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A strategy for innovative capstone design projects

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Abstract

The capstone design course is used by many engineering programs to provide students in their final year of training an opportunity to integrate knowledge from coursework and other sources in order to provide a solution for an engineering problem. The strategy for conducting the course, the process, implementation, and expectations vary between programs and disciplines. Often, there are conflicts or inconsistencies in expectations between course instructors, as well as between students and instructors. In many cases there appears to be no 'systematic' way for arriving at project ideas. Students are sometimes offered a list of potential topics, or asked to brainstorm and submit topics for approval. This non-methodical approach has resulted in a catalogue of poorly-conceived products showing a dearth of creativity and poverty of innovations. This paper discusses a pre-capstone course to guide students through the process of idea-production, selection of a title for a creative product or system, and a plan for development.

Index Terms – Capstone design, creative design, sustainable design.

Introduction

Many programs use the capstone design course as a process for getting students in their final year of engineering training to integrate knowledge from coursework and other sources to provide a solution for an engineering problem. Clearly, and as should be expected the strategy for conducting the course, the process, implementation, and expectations vary between programs and disciplines.

Heitman and Manseur [1] discussed the organization of a capstone design course. Students come up with project ideas, discuss and seek pre-approval from a faculty mentor. Sometimes, students involved in the cooperative education program propose industry-based projects.

Hanton [2] highlighted the organization and conduct of a capstone design course. The work addressed critical issues of what constitutes a "design project" – establishing that an electrical engineering project does not have to culminate in a piece of hardware. Members of the faculty

present their project interest areas to students for consideration and selection. Sometimes the capstone design coordinator puts students in touch with contacts in industries for exploration of viable project ideas.

The environment to foster an outcome-based capstone design experience often motivates programs to seek out real-life engineering problems through collaboration with industry, government agencies, university departments, and community institutions [3-4].

Several studies have focused on the often-neglected non-technical aspects of the capstone design experience such as project management, communication, and interpersonal skills. In some cases, precise strategies for facilitating teamwork in a multi-disciplinary environment on large-scale projects have been identified. In addition, group size and course length are other parameters that have been established as influential in the success of the capstone experience [5-7].

Bielefeldt [8] relates the procedure for identifying topics in a capstone course incorporating sustainable projects. Students were guided to select topics from a range of real-life environmental problems ranging from municipal treatment plants in the US to international locations with projects identified through Engineers Without Borders (EWB) group.

Often, there are conflicts or inconsistencies in expectations regarding what constitutes a worthwhile project topic from one course instructor to the other, as well as between students and instructors within the same program or department. Some capstone design project instructors have come up with fuzzy quantification for hardware-software relationship; fostering the impression that more hardware is always a better project idea. Traditionally, there appears to be few 'systematic' ways or procedures in place for inexperienced students to identify a worthwhile topic or project idea. Students are sometimes offered a list of potential topics, or asked to brainstorm and submit a topic for approval. The lack of clarity in how to approach this phase of the project tends to result in badly-conceived product, showing a dearth of creativity and poverty of innovations. The instructors have not succeeded in guiding students to develop a creative product.

One way to address this weakness is the use of a pre-capstone, proposal course to guide students through the process of idea-production and selection of a title for a creative product or system, and a plan for development. It is should be noted that many programs already have a pre-capstone course in place for developing project proposals. This paper discusses a systematic approach within the framework of the course.

Objectives and Goals for the Course

At Penn State Harrisburg, the proposal course is a required one-credit class taken by students in senior standing during the semester preceding the scheduled capstone design course. The specific objectives that are set for the course are as follows:

(a) Students will learn to access technical information through the library electronic databases, identify relevant themes, learn how to scan through complex technical information, and identify what is the state-of-the-art in relation to ideas under consideration.

Very early in the semester one class meeting is scheduled in one of the technology classrooms at Penn State Harrisburg's Library for hands-on interactive session on electronic resources. The reference librarian guides the students through search techniques on science, engineering, and technology databases hosting several hundred journal titles. This step is crucial in helping familiarize the student with the systematic process of scientific research. Besides technical journal papers, students typically need extensive product information from various manufacturers as they complete their design work. It therefore becomes necessary to familiarize them with online resources and access to various suppliers for circuit components and devices. The Thomas Register at http://www.thomasregister.com/ offers easy and instant access to several thousand manufacturers, suppliers, products and services. Component specification sheets and charts are within easy reach to expedite selection of parts for the project. On-line price list for components and devices, and the process in place for request for quotations (RFQs) assist the student in evaluating the budgetary implications of their design choices.

(b) Students will learn the key clusters of creativity, and the distinctive attributes of a creative product or system.

Most students approach the capstone design course with some trepidation as they are unsure of where and how to start the exploration for a project idea. This may be addressed through an introductory lesson on the basics of creative product development. The concepts would naturally serve to cue the student in on what to look for in the search process. The discussion in this segment of the course covers expressive, technical, inventive, innovative, and imaginative creativity; it goes on to further touch on the attribute of a creative product that includes - originality, reformulation, generationality, complexity, condensation, and hedonics. Students learn to explore opportunities for problem transformation.

This opens up a new horizon for the students as they notice what could be done with existing products or systems.

(c) Students will interact in a 'stimulating' environment that fosters creativity.

Penn State Harrisburg is located within half mile of three very large senior citizen and assisted living centers. This positions the EE program to take on real needs and proffer engineering solutions to social and health challenges common to seniors. A planned class visit and dialog with residents offers a tremendous exposure to students on the range of challenges that calls for creative solutions.

It is common for the non-traditional students that are employed full-time in the industry to come up with project ideas related to their work environment. The ideas or innovations typically present an improvement in products or operation of the production line. In almost all the cases to date, the employers enthusiastically supported and funded the projects as it directly addressed their needs.

(d) Students will learn sustainable design practices or DFE (Design for the Environment) concepts - how to design for life cycle, and how to apply eco-efficient metrics in product design or redesign.

The capstone design course presents an appropriate medium for focusing more extensively on sustainable design practices, beyond what could be done in other electrical engineering elective classes. Case studies from current journal publications are used to illustrate the use of eco-efficiency metrics, design for life cycle, and cumulative impact on energy sources, pollution, and etc.

(e) Students will create a proposal document that details technical information reviewed, identifies a project title, and clearly articulates a justification for the project. Also, the document will specify the attributes of the product or system, a block diagram description of the key aspects, and a time-line for design, simulation, and construction if applicable.

(f) Faculty will be involved in the process through idea evaluation and criticism.

A committee of faculty members takes responsibility for reviewing and critiquing the proposals. The reviewers look for appropriateness of the topic in satisfying the capstone design objectives, how much of the students' cumulative learning will be engaged, and what is achievable within the 15-week period available for completing work on the project.

Resources for the course

The following resources have proved valuable in previous sessions of the proposal development course:

1. Richard C. Dorf, "*Technology, Humans, and Society - Towards a Sustainable World*." Academic Press.
2. Guest lectures on sustainability in engineering systems; reliability considerations in engineering design; oroduct liability; writing technical proposals, etc.
3. Software simulation systems: Altera Max, Matlab (with various Toolboxes & Blocksets), PSPICE, PowerWorld, and PowerTools.
4. Films on creative problem solving; management of large projects, etc.
5. Basic guidelines for the preparation of research papers.

Course Assessment

Students are required to present regular updates on status of their idea formulation and writing through the semester. Also, the course instructor regularly meets with the teams to assess the involvement of the members of the teams. Students are required to turn in a proposal document at the end of the semester, and formally present the proposal to the class.

Some of the questions that the students have been asked to address in their presentation includes the following:

1. Market research: who needs and wants your product?
2. How much are people willing to pay for the product?
3. Why are you seeking to develop this product?
4. If you are certain that you have a creative product, describe at least three attributes of the product.
5. What plans do you have for simulation studies?
6. What aspects of DFE have you incorporated into your design proposal?
7. Why should I fund your project (speaking as a representative of a funding agency)?
8. How do you plan to sell the product?

Conclusions

This paper presents the goals and strategy for a pre-capstone, proposal course to guide students through the process of idea-production, selection of a title for a creative product or system, and a plan for development. The process offers a way for addressing a weakness in current models, and systematically incorporating several desirable design considerations. The students are enabled and empowered to conceive and communicate their plan for creative products and systems through proper guidance and facilitation by the course instructor.

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Biography

Peter Idowu obtained his Ph.D. degree from the University of Toledo, Ohio in 1989. He is a registered professional engineer in the state of Ohio and is currently an associate professor of electrical engineering at The Pennsylvania State University - Harrisburg.