Enhancing the Design Course and Projects in Undergraduate Electrical Engineering

E. H. Shaban and Rambabu Bobba

Electrical Engineering Department, Physics Department
Southern University
Baton Rouge, LA 70813

Abstract

ABET may make recommendations to enhance and improve both the contents and the scientific methodology for senior design projects. Practical engineering projects must be selected, simulated, built, tested and documented in a technical and a comprehensive manner. The students must be trained by the curriculum to design problems that can enhance their design capabilities to build practically working systems. Recommendations are made to eliminate the weaknesses for unsatisfactory design projects by strengthening the student’s concept, understanding, preparation, and execution of a highly successful and practical design projects to meet ABET criteria.

Introduction

According to the accreditation board for engineering and technology (ABET) a program in engineering is an organized educational experience that consists of a cohesive set of courses or other educational modules sequenced so that reasonable depth is obtained in the upper level courses. A definite stem should be obvious in the program and, again, depth should be reached in pursuing courses in the stem. Furthermore, the program should develop the ability to apply pertinent knowledge to the practice of the defined area of the program. A program must also involve broadening educational objectives expected in modern post secondary education [1].

ABET engineering criteria 2000 assess an engineering program with respect to the professional component concerning the depth and content of the design project at the senior level. The design project success depends on many factors and experiences. The curriculum of the program must contain sequenced courses that facilitate the continuation and the stress of the design methodologies so that the student can become acquainted with design tools and simulations. The co-op and the summer experience that are undertaken by the students, in engineering firms and the industry, should add an extra push to the perfection of the professional component in the capstone design project. The intent of this paper is to revise, update, and develop the portion of teaching design in as many courses in the electrical engineering program as possible. Suggestions are made to
prepare the students with the necessary design tools, methodologies, and learning techniques to be able to successfully embark in practically applicable senior design projects. In addition, the students must learn skills in project management, teamwork, technical communications, the opportunity to develop creative and challenging consumer products, and life long learning experience. An assessment instrument is suggested to measure the outcome of the design project. The results of the outcome measurement must be used as a feedback to enhance the design project and improve the overall engineering program and curriculum.

Radical changes have taken place in the industry of how to design, produce, and market a commercial product in a competitive global arena in a record time. Satisfaction of the client need is the number one issue and continuous research and development for a product is a must for survival in the competitive industry. Unfortunately, in some cases, an identical change may or may not have been implemented in the content of various courses at the university’s engineering programs. Computer aided design (CAD) tools have enhanced the design process in the industry and the engineering programs must follow suit. A close and continuous feedback relationship from the industry, the alumni and the academia must be established to enhance the engineering programs [2].

To grasp, understand, learn, and perfect design in the engineering programs requires a lot of theoretical and analytical competence and practical trial and error experiences for an open-ended and continuous development of a consumer product. The curriculum courses provide theoretical/analytical methods and approaches in various sequenced courses to assist the student to reach a reasonable theoretical backbone in design to satisfy given specifications and constraints. Students are expected to utilize all that they have learned in different courses in the curriculum, practical summer industrial experiences, the community engineering needs, and apply it to accomplish the senior design project. In some courses, the stress in learning design represents a small section of the course and the time that is allotted to provide a comprehensive review for a bigger picture of a complete working system design does not exist or is very limited. As a result the senior students may be unprepared to execute a successful and practically applicable senior design system or project.

ABET engineering criteria requires that the faculty qualifications must span the range of topics associated with each program and curriculum [1]. This does not exist in some undergraduate electrical engineering programs. The faculty is the backbone of the engineering program and must have a clearly defined responsibility for establishing curricular objectives, content, and be sufficiently dedicated to the program to assure that it will be kept up-to-date. The structure of the curriculum must provide both breadth and depth across the field of topics implied by the title of the program. Breadth requires both the coverage of multiple topics as well as a balance of topics appropriate for the program. Depth requires both a series of topical areas that are built upon one another as the students advance through the program and a minimum of one topical area at an advanced level [1]. The program must demonstrate that graduates have knowledge of probability and statistics, including applications appropriate to the program name and objectives, knowledge of mathematics through differential and integral calculus, basic science, and
engineering sciences necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components, as appropriate to program objectives [3,4,5].

**Senior Design Course and Project**

There is not a single identified root cause or weakness that can be attributed to the unsatisfactory completion of selected senior design projects. Teaching one or two courses in design tools may be helpful to achieve a successful design project. However, there are a multitude of factors that can help provide a reasonable background for the engineering students to help them complete a successful design to meet ABET requirements, program objectives, course outcome, and the professional component.

In the majority of selective and competitive admission schools and universities the majority of the students joining the engineering program have already established a strong background in the fundamentals of mathematics and physics. They may have decided to major in engineering prior to applying to the university. In some schools, however, open admission is sometimes practiced and some students may not be well prepared in mathematics and physics nor have they entertained an engineering career before they joined the university. Their choice to pursue an engineering career may be motivated mainly from a financial and economical point of view after they join the university. Such students may have some difficulty in their progress in an engineering program. The student’s lack of preparation in the mathematics and physics may make it rather difficult to cope with the flood of the applications of mathematical equations and physics that they have not retained or anticipated. A second factor may be whether the student is willing to spend the time and the effort to learn what the student missed or forgot to retain in order to cope with and learn from the new electrical engineering courses. A third and essential factor is the strength and the contents of the curriculum of the engineering program and the quality of the faculty, delivery methods, and assessment of the students performance.

It is reported that the assignment of projects to the student’s teams and the choice of the members of each team may be problematic in some cases [6]. Furthermore, whether the students are allowed to seek and propose their own projects or whether the instructor makes a pool of projects from which the students are allowed to choose is another factor that should be taken into account. It has been reported that if the students are allowed to choose their own projects, the success rate of the projects is increased as compared with if the instructor assigns the projects to the students. Some projects may span across engineering disciplines and the choice of the team members should be made carefully to allow each member from each discipline to finish their part of the project on time. Although working in a team, that may have students from different disciplines is one of the main objectives of the design project, the choice of the right group that can collaborate to complete the project in a timely and successful manner may arise.

**Design Emphasis in the Curriculum**
In addition to the requirement of knowledge in mathematics and physics, the electrical engineering program requires some fundamental core courses to be taught. These courses are electrical circuit theory, physical electronic devices, digital logic design, microprocessor, electronic circuits, machines, and electromagnetic fields [3,4,5]. The majority of these courses provide theoretical and analytical skills in addition to partial emphasis in design. The design portion of these courses is limited to examples solved in the classroom, homework problems, and examination problems during the semester. In some required laboratories such as electronic circuits and digital logic design, the students are required to complete a small project beside performing the assigned laboratory experiments. The projects are helpful to train the student to search for and select independently or in a group, an electronic circuit from a textbook, a design journal, or by searching the internet. The student is expected to use all the knowledge he learned in previous courses to simulate, build, test, and explain the operation of the project orally and in a comprehensive technical report. This opportunity will allow the student to experience design of electronic circuits in a small scale for the first time. This is a hands on experience, an oral presentation, a pictorial illustration, a written communication skills, teamwork, and the use of the state of the art CAD. This experience will contribute to the student’s proficiency in the final capstone design. Most laboratory courses have adopted the inclusion of a small project to the electrical engineering laboratories in lieu of the final examination.

**Design Course Objectives, Outcomes, and Assessment**

ABET engineering criteria 2000 require that the program educational objectives should provide the students with a broad fundamentals of engineering knowledge and the application of multi-disciplinary backgrounds to provide a creative and innovative product or system [1]. The outcomes should prepare the graduates to learn from the offered program curriculum, the basic experiments, design, and communications skills to be prepared for continued life long learning, at the graduate level program, or for entry positions that requires basic knowledge of electrical engineering, science, and technology [7-11].

The senior design project course addresses the professional component for ABET criteria. It should allow the student to practice as an engineer in solving practical problems with known constraints that require the use of all the fundamental knowledge and the discipline specific knowledge learned in the program. The program and the design project must prepare the graduate for professional engineering practice in the workplace. The following skills are required from the graduate: experience in project proposal writing, oral skills, data analysis using the state of the art CAD, project planning, management, teamwork, leadership, health safety, environment preservation, social issues, professional ethics, service to the local and global community, sensitivity to political concerns, and the economic impact in the community.

A means of assessment, for both the engineering program educational outcomes and the senior design outcomes, must be established to ensure that the graduate has indeed achieved the majority of the anticipated outcomes [12,13]. The measurable outcomes
results, achieved using the assessment tools, with various rates of success should be used as a feedback to improve both the program curriculum and the senior design project [10,11]. These objectives include but are not limited to the following: the students should be able to apply the knowledge they learned in mathematics, physics, and engineering to formulate equations, collect data, analyze data, simulate, build, and test the senior design project. In the majority of cases in electrical engineering, the design can be simulated using CAD tools, built on a breadboard, and tested to satisfy the consumer or the end product desired specifications. The finished product should address all the required various constraints with respect to the environmental laws, standard codes, the avoidance of hazardous materials, the social and the political concerns of the community. The students in a team should learn to work together in a professional manner, adhere to ethical and engineering codes, recognize the contribution and work accomplished by others, manage their system design project, and complete the design according to a planned schedule. The students should be able to communicate orally, technically, and in writing with one another as well as during the presentation of their results among peers, engineers, and professionals. The engineering design product should contribute to the engineering profession in a global manner. The students must be able to engage in a lifelong learning process, to update their knowledge in the discipline of interest, and develop new products based on contemporary needs. The ability to use the knowledge acquired during the engineering study and the skills for solving practical engineering problems in the future is of paramount importance.

ABET requires that an engineering program should prepare the graduate to learn and acquire during the period of study all the above objectives. The program must have an acceptable and measurable assessment tools to demonstrate that the engineering graduate has in fact accomplished those objectives with reasonable measurable outcomes [1]. This is not an easy task, since the program or the curriculum must offer courses that can allow the student to learn and apply ABET criteria in the final senior design project. It is strongly recommended that each of the engineering courses in electrical engineering may have components that teach both analytical and design skills. Each course instructor may state in advance the credit hours portion that can be taught in each course and demonstrates that such a portion of design credit hours of the course has indeed been taught and the outcome of the student knowledge about the design in the course is assessed in a measurable quantity and the results are used to improve the program.

Assessment Tools for an Engineering Program

The assessment instruments to assess program outcome and the capstone design course should serve the mission of the university, the college of engineering, and the program discipline. Assessment instruments for the program outcome may include the following: student design portfolio; national FE examination; program discipline examination; alumni survey; employer survey; graduate placement data; student survey; co-op programs; GPA; exit interview; and faculty evaluation [12].

The capstone design course assessment tools may include: team’s proposal creativity and innovation; strategy or plan, design methodology of approach, management of the
project; documentation of project; oral and written presentation; testing; a successfully working project; and peer assessment.

The college of engineering, Southern University, Baton Rouge, LA is a partner and contributes to the national NSF Coalition that includes the university of California Berkeley, California polytech, at San Luis Obsipo, Iowa State University, Stanford University, Cornell University, Hampton University, and Tuskegee University [13]. The coalition has developed and adopted the following instruments to assess the recommended courses by the coalition and may be used to assess the senior design projects. There are also industry and students’ advisory boards that work closely with all the engineering programs. The NSF coalition has recommended the following assessment tools [13]:

1. Assess the objectives and goals for the design course outcome. (Solve analytical problems, collect and analyze data, design of systems, teamwork, communication skills, ethics, life long learning)
2. Abilities of the student after taking the senior design course (perform as a practicing engineer entry level)
3. Activities that the student perform to accomplish the task of design (design portfolio, design prototype, self/peer evaluation, oral and written communications)
4. Criteria that describes the specific characteristics of the activity that will be measured.
5. Methods or processes by which to collect evidence of outcomes (exams, survey of alumni and industry, national exams)
6. Measure of the level of quality of the student abilities (outstanding, good, satisfactory, unsatisfactory)
7. Feedback of results of the assessment to improve the assessment process and the outcome of the design course (weaknesses and strengths of the evaluation of the outcomes)
8. Evaluation of the design course after the assessment is complete, should be rated as either satisfactory or unsatisfactory. How many performance criteria may be met in order to state that the abilities of the student have been achieved?

Recommendation

1. The establishment of a design clinic as a market place of design project ideas in collaboration with the local and national industry and professional engineers. The projects must address realistic problems that serve the community.
2. Co-op education for the students should be required in order for the student to work in an environment that fosters teamwork and collaboration.
3. All practical engineering laboratories must have a small project as a requirement at the end of the semester so that the student can practice how to search for a project and be able to build, test, and document the project.
4. Most engineering courses must have a design section where the students are exposed to both analytical solutions and design problems with ample homework and test problems for the student to practice design.

5. The students should be encouraged to participate in design competitions nationwide and join engineering professional societies.

6. Successful design projects that are accomplished should be written as a paper and presented in national or regional professional engineering conferences by the students.

7. To adopt offering advanced laboratories to teach the state of the art CAD or course electives in one semester (five areas; control system, computer design, power systems, power electronics, and IC design.) The next semester the capstone design is offered with the five areas taught as a prerequisite. The professors who offered the lab-lecture electives are chosen to be the advisors for the students in those areas of specialization.

**Summary and Conclusion**

The senior design course in engineering programs with respect to ABET criteria 2000 is discussed. The professional component of the capstone design in electrical engineering programs is reviewed and recommendations to assess the outcome of the program and means to improve the design course are suggested.

**References**

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E. H. Shaban
Dr. E. H. Shaban serves as an Associate Professor in the Electrical Engineering Department at Southern University in Baton Rouge, Louisiana. His research interests include semiconductor materials and devices, solar cells, and hetero-junction devices.

Rambabu Bobba
Dr. Rambabu Bobba serves as a Professor of Physics in the Department of Physics at Southern University, Baton Rouge, Louisiana. His research interests are the nanostructure synthesis and characterization of novel mixed conducting cathodes and cathodic catalysts for fuel cells (SOFCs and DMFCs), batteries (Li-ion, and lead acid), sensors (H₂, NH₄, and CO) and CMOS Devices. At present, he is executing several funded projects from U.S.DOD-ARO, and U.S.DOE-NREL.