Capstone Design Course –Evaluation of Outcomes and Senior Design Projects

Mohan Devgun
State University of New York College at Buffalo
Department of Engineering Technology
DEVGUNMS@BuffaloState.edu

David J. Kukulka
State University of New York College at Buffalo
Department of Engineering Technology
kukulkdj@BuffaloState.edu

Abstract

Students studying Mechanical Engineering Technology (MET) Program at the State University of New York College at Buffalo (BSC) are required to complete a senior design project. The Accreditation Board for Engineering and Technology (ABET) has developed a set of learning outcomes that are used to guide faculty in assessing the effectiveness of academic programs. The MET program at BSC uses the ABET criteria to assess student learning in the MET courses. These learning objectives help students understand the general skills and knowledge that they will demonstrate in order to complete the course. The senior design class at BSC is the class that verifies that our students have demonstrated proficiency in the various areas. Prior to entering the senior design course students must document their basic mechanical engineering technology skills by presenting a portfolio of work and they also must pass a comprehensive test.

After the students have been admitted to this course they put together a proposal that details the work that will take place in the senior project; then they need to present their project and have their design project accepted by a review board that consists of their professor, sponsors from industry and student representatives. Their industry-sponsored senior design project requires the student to participate in a team that designs, builds, tests, reports and evaluates their results. This paper details the process that takes place in order to ensure that our graduates have those skills.

Introduction

In recent years the makeup and background of students in most engineering programs has changed dramatically. Programs are very diverse in both student motivation and background. In the 1960's and 70's the major deviation from the traditional undergraduate student was being a female in an engineering program. Recently a more diverse student body exists; individuals from various races and countries, some with learning or physical disabilities,

traditional students that work part time, nontraditional students (older individuals, supporting a family, working full time - going to school part time), single parents, students transferring from other institutions, students seeking a second degree, and the list goes on. In addition, the economic disparity between students is greater than at any other time in the past. While it is said that outside factors do not affect the grade that a student receives in a course, these factors may certainly affect the outcomes of some students. In some situations a student just does enough work to get through a course and does not master the subject or occasionally a course requirement may be softened because of some unusual circumstance.

Employers require our graduates to be better prepared in more diverse areas. As a result institutions must somehow ensure that their graduates are at least capable of several fundamental skills; therefore it is necessary to implement and administer the rigorous requirements in the capstone senior design course in the Mechanical Engineering Technology Program at Buffalo State College. Additionally it is also important to effectively evaluate the performance students in the senior design class.

College enrollment is growing and the make-up of a college classroom is changing with more students attending college in a nontraditional manner. The diversity of students in the MET program at BSC (see Table 1) is similar to many institutions. It is made up of males and females, African Americans, Hispanic Americans, Native Americans, Asian Americans and foreigners. However, the typical individual enrolled in our program is a Caucasian; employed (working full or part time in an industrial position); male student; and a resident in our geographic area. Many of our students are transfer students that may have a college degree. Almost any course on a student's transcript can be transferred from a previously attended institution. Students currently in our department have transferred as much as two years of college credit, from more than fifty different institutions. Since transfer credit is often given, there is often the question of how well the student was prepared at the college the transfer course was taken. While a student may have received credit for a course in thermodynamics or fluid mechanics taken at another institution, it is important to know what was covered and in what depth? Faced with this mix, the main concern that we are facing is how to ensure that the students that are being sent into industry are truly prepared and ready to contribute.

Table 1. Student Ethnicity Data at Buffalo State College

Native	Asian	Black/African American	Hispanic/ Latino	Multi-Race	Pacific Islander	White	Unknown
0.3%	2.5%	26.2%	11.9%	3.4%	0.2%	55.3%	0.2%

When a degree is granted to a student, it is important that the student be familiar with several important principles from each course. A prerequisite test is given for each required

mechanical engineering technology class taken at Buffalo State College. More importantly, the prerequisite test is important in order to certify to potential employers that our graduates possess certain basic skills. Additionally a comprehensive diagnostic test is taken by seniors before they are allowed to take the senior capstone course. Many institutions have a senior design course; each program has unique requirements. For many institutions the course is mainly a design project that is completed by a senior during the last semester that the student attends school; few programs have an industrially based senior design project.

Flores et al. [1] describes problems associated with the completion of senior design projects and their efforts to address those problems through the use of systems engineering techniques. This has led to more qualitative, competitive and successful projects. Rahmat et al. [2] summaries the design of a capstone project requirements in order to provide learning experiences which will develop the students ability to satisfying learning outcomes in their structural engineering program. Agboola et al. [3] describes assessment methods for their capstone course. Parker et al. [4] discussed Alabama's program. At Alabama, students participate in a competitive design project during the first part of the first course and during the rest of that course, as well as the second course, the students focus on a single, external, industry-sponsored project. Bekkala et al. [5] describes their senior design courses in electrical engineering. McDonald et al. [6] presents the details of using a multidisciplinary design team to work on a senior design projects at Lake Superior State University. This is an excellent approach; however the course is very difficult to coordinate.

The Accreditation Board for Engineering Technology (ABET) currently requires a capstone design component. The senior design course is probably the most critical course in the student's education. It requires a considerable time commitment by students, sponsors and instructors. The course at Buffalo State College provides mechanical majors with an interdisciplinary creative design and problem solving experience. The ability of the student to effectively manage a project; and interact with the other team members on projects that stretch over several disciplines are important lessons to learn early in a student's career. Exposure to these concepts will better prepare our students for success early in their careers and help employed students to advance to new positions. Some students become very interested in the project and go well beyond the requirements of the project.

At Buffalo State College, a design team is responsible for the senior project from conception to completion. There are also additional requirements in the course that ensures a well prepared graduate. The requirement most talked aboutby the students is the "diagnostic exam". In order to sit for the exam, the student must first provide a detailed portfolio of student work that demonstrates their experience in the various required courses. When that requirement is satisfied, the student is allowed to sit for the exam; this typically takes place the semester before the senior project is assigned. Exam content varies from year to year and includes multiple choice and long hand solution problems. The test is open book, with questions coming from various required courses in the curriculum. A student needs to pass (> 60%) the diagnostic test before being allowed to register for the capstone course. If the test isn't passed, the student must attempt to take the exam the following semester. The next major task is the design project. This takes place in local industry; students need to report

their progress weekly to the class. Additionally, there are several minor design projects (i.e. develop a web site that is used to report the results of the project, a larger team project that involves multiple groups, etc.). The culminating senior course changes slightly each year, but utilizes the same basic requirements.

Content of the senior design project includes engineering principles that are covered in the various core MET courses. A partial list of the course topics include: design process, design teams, engineering management, engineering ethics, professionalism, project management, failure analysis, optimization in design, concept generation, financial considerations, concept evaluation, product design, product specification, product generation, product evaluation, proposal generation, final project assembly and oral/written presentation. Design creativity is emphasized, with imagination and learning from mistakes being encouraged.

The senior project requires a proposal, design, prototype, evaluation and final report. This process is completed by a team of three or four students over one semester. Results are presented in a detailed, with a final written report. There is a certain amount of group work involved in the senior design course; however the weak student cannot hide in the group. All group members are required to be part of the group's oral and written presentations. Upon completing this course, students perform a self-evaluation of goals achieved and discuss the difficulties of attaining the goals that were set forth at the start of the project. Professors and sponsors evaluate each student on how well they have achieved various skill areas. Additional student members evaluate other team members.

Evaluation - Diagnostic Exam

The comprehensive exam evaluates the students' knowledge of the required courses in the curriculum. A student may have taken these courses at BSC or another institution. The topics are fundamental in nature; however because of the nature of the test and the breath of the subject areas, it makes for a very difficult evaluation. The students that do not pass the exam are not allowed to register for the senior design class and they are required to take the course the next time it is offered. As one can imagine this adds even more stress to the taking and evaluation of this course. The evaluation is a written test with several areas tested during the session. Question content comes from instructors that teach the courses at BSC; as well as old test questions from EIT review books. Graded tests are returned to the students for review (tests are kept on file by the instructor), and correct solutions are posted for limited viewing (during class time). If they did not pass the test they must take another test during the next semester.

Senior Design Project

After passing the exam the students are allowed to register for the senior capstone course and the students can start work on their senior design project. Initially students will spend some time developing a proposal that outlines the work they hope to accomplish during the project.

This proposal is presented to an evaluation board is made up of the class professor, student members and representatives from the sponsoring organizations. Initially the students must present their work to the board, with the board members ensuring that proper procedures are being followed. Each board member evaluates the work and writes comments. Evaluations are given to the students after their presentations. If the board requires additional work, the group would have to resubmit their proposal before they are allowed to proceed to the sponsor submittal stage. The students must answer to this board and ultimately to the sponsor.This proposal is the agreement between the student group and the sponsor on what is required by the group, when it will be delivered and the various responsibilities on the project. A good deal of work is performed during the proposal stage; this virtually eliminates any problems in determining when the project is completed. Each group is required to make a short weekly presentation to the board and the presentation is evaluated using a rating system, with evaluation results being returned to the group. A mid-project report and final report similar to the initial proposal is also required. The final report is a summary of results and includes a recommendation for future work. Periodic videotaping of the oral presentations is made and the video used to help students to improve their presentation style. The final report is very easy to put together since it is simply an assembly of all their previous work. Table 2 provides titles and some objectives of typical projects.

Table 2. MET Capstone Projects at Buffalo State College

Sponsor	**Project Title**	**Objective**
Praxair	*Gas Manifold Component Redesign*	Redesigning three components of the gas generation system
Cameron International	*Heat Exchanger Design*	Feasibility study on the development of an aftermarket heat exchanger
RP Adams	*Steam Inlet Housing For External Backwash*	Design a system so that when a predetermined differential pressure is reached the unit goes into backwash mode and cleans each tube until the differential pressure is back down to normal operating pressure.
FS-Elliott Co.	*Centrifugal Compressors: Inlet Throttle Valve*	Redesign compressor inlet throttling valve.
Fisher Price	*Dynamic Stability Testing for Children's' Electric Powered Vehicles*	Design of test station to perform a dynamic stability test on a child's electric power vehicle.
FS-Elliott Co.	*Hirth Attachment Coupling*	Use a Hirth Attachment Coupling to attach the main drive gear of an air compressor to the smaller pinion gear in order to power an

		air compressor.
Xylem Inc.	*Tapping Machine Redesign*	Objectives of this project were to create an easier, more efficient way to tap the aluminum carry and guide bar extrusions for Xylem's casketed plate and frame heat exchangers and make this process safe, fast, and less expensive.

Summary

As one can imagine this course is not a course that the students initially think they would like. However it does evolve into certainly the course that students have the most memories of; and for many students their most meaningful course. The senior project is well received by all sponsoring industrial members not only because of the exceptional work that our students produce, but more importantly it allows many of the companies to evaluate potential new employees. Many nontraditional graduates either change positions or receive promotions as a result of their project. All in all, the course is a very demanding and a very satisfying course to teach. Some written comments from recent self-evaluations performed by graduates regarding the senior design course include:

• "I think that this was the best class in the program.... The objectives of the course were clearly defined at the start and seemed very consistent with how our design project evolved. The class format emphasized the real world rather than a traditional class.... I think that the hands-on project was definitely an important exercise in preparing oneself for the real world of engineering."
• "I felt the way that everyone in the class was forced to get up in front of the class every week and give a small presentation is one of the greatest things that this class can offer to an undergraduate student getting ready to go out into the work force."
• "Truly this course has been the greatest challenge for me. To balance work, school, community commitments while at the same time forget the family and home responsibilities. I speak as a part time student with these sacrifices but would hate to experience this (senior design course) as a traditional student taking a full course load"
• "Although challenging, time consuming, and all encompassing, this class was a great learning experience. The refresh of what was learned in previous years via the diagnostic exam is a great way to evaluate a student and a great way for a student to evaluate him/herself."
•".... I enjoyed my experiences in this class. From the diagnostic exam to the senior design project this class gave the chance to experience a large portion of what it is like to be an engineer.... I believe that the diagnostic exam was a very important part of this class. It forced me to review all the subjects that I have taken and may have forgotten about...I don't believe that the exam was all that difficult, it was just a lot of material to cover."

•"It (the senior design course) gives the student experience and confidence in the acquired education."

One comment from a first generation college student that was important to receive went on to say..."I know it seems that I got off to a bad start.....This semester has been a great learning experience and it is very clear that this is the beginning of a much larger experience..." The same student when discussing the evaluation of the final project by his peers: "... they even gave me a complement on the final product. That was a big reward. I had never received that before. Now that I know what it involves, I know more of what is expected and of what to expect. I am graduating this semester and I'm looking forward to a better life of hard work, accomplishments and respect."

As can be seen from the comments, this course has offered a little something for everyone. Not every student liked every portion of the course; however the course provides a challenging environment that upon completion produces a well-qualified student. BSC students are well received in industry and sponsoring companies are eager to participate in the program.

References

[1] J. A. Flores, O. H. Salcedo, R. Pineda, P. Nava, 2012, "Senior Project Design Success and Quality: A Systems Engineering Approach", Procedia Computer Science, Vol. 8, pp 452-460.

[2] R. Rahmat, K. Rashid, Z. Chik, W. Badaruzzaman, 2012, "Capstone project to satisfy EAC criteria", Procedia - Social and Behavioral Sciences, Vol. 60, pp 615 – 619.

[3] O. Agboola, M. Hashemipour, F. Egelioglu, U. Atikol, H.Hacisevki, 2012, "Assessing a decade old capstone senior projects through ABET accreditation program outcomes", Procedia - Social and Behavioral Sciences, Vol. 47, pp 12- 125.

[4] J. Parker, C. Midkif, and S. Kavanaugh, 1996, "Capstone senior design at the University of Alabama", Proceedings of the 1996 Annual Conference on Frontier in Education, Part 1, IEEE, Piscataway, NJ, pp.258-262.

[5] A.H. Bekkala, R.A. Higgins and S. Lekhakul, 1995, "Senior design projects in electrical and manufacturing engineering", Proceedings of the 1995 Annual ASEE Conference. Part 1, ASEE, Washington, DC, pp 378-384.

[6] D. McDonald, J. Devaprasad, P. Duesing, A. Mahajn, M. Qatu and M. Walworth, 1996, "Re-engineering the senior design experience with industry-sponsored multidisciplinary team projects", Proceedings of the 1996 Annual Conference on Frontier in Education, Part 3, IEEE, Piscataway, NJ, pp.1313-1316.

Biographies

Mohan Devgun is currently a Professor and department head for Engineering Technology Department at State University of New York College at Buffalo.

David J. Kukulka, is a Professor at the State University of New York College at Buffalo and the coordinator of the Mechanical Engineering Technology Program. Dr Kukulka is a registered Professional Engineer in the State of New York and is a consultant for many local and national companies.