Reassessing Capstone Courses to Support TC2K Program Accreditation

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Abstract: An assessment and evaluation of an outcomes-based two-semester undergraduate capstone design course in our electrical and computer technology curriculum and its value for supporting TAC/ABET, TC2K accreditation was conducted. The discussion topics include course objectives and outcomes, description of project design phases, assessment and evaluation methods, and a summary of study results over two years of implementation.

I. Introduction

Recent efforts to improve quality and accountability in engineering technology education have concentrated on outcome-based preparation and continuous quality improvement. The Technology Accreditation Commission of the Accreditation Board of Engineering and Technology (TAC/ABET) addresses new philosophy including enabling program differentiation, outcome-based preparation, comprehensible and achievable criteria, and educational objectives. New emphasis is placed on the practice of continuous quality improvement, knowledge required for entry into the profession; and linking student, faculty, facilities, institutional support, and financial resource issues to program objectives [1].

The Electrical and Computer Engineering Technology (ECET) has been continuously accredited for over 30 years, was last accredited in 1998, and is preparing for a reaccreditation visit in 2004 during the first year of exclusive use of the TC2K criteria. While in the process of refining our curriculum as outcome-based, the authors found that the importance of capstone or integrating experiences is also recognized by ABET and highlighted in the Self-Study Questionnaire [1]. The Senior Design Project courses have been in place since 1968 and it was concluded in [2] and [3] that the course provides students with the best possible preparation in terms of current technical knowledge, techniques, skills, and written/oral reports for industry employment.

During spring 2000, the authors redesigned the senior design project course using an outcome-based approach that focuses primarily on criteria and procedures for serving as part of requirements for assessment of student achievement. The following terms specified in [6] and [7] are referenced throughout the course design, implementation, and evaluation:

- Program Educational Objectives – statements that describe the expected accomplishments of graduates during the first few years after graduation.
- Program Outcomes – statements that describe what students are expected to know and able to do by the time of graduation. These relate to the skill, knowledge and behaviors that students acquire in their matriculation through the program.
- Performance Criteria – specific, measurable statements identifying the performance(s) required to meet the outcome: confirmable through evidence.
- Assessment – one process that identify, collect, use and prepare data that can be used to evaluate achievement.
- Evaluation – process of reviewing the results of data collection and analysis and making a determination of the value of finding and action to be taken

For the past three semesters, the authors have practiced this new approach to collecting, organizing, and interpreting the course outcomes for use in the annual program assessment report for our University. This course assessment and evaluation results will also be used to support the TAC/ABET TC2K visit in 2004.

This paper reports our findings in reassessing senior-design courses to support Program Accreditation Review Evaluation under TAC/ABET Criteria 2000 (TC2K). The discussion topics include an overview of the outcome-based senior design course, senior design project development, course evaluation, and conclusions.

II. An Overview of Outcomes-Based Senior Design Course

The general goal of the two-semester senior design project course is to provide students with technical design experience for appropriate careers through systematic exercising of design projects in a carefully controlled academic environment. Students are encouraged to collaborate on design projects with industry, government agencies, university departments, or community institutions. The scope and level of the course is set by the following course descriptions:

> EET 490 – Senior Design Project, Phase I
> Credit 1, hours arranged
> Prerequisite: 12 credit hours of EET electives with a grade of C or better.
> An extensive individual design and/or analytical project performed in consultation with one or more faculty advisors. Collaboration with representatives of industry, government agencies, or community institutions is encouraged. Evidence of extensive and thorough laboratory performance is required. Phase I includes, but is not limited to: (1) faculty acceptance of project proposal, (2) defining and limiting project objectives, (3) initial research and source contacts, (4) procurement of materials, and (5) periodic progress reports.
>
> EET 491 – Senior Design Project, Phase II
> Credit 2, hours arranged
> Prerequisite: 490. Phase II includes, but is not limited to: (1) continued research and

finalized design, (2) oral presentation to faculty and other interested parties, (3) standard-format written technical report.

Figure 1 Capstone Course Descriptions.

To support this capstone course, the ECET department reserves a dedicated PC-based workstation with a scanner, digital camera, and software including MATLAB and Electronic Workbench, etc. The course web site (http://www.etcs.ipfw.edu/~lin) includes such information as a course syllabus with course description and outcomes, assessment forms, design reference materials (design practices, system emulation/simulation, system prototyping, system integration, system testing and validation, system evaluation and safety, online design magazines, design libraries, ethics, design research, etc), a discussion page for posting questions, E-mail, and samples of previous senior design project presentations.

The expected course outcomes are as follows:

EET 490/EET491 Course Outcomes: A student who successfully fulfills the course requirements will have demonstrated the ability to

1. integrate the knowledge gained in earlier courses, and be creative in identify, analyze, and solve a real-world problem with a hardware and/or software solution (Criterion 1, items a, b, f, h, i, j),
2. observe and apply ethical principles, personal values, and responsibility management practices (Criterion 1, items i, j, k)
3. use mathematics and sciences knowledge and apply them in all phases of one's design project: analysis, design, prototyping, and testing (Criterion 1, item b),
4. use manuals, handbooks, library and technical references, Internet search engines and Web sites, and material/equipment specifications, and computer in one's design project, where applicable for preparatory research (Criterion 1, items a, b),
5. apply hardware and/or software design methodologies and procedures: project identification, initial research and source contacts, system analysis/requirements, requirement review, design, design review, periodic progress report, procurement of materials, and planning (Criterion 1, items a, b, c, d, e, f, g, h, i, j, k)
6. use oral and written communication skills in a real-world problem solving situation (Criterion g, item g)
7. provide and present the good project proposal, periodic progress reports, project presentation, and project proposal report (Criterion 1, items e, g, k)

Figure 2 Capstone Course Outcomes.

Students enroll in the course for two consecutive semesters and work on the design projects on a part-time basis and are expected to follow the guidelines specified in the following two assessment forms:

EET 490 Senior Design Phase I - Assessment Form

Student Name: Date:

Project Title:

Project Type: Work related Non-work related

Project Selection (10%):
Technically challenging and potential benefits ______
Safety and reliability concerns ______
Initial research and source contact ______
Comments about the project selection ________________________________
Project Planning and Management (50%):
Specification/Requirements ______
Periodic progress report ______
Time line and schedule ______
Feasibility study ______
Interaction with project advisor ______
Comments about the project operation ________________________________
Project Design (10%):
Modeling/simulation ______
Logging testing results and progress ______
Comments about the project operation ________________________________
Report (20%):
Comments about report
Oral Presentation (10%):
Professionalism (include preparation and use of visual aids) _______
Familiarity with the project (include ability to answer questions) _______
Comments about the oral presentation
Evaluator: Grade:

Figure 3 Capstone Course I Assessment Form

EET 491 Senior Design Phase II - Assessment Form
Student Name: ________________________
Project Title: ________________________________ Date: ________________
Project Type: Work related ___ Non-work related _____

Project Planning and Management (25%): _____
Specification/Requirements ____
Analysis Results _____
Periodic progress report _____
Time line and schedule _____
Interaction with project advisor _____
Comments about the project selection ________________________________
Project Design (25%): _____
Modeling/Simulation _____
System Architecture _____
Logging testing results and progress _____
Comments about the project operation ________________________________
Project Implementation/Operation (20%): _____
Meets or exceeds specifications _____

Test results available _____
Understanding of the project operation _____
Comments about the project operation ___________________________________
Oral Presentation (10%): ____
Professionalism (include preparation and use of visual aids) _____
Familiarity with the project (include ability to answer questions) _____
Comments about the oral presentation ____________________________________
Report (20%): _____
Comments about report ____
Evaluator: __________________________ Grade: __________

Figure 4 Capstone Course II Assessment Form

These two forms were originally designed in 2000 by the capstone course instructor, Ron Emery, approved by ECET faculty, and updated annually. The forms are used at the end of each semester for course assessment. The capstone course instructor arranges and invites faculty to attend phase I and phase II presentations. Data entered in assessment forms by each faculty include percentage score of each specified category, comments, and grade. Student's final course grade is then averaged by the capstone course instructor.

III. Senior Project Development

A design project is often thought of as a constructive problem-solving process. In general, students learn about the design by experiencing several interdependent and overlapping stages, including Project Identification and Inception, Project Planning, Iterative Design, Implementation, Integration and Beta Testing, Documentation and Report Writing, and Project Presentation. Terms used in the project development are defined as follows:

- Project Selection means the link between what was taken in the undergraduate program and the project. The Senior Design project is intended to be a capstone experience for students. As many course concepts as possible should incorporated in the project. The project should provide a technical challenge to the students and broaden their technical horizons.
- Project Design: Project analysis and design often requires thinking at various levels of abstraction and addresses design concerns, such as cost, reliability, stability, safety, performance, manufacturability, and so forth. Broadly classified design methodologies include Top-Down Design, Bottom-Up Design, Middle-Out Design, Concurrent Design, Iterative Design are normally considered. The design process requires the students to transform requirements and specifications into a physical system
- Project Implementation/Operation refers to what extent the project is operational as defined in the student's proposal and progress report. The goal is to meet the proposed specifications. Achievement of that goal includes showing test results to validate the operation. It is also expected that the student have an in-depth understanding of the project operation.

- Oral Presentation identifies the professionalism and oral communication skills that the student possesses. The student must be able to answer questions and demonstrate familiarity with the project.
- Project Report is the written document that evidences the student's written communication skills. This report is usually produced to satisfy the requirements of English 421 Technical Report Writing course as well as the requirements of the Senior Design Project course.

This interactive process is shown in Figure 5.

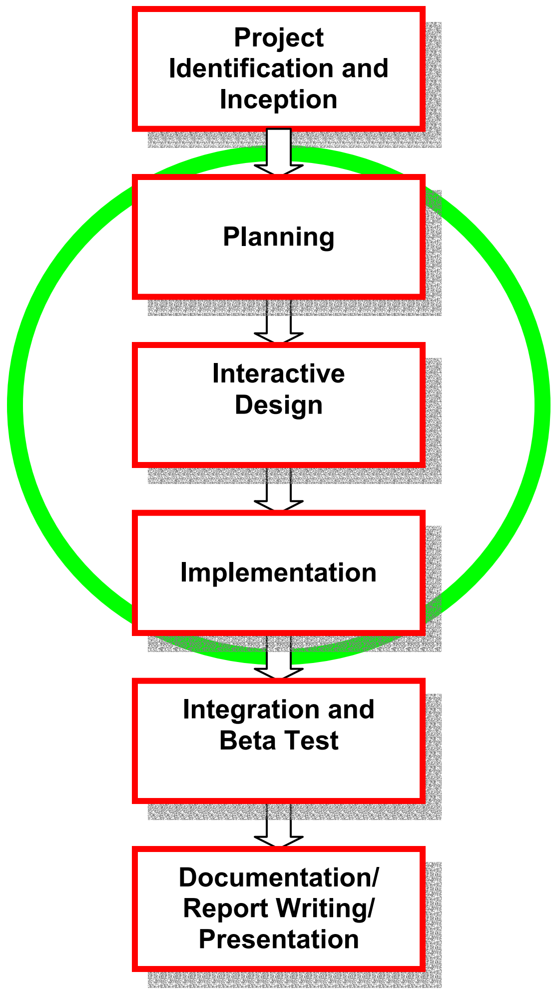

Figure 5 Stages of Senior Project Development.

Instruction methods for the course sequence starts with students' researching project ideas, writing a project proposal, defining and limiting project objectives, making initial research and source contacts, procuring materials, and making periodic progress reports, reviews, and presentations. The implementation of the proposed project starts in the second semester and includes research and final design, construction and testing, standard-format written technical reports (design review reports, design progress reports, testing reports, and final report) and oral presentation to faculty and other interested parties. Typical project development activities are planned by the primary advisor as shown below:

EET 490 Senior Design Project Phase I - Schedule

First Meeting and Preparation (project period - 2 weeks)

Second Meeting - Project Identification Phase (project period - 4 weeks)

- Sources of Senior Project Ideas: Previous senior design projects (in IPFW Library), IEEE Technical Magazines (Industry Applications Society, Computer Society, etc), Application and Design Data books, Ideas from other department (MET, CAET, etc), Community institutions, Industry, Faculty members, etc
- 1st progress report due

Third Meeting - Project Proposal Preparation Phase (project period - 3 weeks)

- A typical design project proposal tends to include the following information: Title, Statement of the problem, Proposed solutions, Methods, Required resources, Schedule, and Potential benefits.
- Basic characteristics of a good proposal: unambiguous, consistent, complete, correct, and clear.
  A draft of project proposal due

Fourth Meeting - Review and Approval of the Design Project (project period - 2 weeks)

- Proposal will be reviewed critically and subject to approval by the advisor. Based on the review, your project proposal may be accepted without change, asked to make suggested change, or rejected and asked to select a different design project

Formalized Design Report (project period - 4 weeks)

- A proposal due

Fifth Meeting - Final Report and Presentation

All ECET Faculty members are invited to sit in the presentation. The EET 490 Senior Design I Assessment Form will be used for evaluation.

- Microsoft PowerPoint presentation is recommended; a softcopy of the presentation should be available for the advisor
- A written final report is expected

EET 491 Senior Design Project Phase II - Schedule

First Meeting and Preparation (project period – 2 weeks)

- Design review, assign technical advisor, and an updated progress report including the following sections are required: project title, problem statement, proposed solution (with appropriate block diagrams), required resource and estimated cost, project timeline.

Iterative Design Phase (project period – 4 weeks)

- Preliminary Design: continuing on your Phase I design project, and making a schedule to meet with your technical advisor
- Final Design: define detailed requirements specifications (hardware/software subsystems and interface, I/O interface, timing, events, constraints, etc) and overall characteristics of your proposed project for implementation; consider system usability (human factor), performance, reliability, supportability, off-the-

shelf parts, assembly time, power, weight, size, cost, tradeoff, etc; system Architecture (software and/or hardware)
- Perform circuit simulation, system simulation, and or mathematical modeling: MATLAB, PSpice, Electronics Workbench, etc; log and gather simulated data; analyze, and document the testing results
- System function modeling (flow chart, data flow diagram, state transition diagrams, activity diagrams, collaboration diagrams, block diagrams, etc)
- Make sure all the needed hardware and/or software are ordered
- Design reports due to both your technical advisor and primary advisor for critical review

Project Management and Implementation (project period - 4 weeks)
- Define an implementation plan and timeline for project management
- Prioritized hardware/software co-construction
- Incrementally build and test your prototype system
- Document your activity, unit testing results (signal measurement, observation, program running, etc)
- System construction and unit testing report due

Testing and Evaluation (project period - 5 weeks)
- Complete the system construction
- Final testing and gathering testing results for final report
- Two final testing reports due

Final Report and Presentation
- All ECET Faculty members are invited to attend your presentation. The EET 491 Senior Design II Assessment Form will be used for evaluation.
- Final project presentation: request Computer/LCD at least 2 weeks in advance; Microsoft PowerPoint presentation is recommended; a soft copy of this presentation should also send to primary advisor
- Two copies of final report due

IV. Course Evaluations

Student Accomplishments: All graduates must successfully complete the BS capstone course. Projects generated in this course are evaluated by ECET faculty using the evaluation forms. The majority of students who enrolled in this course also take ENGW 421, Technical Writing, at the same time. Students and ECET faculty are encouraged to collaborate with local industries for work on senior design (creative & research) projects. Senior projects completed in 2002 include:

Spring 2002
- Design and Implementation of a Beat Frequency Oscillator Metal Detector
- A High Frequency FM Scanner
- Database and Web Integration – An ASP Solution
- Designing and Building a Tensometer
- Design and Build a Web-Driven Time Clock Application
- Design and Build an Inverter Grade Leakage Current Fault Monitoring System
- Ethernet-based An Automatic Screw Detection Using Vision System
- Design and Construction of an IR Wireless Speaker
- ESC Sleep and Wakeup Set Scenario Test

Fall 2002

- Semiautomatic Bottle Filler
- Fan Filter Unit Automation
- Three-Phase Motor Controller
- Internet-based Wireless Monitoring and Control Applications
- Computer Controlled Production of Small Diamond Drawing Dies
- Redesigning the Modern Guitar Amp System
- GM – ECM Motor Demonstration Box

As we can see these senior design projects are many and varied and generally, fall into the following broad categories: microprocessor applications, advanced RF applications, measurement and testing, hybrid electronics systems (analog/digital), PLC-based control applications, communication subsystems, Web-based applications, and Internet-based control applications. The quality of the 2002 senior design projects were assessed as follows:

1. *Measures completed.*
Spring 2002 - EET 491 (9 students): 8 - A grade, 1 B - grade
Fall 2002 - EET 491 (7 students): 7 - A grade
2. *Findings.*
All the presented senior design projects were quite good. ECET Faculty and ENGW 421 professor were very impressed with student projects and presentations. Many projects dealt with emerging technologies. Majority of students who complete their senior design projects are able to receive their B.S. degree at the end of that semester. The expected course outcomes meet TC2K Criterion 1, items (a) through (k).
3. *Conclusions.*
This course continues to serve well as a capstone course not only for satisfying the BS EET degree requirement but also for use in student's job hunting as well. With the new requirements and objectives that we implement in the Spring 2002 and Fall 2002, it should help career training and better serve our students.

Figure 6 Capstone Course Assessment.

The annual graduate survey and employer survey are believed to provide additional measured information on graduate's technical knowledge, problem solving skills, use of equipment, work attitude, and work quality. Samples rating for the year 2001 are shown in the following table: (The rating is based on the following grading scheme: Very Good - 5, Good - 4, Average - 3, Poor - 2, Very Poor - 1)

Questions in the survey form and the results are (based on 31 returned questionnaires):

Questions	Very Good	Good	Average	Poor	Very Poor	N/A
Technical Knowledge (4.39 /5.00)	14	15	2	0	0	0
Use of equipment (3.65/5.00)	2	18	9	2	0	0
Problem solving skills (4.19/5.00)	9	20	1	1	0	0
Overall general education (4.32/5.00)	12	17	2	0	0	0
Degree satisfaction with current employment (4.23 /5.0	11	17	2	1	0	0

Figure 7 Year 2001 Annual Graduate Survey.

Some additional comments provided by graduates are: "IPFW electronic equipment is way behind the industry. i.e. oscilloscopes, IFR spectrum analyzers, SAE specification CDROM, SAE J1939 CAN bus analyzers, stereo lithography machines, environmental chambers, EMC screen rooms."

The 2001 Employer Satisfaction Survey rating is based on the following grading scheme: (Very Good - 5, Good - 4, Average - 3, Poor - 2, Very Poor - 1). Questions in the survey form and the results are (based on 15 returned questionnaires):

Questions	Very Good	Good	Average	Poor	Very Poor	N/A
Technical Knowledge (4.5/5.0)	8	7	0	0	0	0
Work Attitude (4.6/5.0)	10	5	0	0	0	0
Work Quality (4.5/5.0)	9	6	0	0	0	0
Promotion Potential (4.4/5.0)	9	6	0	0	0	0
Overall Evaluation (4.4/5.0)	9	5	1	0	0	0

Figure 8 Year 2001 Employer Survey.

The Graduate survey result shows that they are quite satisfied with the technical knowledge that they gain from IPFW education, but not satisfied with the "Use of Equipment" is not updated and compatible with regional industries. The Employer Survey results show that the overall satisfaction rating is about 4.4/5.0, which is very close to 90%. It indicates that the employers are quite satisfied with our ECET graduates. All 15 returned survey forms say they would hire additional graduates from Indiana-Purdue University in this or other technical areas. Some additional written comments include: A written comment, dated 7/20/2001, states: "We have several IPFW gradates at Carrier and at our UT Electronics Control facility in Huntington, Indiana. They are very high-caliber. We look to IPFW as one reliable source for future talent."

Faculty Loading: Currently, six full-time faculty members advise on projects on a regular basis. The advisors, in addition to their other departmental duties, usually advise two to three projects. This requires meetings with the students which take several hours per week. To work with them successfully, a project advisor must spend extra time to become familiar with up-to-date hardware and software, as well as design tools, so that students will not be too remote from the real world.

Student Loading: It is the student's responsibility to be actively involved in the project, talking with future product users, doing research in the library, analysis, construction, testing and documentation of the prototype in the laboratory. It is difficult to estimate the length of time an individual spends on their project. Obviously, students that are already employed in industry can complete the design tasks in less time because of their familiarity with a real-world project. Typically, the level of a student's activity is equivalent to one-third of a full academic load per semester.

Student's Feedback: The students have not been asked to evaluate the course by means of a questionnaire or in personal interviews at the end of course. But one of the most interesting observations from student project reports is that the students are generally very pleased with the effort thus far and have no major complaints. It seems that most students look upon this course as an opportunity to enhance their skills and knowledge, and to prepare themselves for employment. Most student-financed projects were designed products that used the availability of new technology, and integrated the concepts of designing for cost effectiveness, reliability, safety and maintainability than the earlier products. This is no different, in terms of quality, than industry sponsored projects. However, experience has shown that students work best in this course when the sponsoring company expresses a great deal of interest in the project result.

Continuous quality improvement: Students and employers are quite satisfied with their degrees. However, our graduates ranked the "Use of Equipment" below average. The department is pursuing all possible funding sources to improve this weakness. During 2001, the department received software and equipment donation valued at $617,968 for use in EET and CPET courses.

However, the equipment and hardware grants and/or donations are much more difficult to secure. We pursue to expand funding for improvement from all sources. The ECET Laboratory Improvement Committee will be formed to work on this issue (identify the need, equipment acquisition strategy, and implementation).

TC2K Criterion 1: The Senior Design Project courses have been in place since 1968 and it was concluded in [2] and [3] that the course provides students with the best possible preparation in terms of current technical knowledge, techniques, skills, and written/oral reports for industry employment. The outcomes of capstone course satisfy the TC2K [5] Criterion 1 (a) through (k) which reads as follows:

"**Criterion 1. Students and Graduates**

An engineering technology program must demonstrate that graduates have:

a. an appropriate mastery of knowledge, techniques, skills, and modern tools of their discipline
b. an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology,
c. an ability to apply to conduct, analyze and interpret experiments and apply experiments results to improve processes,
d. an ability to apply creativity in the design of systems, components or processes appropriate to program objectives,
e. an ability to function effectively on teams,
f. an ability to identify, analyze and solve technical problems,
g. an ability to communicate effectively,

h. a recognition of the need for, and an ability to engage in lifelong learning,
i. an ability to understand professional, ethical and social responsibilities,
j. a respect for diversity and knowledge of contemporary professional, societal and global issues, and a commitment to quality, timeliness, and continuous improvement"

V. Conclusion

The Senior Design Project at ECET department of Indiana University – Purdue University Fort Wayne has been a rewarding and successful course. This course represents a constantly ambitious and complex undertaking that requires dedication by students and faculty alike. The ECET faculty members, graduates, and employers verify that the capstone course satisfied TC2K [5] Criterion 1 (a) through (k) and should be used as a valuable tool for supporting TC2K program accreditation.

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Biographies

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Paul is Associate Professor of the Electrical and Computer Engineering Technology, at Indiana University - Purdue University Fort Wayne. He has been with Purdue University since 1985 and served as a department Chair from July 1999 to July 2002. He is a registered Professional Engineer (EE) in California and Indiana. Prior to joining IPFW, he taught in the Engineering and Technology Department of Dutchess Community College (NY) for three years; in the Electrical Engineering Department of National Taipei Institute of Technology, now called National Taipei Technical University of Technology and Science, for two years; and worked in industry for 8 years. He was a Visiting Associate Professor in the Electrical Engineering

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