had to be structured, and the author, as department chair, was placed in charge of this coordinating task. One of the main goals for this course was to introduce the senior engineering technology students to a setting which was somewhat reminiscent of the industrial setting that they will be entering after graduation. To achieve this, it was decided that there will be one faculty member (the author) serving as project manager to oversee all of the projects. The duties of the project manager included tracking project progress, forming design teams, and project leadership, as well as overseeing costs and material purchases. To oversee intermediate aspects of the projects, each team was assigned a faculty project advisor, who met with the teams semi-weekly to provide input and make sure that the teams were not deviating from the desired paths, as well as to track progress and give the teams any needed push. The faculty advisors also provide a key role in the grading of the projects.

The final piece which was needed for the development of this course was a model for the typical project. Based upon discussions between all of the ET faculty members, it was decided that each project should include the following components,

- Clear components from Manufacturing and Electrical Engineering Technology

- Difficulty level must be appropriate
- Must include information from various courses of study in student program
- Groups cannot just construct project
- Project must have well defined theory component
- Projects must have some industry related component
- Projects must have an ability to perform research
- Projects should be cost effective, unless support by company

One of the other underlying premises of this course development was that at the end of this class, the students will graduate (if all goes well with the project!!), and as such, some industry traits should be brought into the project. One industry occurrence was included in the administration hierarchy, where the teams dealt with the project manager and project advisor. The other industry occurrence was the fact that in industry, employees do not get to choose projects or teammates. As such, the project manager selects the team composition and project on which they work. This group and project selection assists the project manager since student teams will generally choose friends for their teammates and projects in which there is more of a construction component and much less of a research and theory component. Since the projects are selected by the project manager, with great input from the faculty, it is certain that there will be more inclusion of curricular topics within the year-long work.

### **Engineering Technology Curricula**

In order to assign projects and assemble the design teams, it is important to examine the technical components of the programs offered at NIU. There are currently two programs which are included in this course, Manufacturing Engineering Technology and Electrical Engineering Technology. Within these two programs, there is a common core of Mathematics, Science, and English skills. All ET students are required to take the following fundamental courses, which are used as prerequisites for the upper level technology coursework.

|                              |  |
|------------------------------|--|
| Engl 103 - Rhet and Comp I   | Math 230 – Calculus II   |
| Engl 104 – Rhet and Comp II  | Stat 208 – Basic Statistics                                    |
| Engl 308 - Technical Writing | Phys 250 – Physics I   |
| Coms 100 - Fund of Oral Comm | Chem 110 - Gen Chemistry I                                     |
| Math 155 – Trigonometry      | Computer Programming – C++ for EET and Visual<br>Basic for MET |
| Math 229 – Calculus I        |  |

The projects which are included in this senior projects course must allow the student design teams to include various information which has been learned through their program of study. To understand the development and choices of the projects, it is useful to understand the composition of each of the programs. The course work in the MET program includes the following courses:

|   |                                  |
|---|----------------------------------|
| Tech175 - Electricity and Electrical Fund | Tech 211 – Computer-Aided-Design |
| Tech 210 - Engineering Mechanics          | Tech 212 – Engineering Dynamics  |

Tech 262 – Machine Production Processes  
Tech 265 - Basic Manufacturing Processes  
Tech 312 - Design, Dim, and Tolerancing  
Tech 326 - Fluid Power  
Tech 342 – Manuf Component Design  
Tech 362 – Numerical Control Systems  
Tech 369 – Strength of Materials  
Tech 391 – Indust Quality Control

Tech 393 - Structure and Prop of Matls  
Tech 420 - Comp Integrated Manuf  
Tech 423 - Automated Manufacturing Sys  
Tech 425 – Prog. Elect Controllers  
Tech 443 – Engineering Economy  
Tech 477 - Senior Design I  
Tech 478 – Senior Design II

The course work in the EET program includes the following courses:

Tech 211 – Computer-Aided-Design  
Tech 175 - Electricity and Electrical Fund  
Tech 270 – Elect Fund and Circuit Anal I  
Tech 271 – Elect Fund and Circuit Anal II  
Tech 265 - Basic Manufacturing Processes  
Tech 276 – Electronics I  
Tech 277 – Digital Logic Design  
Tech 375 – Control Systems

Tech 376 - Electronics II  
Tech 377 – Microproc and Interfacing  
Tech 378 – Communications Sys Design  
Tech 379 – Electric Mach & Transformers  
Tech 443 – Engineering Economy  
Tech 476 – Industrial Control Electronics  
Tech 477 - Senior Design I  
Tech 478 – Senior Design II

In general, most of the projects undertaken include some aspect of control, either through PLC or micro-controller. In addition, most projects include various components of circuits and strength of materials. Due to this balance of needed knowledge between manufacturing and electronics, most projects lent themselves to the interdisciplinary goals.

### **Course goals and ABET**

The idea of industry involvement within the projects has been developed and redeveloped<sup>[5,6]</sup>. During the 1999/2000 school year, it was decided that the inclusion of industry within the project was a positive feature<sup>[7]</sup>. However, at that point, the industries were supplying ideas for projects and either the capital or parts needed to complete the projects, and there was little or no discussions between the company and group. After completing many of these projects, the sponsoring companies were disappointed with the outcomes and lack of a finished professional product, for which the companies paid little. After much discussion, it was decided that faculty members can develop needed industrial-type projects and the students can complete them in-house with a very limited funding. This solution was working well until the department was approached by several large companies like G.E. and Caterpillar. The concept of industry sponsorship was brought back under the rule that the companies have to interact with the students on a regular basis, working with the faculty advisor. This solution has worked well as is currently being expanded.

This course also provides the students with additional material. Over the year-long time frame, the weekly lectures which are held in this class included the following topics.

- Application of basic accounting and economic analysis
- Project management techniques and ethical consideration

- Interaction as an employee with both co-workers and supervisors
- Interviewing and resume writing skills
- Intellectual property rights
- Effective presentation skills
- Interacting with teammates in the group environment

In most cases, external experts were invited to provide hour-long lectures on the above topics.

This past year, the Manufacturing Engineering Technology and Electrical Engineering Technology programs hosted the initial ABET accreditation visit. The capstone course presented was prominently displayed as part of the accreditation process. This course encompasses most of the ABET learning outcomes for the program. The following table details the course objectives and their relation to the ABET outcomes.

| <b>Learning Objectives</b>  | <b>Relational ABET Learning Outcomes</b> |
|---|--|
| Ability to identify problem and determine path for solution   | A, B, C, D, and F                        |
| Ability to interact with supervisors to discuss project details   | D, E, F, G, H, J, and O                  |
| Ability to present designs and systems developed  | D, G, and H                              |
| Ability to function on a design team  | E, G, H, J, and K                        |
| Ability to perform integrated design tasks utilizing base engineering technology knowledge                  | A, B, C, F, I, M, and N                  |
| Ability to apply ethics and quality concepts to design tasks  | J, K, and L                              |
| Ability to apply engineering economy concepts and societal issues to design tasks                           | B, D, F, J, K, and L                     |
| Ability to apply laboratory skills to an open ended design project and selection and purchase of components | A, B, C, D, F, and N                     |
| Understanding of research in project development and component determination                                | A, I, J, and K                           |

As a result of the student work done in this capstone project course, and in all of the other programmatic courses, the programs were received very favorably by the accreditation team.

### **Senior Projects Course Grading**

During the initial semester of this course, the design teams are formed and presented with the premise of an open-ended project. During this semester, each team develops a series of designs, including the benefits and draw-backs of these designs. The teams must submit progress reports detailing progress on the design process. During this semester, the teams research the various components needed for the project as well as examining the theory behind the designs. The design teams must then narrow the design choices to what the team perceives is the “best” choice. The final design is then presented in both detailed written and oral form. During the final semester of the course, the teams are involved in both design and construction of the project. At the end of the final semester, the teams must submit a detailed final report, and make a detailed oral presentation of their final design. Both the final oral presentation and written report *must* include the following components,

- Literature search
- Background Theory
- Analysis and Design - Data, calculations, figures, bill-of-materials
- Time Line
- Economic (cost) analysis
- Ethical Considerations
- Conclusion/results
- Group interaction
- Group/advisor meeting summary
- Bibliography
- Appendices

each of the above topics forms a percentage of the team grade. The final requirement for the project groups is the demonstration of the completed working project to the project manager and advisor.

### **Projects Completed – Integration of Theory, Design, and Construction**

Based upon the goals and outcomes which have been developed for the NIU Engineering Technology senior capstone course, the following details the research, design, and construction tasks completed within a typical project. It should be noted that one of the initial goals and outcomes of this course was the interdisciplinary aspects of manufacturing and electrical students working in teams. However, this project was completed by a group of four MET students. The project was supplied by a regional division of Caterpillar, and it represented an excellent opportunity to blend many aspects of the MET curriculum with a real-world industrial problem. The project arose from the need to apply 50# steel lugs to a steel wheel (figure 1).



Figure 1 – Lug attachments on compactor wheel

Currently, workers are lifting the lugs and securing them for the welding process. In this process, some workers injure themselves, and thus, a new method of assembly needed to be developed. The student team interacted well with the Caterpillar engineers, and they spent

many hours in the factory observing the current installation process. The design team developed 4-5 different designs which performed the required task. The team also made several presentations to Caterpillar engineers detailing the designs which were developed, resulting in one “best” design (figure 2). The team integrated the theoretical analysis to this design, examining various aspects from welds to material weights and cross-sections; the team modeled the lifting device using FEA (figure 3). Each component of the design was modeled using Solidworks and a complete series of construction drawings was developed in AutoCAD. This project required the team to utilize most of the required coursework in their program of study. In addition, they gained a more in-depth knowledge of subjects like FEA, strength of materials, fluid power, solid modeling, and controls, to name a few. Through this project, the design team interacted with both company engineers and component suppliers. Figure 4 shows the completed device. At the completion of this project, two members of the design team were offered interviews with Caterpillar, based upon the quality of work and effort on this project.

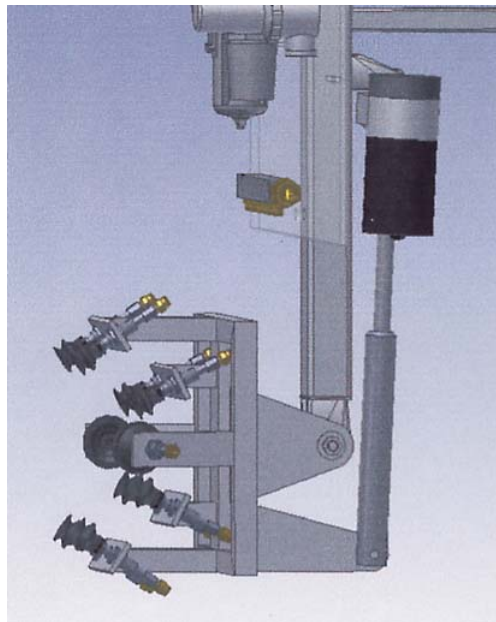


Figure 2 – Lug lifting design

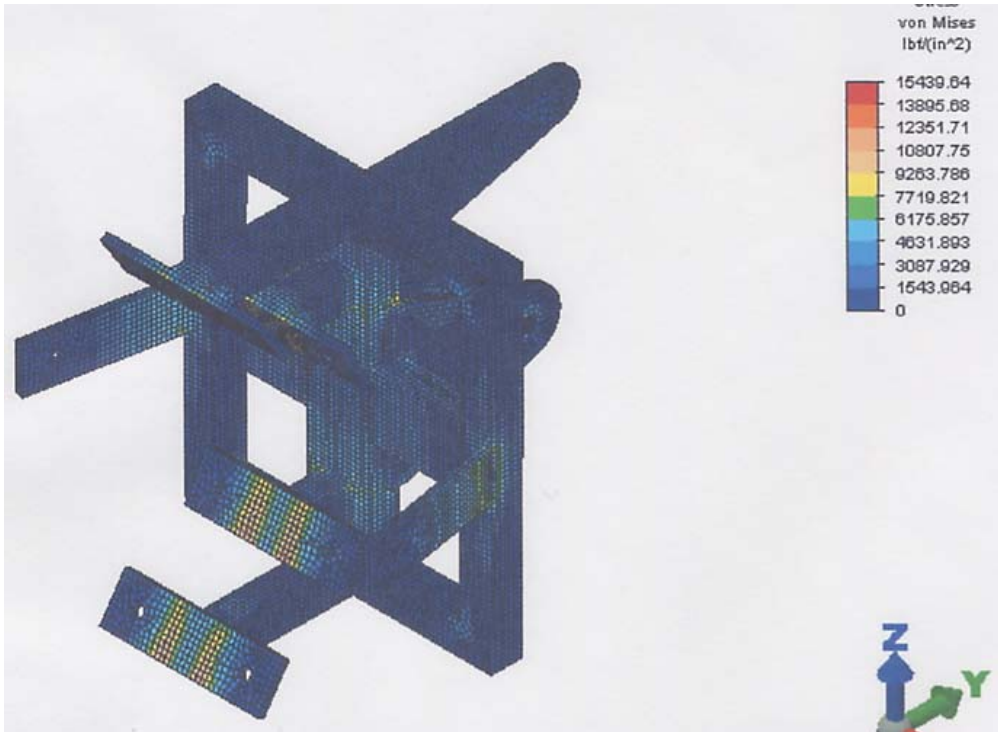


Figure 3 – FEA model of lug lifting device



Figure 4 – Completed lifting device



## Conclusion

The topic of culminating experiences within an engineering technology program is under continual discussion. Like the programs and course contents themselves, the goals and objectives of the important capstone course must also evolve over time. The Engineering Technology program at Northern Illinois University has developed a model for a two-semester interdisciplinary capstone experience which integrates design, theory, and construction into the completion of an open-ended project. The goals and objectives for this important course have been developed over the past few years by both faculty and industrial input. This capstone experience was developed to serve as a bridge from the role of the student to that of the employee, and it seeks to provide the students with an experience intended to tie together the education coursework into industrial-type project. Prior to the start of the projects, design teams are required to report on the research and theoretical background of the given projects. At all phases during the year-long course, the design teams are required to both prepare detailed oral presentations and written reports, with all of the designs and components documented. In hindsight, students have difficulty with the freedom which is given them, however, most groups find that the design process is both enjoyable and a learning process.

## References

1. Bullen, F., Sargison, J., and McCulloch, J. Developing multi-discipline design skills in undergraduates. Proceedings of the 2004 ASEE Annual Conference, Salt Lake City, Utah, 2004.
2. Hanlon, P.D., Goda, B.S., and Shay, L.A. Experience with Multidisciplinary Design Projects at the US Military Academy. Proceedings of the 2004 ASEE Annual Conference, Salt Lake City, Utah, 2004.
3. Idowu, P. A Strategy for Innovative Capstone Design Projects Proceedings of the 2004 ASEE Annual Conference, Salt Lake City, Utah, 2004.
4. Cornachione, H.S., Cornachione, M.A., and Vance, V.J. A Capstone Design Approach in Civil Engineering. Proceedings of the 2004 ASEE Annual Conference, Salt Lake City, Utah, 2004.
5. Crain, G.E. and Tull, M.P. A Capstone Course Targeting Industry Transition. Proceedings of the 2004 ASEE Annual Conference, Salt Lake City, Utah, 2004.
6. Rosentrater, K.A. Integrating Ethics, Design, and Service Learning in the Engineering Classroom, Proceedings of the 2004 ASEE IL/IN Sectional Conference, Peoria, Illinois, 2004.
7. Otieno, A. and Mirman, C.R. Engineering Technology Capstone Experience - An Industry Based Partnership. *International Journal of Modern Engineering*, Vol. 3, No. 2, Spring 2003.

## Biographical Information

CLIFFORD R. MIRMAN received his Ph.D. degree from the University of Illinois at Chicago in 1991. From 1991 until 1999, he was a faculty member in the Mechanical Engineering Department at Wilkes University's. He is currently the Chair of the Department of Technology at NIU. His research areas are CAD, Finite-Element-Analysis, and kinematics, both securing grants and writing publications. Dr. Mirman is actively involved in ASEE and SME.