On Challenges of Design-Based Curriculum

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***Abstract* - A design-based curriculum has become an integral part of most engineering institutions in the US. The main objective is to meet industry demand for the readiness of new college first degree graduates for effective global competition. Design based curriculum is also of major concern of the Accreditation Board for Engineering and Technology (ABET) in US education system. A design-based curriculum will be presented that includes: special design courses developments, selected examples of students design projects (including multi-disciplinary teams), team work and ABET program outcomes assessments, data collections and how to close the loop. Future challenges in undergraduate design programs will also be discussed. The role of engineering ethics and safety play integral parts of designs.**

ABET defines design as an: engineering process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective [1].

Index Terms - Design-based curriculum, challenges, outcomes assessment, ethics

I. Introduction

Design is a required component by the Accreditation Board of Engineering Education and Technology (ABET) of most engineering institutions in the US. Engineering design has been defined by several authors. For example, engineering design by definition, is a methodical approach to solving problems (may be complex or large) to meet the needs of society. Among the specified elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, optimization methods and evaluation. In addition to design across the curriculum, the Department of Electrical and Computer Engineering has developed two special capstone design courses (Senior Design I, and Senior Design II) senior undergraduates.

Design I, discusses design topics such as: communications, oral and written to convey thoughts and reports, fundamentals of design and applications, design process, design tools, basic sciences, mathematics, optimization, personal considerations, reliability, quality, concept generation, and team work. Students tackle typical design problems. In design course II, students concentrate on specialized topics to meet desired needs. They work in teams to solve a specialized design project with concentration in area of interest.

II. Design-Based Curriculum

The Department has adopted a design-based curriculum that assigns design projects in most courses in addition to the required traditional problem sessions. However, there are two-sequence capstone design courses as described below.

(i) Senior Design I
Discusses fundamentals of design principles and applications.
***Goals*:** To equip electrical engineering students with the basic tools for analyzing design projects. Prerequisite: Senior Standing.
Topics include: Communications, analytical techniques that include design process, management, introduction to design, problem formulation, functional analysis, conceptual design, probability and statistics. Also included are reliability, quality, optimization methods in design, safety, ethics/societies, and project selection (with a written proposal) that leads to Senior Design II. Students work with the guidance of technical advisors in an area of interest, make progress report presentations and participate in peer reviews of each others work. This course is evaluated to determine if the student can demonstrate competency and mastery in: ability to research a technical topic, and application of design/research methodologies to solve comprehensive problem.

(ii) Senior Design II
Covers: analysis, design and development of engineering projects using design concepts in Senior Design I.
Goals: 1. To solve a well defined project using engineering electives and core courses. 2.To apply the knowledge gained in Design I to solve a complex task.
The course provides training and experience in project planning, problem analysis, synthesis, oral and written reports. Students are required to design, build, and test a device or simulate model to solve a real world problem. ***Prerequisite:*** Senior Design I.
Topics: Students are encouraged to read current technical journals (such as IEEE transactions) for proposal/project review (proposal written format: cover sheet with title, team members, summary, introduction, problem formulation, approach, task dates of, budget, references). Lectures cover:

schedule planning, report writing, synthesis, ethics/safety, quality and design techniques, constraints, standards, open-ended problems, technical, economical, time and ethical constraints, ability to defend and articulate one's work to their colleagues. Where applicable, the design must be experimentally verified. Working prototype must be produced. Safety and ethics are heavily emphasized.

Professional Component:

Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in previous course work and incorporating appropriate engineering standards and multiple realistic constraints.

The major design experience involves knowledge, standards, and constraints related to the electrical and computer engineering disciplines.

The design experience of electrical engineering students culminates in two senior design courses. The Senior Design I course emphasizes the important characteristics of a major design project. The instructor guides the students through project proposal writing, collaborations with technical advisors/consultants, project requirements, safety, and ethics. At the end of the Senior Design I, each students' project specifications will be revised according to the recommendations of technical advisors and course instructors. In Senior Design II, hands-on design experience is emphasized and monitored through project progress reports and class presentations. They continue to look for alternative approaches due to budget limitations, standards/regulations constraints, time limitation, inadequate calculation or unsatisfactory circuit behaviors. The review of the progress report sessions is the most important feed-back provided to the students by the faculty. During the progress report sessions, the instructor and faculty members monitor closely the "real" progress made by the students and make sure that the requirements of the major design are satisfied..
(a) apply the methods used in at least one area of electrical engineering (EE) concentration, and consider alternative methods for feasible optimal solution while meeting imposed limitations or constraints, regulations/standards of the field; (b) successfully complete and assess the projects by the end of the semester.

There have been two main problems identified during the past assessment: (a) technical advisors have observed a lower-than-expected level for the completeness of the projects. Many of projects were considered to be too large for one student to complete satisfactory during the allotted time interval;
(b) standards useful time was limited. The following recommendations have been made in order to solve the identified issues: (a) the technical advisors suggested that the design projects become group based projects, rather than an individual project. (b) students should study industry standards and constraints. The design should have more specifics dealing with the "requirement" component of the project proposal that consists of rules/regulations/standards and limitations/constraints imposed.

Improvements Made:
Based on the recommendations made in the previous academic years, student team projects have been introduced. Professors with design experience have been chosen to review progress reports. Faculty will also attend class presentations to critique and provide input for improvement.

Improvements include:

i. Change individual projects to team projects.

The draft committee reviews specific reports for comments (using the monitor matrix in Table 1). Students projects with common background are merged to form a unified project for team work.

Table 1 The matrix used to monitor the students projects

Area	Review Comments	Action/ other
1. Problem Formulation		
2.Communications Proposal writing, literature search Oral/poster presentations		
3. Modeling Mathematical description, Assumptions, Constraints (cost, weight, size, power supply, available devices} Standards (American National Standards ANSI, European Standards, Institute of Electrical and Electronics Engineers (IEEE), NEC		
4. Synthesis Utilization of mathematical tools, science physics, economics. building and testing, benchmark system		
5. Evaluation Robustness, stability, sensitivity Scalability, optimization		
6. Aesthetics Performance, hardware/software User friendly		
7. Economics Ethics, budget Environmental, Social impact		
8. Prototyping Cost of mass production		

ii. The draft committee reviews the students projects proposals to ensure that each proposal meets design standards (such as problem formulation, modeling, analysis, synthesis, evaluation, performance, standards, constraints, economics, ethics, safety, and prototyping). Students are required to use standards (such as American National Standards Institute

(ANSI), Institute of Electrical and Electronics Engineers (IEEE) and constraints-cost weight, physical dimensions, and other.

iii. The general EE faculty are asked to review the new projects (the approval of these projects is documented).

iv. Three Teams of faculty continuously monitor their progress (proposal writing, progress report presentations and provide guidelines. The faculty also reviews written progress reports to provide technical advice. The students like the new approach of team work.

Interdisciplinary Projects

The interdisciplinary design projects (for one academic year/2-sesmsters) have been posed by industry (with constraints and standards). The group consists of faculty and students from mechanical and electrical engineering, fine arts and the School of Business. Each group contributes to the design project with a component from their respective areas.

Sample Projects from industry

(a) Automobile Body Enhancement: Capstone Design
Concept and Design a power open/close side-door with obstacle and pinch detection.
Concept and Design a new front and rear fascias with a remote and/or speed activated rear spoiler.
For both projects, the electrical engineering students are involved in all aspects associated with the design of the electrical feedback systems for the opening and closing events. In addition, our students are able to integrate the design of their power open/close system modules. The assembly plant is closely allied with engineering students in the process of engineering the hardware and controls systems for the fully automated subassembly processes. In addition to the faculty from these disciplines, the activities of the capstone design project are supervised by two engineers who visit campus regularly to interact with students and advise them on all project related activities. Deliverables/activities for all groups associated with this multi-disciplinary design project are discussed.

(b) Particle Flow Rate
The goal of this project is to research the possible designs of solids mass flux meters based on several physical properties. A suitable test apparatus for producing a controlled, repeatable flow of solid particles project include both mechanical and electrical design, modeling and analysis. Documentation is very important to this project as successes and failures will be critical and must be well documented.

Proposed Deliverables:

1. Design of test apparatus and solids flux measuring system
2 Fabrication of test apparatus and solids flux measuring system
3 Testing. Variables might include particle type, size, solids flux, and gas flux, and Report results including experimental uncertainty and suggestions for system improvement
4. Submit written report for deliverables listed above. The report should include: text, figures (photographs, plots, etc.), and data tables (where appropriate).

III. Samples of Students Abstracts Design Projects

Selected team projects that cover several areas of interest.

(a) Automobile Alarm Immobilizer and Notification System

Abstract: Our design aims at integrating a car alarm system with motion sensing capabilities, ignition cut-off capabilities, as well as a notification system that alerts the car owner when car alarms goes off. This wireless device uses radio wave technology to transmit the signal. Radio wave has been deemed as a cheaper way of signal transmission. There are many cases where alarms have been activated, but the car owner is completely unaware of this fact if they are not in close vicinity of their vehicles.

This report includes an introduction of our subject that states the present available auto industry car security systems, and how we hope to modify these existing models to emerge with a more efficient solution in terms of added functionality and user autonomy. The problem statement highlights the issues we hope to resolve with this design. We present details of the approach with sub features we are able to implement on the alarm system. The report sheds light on the tasks the team members accomplish, decisions and choices that must be made in selecting our adopted approach, as well as issues relating to ethics and security.

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(b) Design of Sleep Sensor and Control System

Abstract: The goal of this project is to create a device that monitors the characteristics indicative of sleep, so as to trigger an alarm whenever these characteristics are encountered. The purpose of the said device is to ensure that target users, (such as students, truck drivers and operators of heavy equipment), who are required to be awake and coherent at specific times, are not allowed to fall asleep. The device, labeled "The Sleep Detector" would fall under the prototype category of functional control and access, and would provide a platform for future developments in practical sensory equipment for a variety of persons and applications. The project involves the use of past research done concerning sleep tendencies and characteristics, with special focus on the symptoms of sleep. The symptom eventually chosen is specially researched and decided upon with the principle charge being a feasible characteristic that could be effectively measured using both robust and cost-friendly sensor equipment. The comfort and placement of sensory equipment is also considered. The main concern is the reliability of the device as well, and this requires extensive testing.

The new sleep detector design makes use of a decreasing blink rate that is a reliable indicator in comparison to previous options considered. A medical personnel has given us more insight into the safety requirements of any device that involves the eyes. With this information, we begin building the final design. There is a design prototype shown on ECE day, but the actual final design is forecasted to be even smaller and more reliable given further testing in a controlled environment. With regard to the targeted users, the persons that the device will be best suited for are separated into two (2) categories (as shown in Table 2): first degree (in need of a sleep indicator that reacts quickly, meaning a focus on blink-rate with the onset of drowsiness) and second degree (individuals that can use the device with not-so-dire consequences).

Table 2 Separation of Target Users

First Degree	Second Degree
Truck and general Drivers, Pilots Operators of Heavy Machinery	Students Security Guards

The goal is to have a device that can serve both categories. However, given the time constraints, the primary focus is on second degree users. The group recommends improvement in reliability for future work.

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© Auxiliary Automobile Battery System Using Super Capacitors

Abstract: The development of the automobile has indeed been a fast paced and lucrative one. This project presents the design for an improvement in one of the more integral subsystems of the automobile: the starting circuit. The battery, that has long functioned as the sole provider of charge for the starting of a car, has limitations due to its nature. As an alternative, the super capacitor, whose development has stemmed from its numerous advantageous properties such as high efficiency, high power density and short charge and discharge times, is being proposed as an alternative. The modeling of a super capacitor is conducted to lend some insight into the nature of this powerful component. Subsequently, a design is provided as an auxiliary car starting system. Due to the high current nature of the system, simulation was depended on to ensure that all components would respond favorably, before any attempt of building it is made. In the power system of an automobile, the car battery has many important functions, such as: power supply to the starter and ignition system to start the engine, it supplies the extra power necessary when the vehicle's electrical load exceeds the supply from the alternator/charging system and functions as a voltage stabilizer in the electrical system by evening out voltage spikes. Present day chassis battery power requirements are high. due to great increase in the number of electronic devices on board. They form the bulk of the accessory circuit and use the battery as their reliable source of power that drains the car battery.

Super capacitors are electrochemical double layer capacitors with high power densities, low voltage ratings and long lifetimes. It is different from a battery, and depending on the application, may be a better solution. They are primarily applicable in electrical systems that have a high peak to average power ratio, and where it is required infrequently. The electrostatic nature of the energy storage mechanism of the super capacitor is highly reversible, resulting in the characteristically high number of time the super capacitor can be charged and discharged. The development of super capacitors have lead to alternate applications such as auxiliary automobile starter to augment battery system efficiency. Constraints: must be integrated into the present system and fit under the hood of the automobile.

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The final projects for all teams are presented and defended during an annual special conference called Electrical and Computer Engineering (ECE) Day in April. Students at all levels, family members, alumni, Industry Advisory Board, and ECE faculty are involved in the event. All teams must provide the following items: (a) Poster Board (oriented toward a general audience (b) Power Point Presentation (c) Final Project Written Report according to industry standards (d) Final Product of the Project (in terms of hardware and/or software). Student presentations, posters and final products are graded by alumni, industrial affiliates board (IAB), and faculty. Technical reports are graded by the course instructor and technical advisor. In addition, technical advisors are required to file an advisory report on students' projects. The teams are assessed/scored based on the subtitles: for oral and poster sessions: Knowledge of problem, use of design concepts, use of fundamental engineering/science concepts, communications, standards and constraints, hardware/software working.

Significant improvements are made each year in various components of this process based on faculty, alumni, students, and Industry Advisory Board feedback. Also, from the technical advisors' reports, the instructor obtains recommendations and suggestions for better design experience for students.

IV. ABET Program Outcomes and Assessment

Faculty Survey: The outcome of the survey is used for future improvement. Competency is achieved with a minimum grade of "C" (2.0 on a 4.0 scale). In our efforts to improve program performance, the Department solicits your response to this survey. Part A below lists the Educational Objectives while Part B lists the Program Learning Outcomes of the Electrical Engineering Program. Please, use the following ranking system to aid us in the evaluation of our program: 4 - very effective, 3 - effective, 2 - moderately effective, 1 - somewhat effective, 0 - not effective

Part A

Attributes that our graduates should have at the time of graduation are listed below. Based on your experience with our graduates, on a scale of 0-4, please rate how well the Electrical Engineering Program prepared them personally and professionally for a successful engineering career.

Graduate students of electrical engineering program have acquired:

Table A

I. basic concepts of Math, Science and Engineering and developed problem solving abilities and skills needed for entry into the profession and life long learning.
II. skills in analysis techniques and understanding of EE core courses and specialization of at least one area of Electrical Engineering concentration include: Power System/Control, Electronics, Digital Systems, Communication and Microwaves/Antennas. Students are required to take at least two courses.
III. knowledge and skills to conduct experiments, analyze and interpret data and effectively use state-of-the-art tools and laboratory for research, education and problem solving.
IV. ability to formulate engineering problems, engage in analysis, synthesis, evaluation and design of electrical systems. This is achieved in two capstone design courses in addition to design across the curriculum.
V development of interpersonal, teamwork and leadership skills to solve engineering problems effectively.
VI. .Understanding and importance of professionalism, ethical responsibility and understanding of the environment and society.

Part B

As one moves through the undergraduate program in Electrical Engineering at Howard University, the courses she/he took should allow her/him to develop the skills listed below. On a scale of 0-4 please rank the effectiveness of the program in the student development of these skill sets

Students should obtain:

ABET Program outcomes and assessment:

(a) An ability to apply knowledge of mathematics, science, and engineering

Students must have the ability to derive expressions using science and mathematics (for modeling systems) with clear understanding including assumptions.

(b) An ability to design and conduct experiments, and analyze data

Students must have clear knowledge of their projects design and verify experimentally, collect data and analyze results with tables, plot graphs (using software) and draw up conclusions with modifications.

© an ability to design a system, component, or process to meet desired need.

Students must have problem definition, use technical design (standards/constraints), use computer generation, time and information management in design. They must determine appropriate type of data to acquire and analyze them for proper functionality. Design is multiple/open-ended.

(d) An ability to function on a multi-disciplinary team

Students must contribute their knowledge in interdisciplinary teams (consisting of students from other departments), share tasks, communicate effectively within team, must have discipline and professional conduct.

(e) An ability to formulate, identify and solve engineering problems

Once a problem has been posed, students must be able to use mathematical techniques for modeling and design, manage multiple sub-problems, use multiple tools and arrive at an optimal solution using constraints and standards.

(f) An understanding of professional and ethical responsibility

Prior/during design project work, students are required to understand that engineering is a learned vocation, demanding an individual with high standards of ethics and sound moral, demonstrate respect, social/technical ethics, copyright laws, code of ethics (such ABET, IEEE, Engineers Creed published by the National Society of Professional Engineers).

(g) An ability to communicate effectively

Students must be able to write with proper grammar and style and present their work orally using (audio visuals such as power point) format, organization, content, conclusions

(h) Broad knowledge to understand the technical impact of engineering solution in a global and social context
Students must have knowledge of social and environmental issues, accommodate cultures from other countries, design to reduce global warming effects.
(i) A recognition of the need for and ability to engage in lifelong learning
Students must engage in continuously researching from library and other sources, attend society meetings, read journals and compare designs with existing ones, be able to use new tools in solving projects.
(j) A knowledge of contemporary issues
The student is encouraged to read current journals and papers about design and join professional societies such as IEEE, must understand the impact of a global engineering environment and the role of the profession in a global society.
(k) An ability to use the techniques, skills and modern engineering tools necessary for engineering practice
Students must be able use the internet, apply modern computational tools (such as MATLAB and toolbox,, power point, word processing, PSPICE, lab-view, graphics, internet, and new (laboratory) equipment to solve problems.
(l) obtain and understanding of issues related to historical awareness of Africa and its Diaspora
Students should be aware of engineering practice (social and political) and economics related to Africa, environmental issues, standards and constraints.
(m) An ability to improve leadership skills interactions
Students must demonstrate leadership skills in team work, must also join professional and social societies and lead.
(n) Ability to use computers and internet as a means of enhancing engineering research and development
Students should be able to use computational tools such as MATLAB (plus tools box), use the internet as a source of knowledge/reference for research.
(o) ability to use advanced mathematics including probability and statistics
Student should be familiar with optimization techniques in modeling their designs. Probability and statistics should be used in modeling uncertainties, reliability and quality control.
Please add additional comments on your experience with our program students and alumni, if you desire.

V. Challenges –Closing the Loop

To ensure standards set up by ABET in assessing our program assessment is done through several approaches that include:
(a) Grading (b) Faculty survey (c) Students exit survey (c) Industrial affiliates survey (d) Alumni survey
At the annual Electrical and Computer Engineering day students to present their design projects before invited guests who also act as judges/critics for quality of work done needed for future improvement. Closing the loop is a rather easy process. However, some data must be collected based on surveys from students, faculty and industry, analyzed and fed-back to the students and faculty for continuous improvement.

VI. Conclusion

Challenges for design-based have been presented. Data collection and analyzing based on surveys and students sample work keeping will help enhance performance of design projects and prepare young graduate to meet industry standards as well as continue for advanced studies. Response of the surveys also help in continuous improvement of the design component of our curriculum. The annual Department's Electrical and Computer Engineering Day (held in mid-April) plays a major role in our design curriculum. Students present their projects (oral and poster sessions with hardware) before invited guests that include representatives from industry, alumni, faculty and administrators. Attendees, at the ECE occasion, provide inputs (suggestions) for the next group of students to ensure continued success and improvement of our program. Samples of students' team projects show continued success of the program. ABET outcomes and assessments are followed to meet the Department's educational objectives.

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IX. Biography

Peter Bofah obtained his BSEE and MSEE both in electrical engineering from the University of Nebraska-Lincoln. He obtained his PhD in controls from Howard University. He is a faculty member at Howard University in the Department of Electrical and Computer Engineering. His areas of interest include: modeling and control of large structures, energy, power electronics, design and engineering education.

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