AC 2010-304: ENGINEERING SENIOR DESIGN COURSE (“NEW AND IMPROVED”)

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Engineering Senior Design Course (“New and Improved”)

Abstract

Senior Design is one of the most important courses in an engineering curriculum, because Senior Design utilizes much of the knowledge and skills gained during the undergraduate study. Therefore, many program outcomes for the engineering curriculum can be assessed in the Senior Design course.

Before 2007, the senior design course in our relatively new Computer Engineering program was similar to a Master’s thesis, was mainly focused on technical knowledge, and was especially focused on building a working prototype. Each student had his own technical advisor. However, we realized that this focus did not teach the early stages of design (such as literature search, market study, and cost analysis) and did not adequately emphasize soft skills (such as working effectively as a member of a multidisciplinary team, understanding professional and ethical responsibilities, understanding the impact of engineering solutions, communicating effectively, and learning by oneself). Therefore, we revised the Senior Design course to include these topics.

This paper describes the restructured (“new and improved”) Senior Design course, including: how the student teams are formed, the early design stages, prototyping and test, oral presentations, and conference attendance for the last two years. The students’ evaluation methods and outcomes assessments are also presented. Finally, the problems and challenges in the Senior Design course are discussed. Overall, this “new and improved” Senior Design course helps students to develop many skills which were not previously developed. As one example of a successful student project, “Sense-o-matic Cane: Ungrounded Detection for the Blind” won Second Place in Technology and Engineering at the 2008 HBCU-UP National Research conference.

Introduction

The Computer Engineering Program at the Virginia State University, a small Historically Black Colleges and Universities (HBCU), was established in 2001 as a traditional program of study, with most of the freshman directly graduated from high school. The program underwent ABET accreditation during the 2006-2007 academic year for the first time, and the first cohort of students graduated from the program in May 2006.

Senior Design was initially a one-semester course with multiple teachers. Each teacher taught a distinct section. Each student selected his own teacher/section. Generally there were 3 or 4 sections, each section having only 1 to 3 students. One problem with this initial structure was that the sections were very non-uniform. Another problem was that the class focused almost exclusively on building a working prototype, and neglected the overall process of design (especially soft skills).

In order to prepare our students for the local and globalized workplace, the Senior Design course was restructured during Fall 2007. The restructuring Senior Design course is two semesters
instead of one semester, in order to offer the students an opportunity to apply the skills learned throughout undergraduate education to a real work engineering project.

Further, the teaching has been reorganized into a single supervisory faculty member (supervisor) supported by multiple technical advising faculty members (advisors).

Fall Semester

Starting in Fall 2007, all the senior students (who would graduate in either next Spring or Fall) must enroll in the restructured two semester Senior Design course: Senior Design I in the Fall, and Senior Design II in the Spring.

There is only one section of Senior Design I, and only one section of Senior Design II (instead of multiple sections of each).

The supervisor supervises all projects and determines all grades. The faculty members within the Computer Engineering program take turns being the supervisor. The supervisor is the only faculty member of record.

At the beginning of the Fall semester, students are given an extensive set of guidelines and a comprehensive set of assessment tools and evaluation procedures for the senior design projects.

The first step of design is forming a project team with 2-3 members. Teams are formed freely by students and must be approved by the supervisor. Then each team chooses their own advisor (which cannot be the supervisor). Through lectures and class discussion from the supervisor, students gain knowledge of the product development process, project management, professional engineering practice, and the regulatory, legal, ethical, and economic aspects of design.

The students adhere to an engineering design process that includes early stages of design project development including three design proposals. They must conduct customer surveys to select one best design proposal. The advisor for each project must technically evaluate and approve the selected best design proposal.

The design process provides the students with an important experience in defining and applying their own individual knowledge and skills to a realistic design problem, as well as in being responsible professionals aware of the impact of their work on others. Further, the students develop skills for lifelong learning by conducting literature and patent searches, and by staying abreast of developments in their field of knowledge.

Within the team, students develop teamwork skills (such as leadership, cooperation, and conflict management) by taking turns being the project leader in the different design stages. The students also develop oral communication skills by discussing, listening, and explaining within the team. Each member of a team performs individual evaluations of the other members on the team every week.
Another benefit of this approach is to hardwire the concept of “deadlines” by relating the number of points earned in each step of the project to timely submission of the required documents. Time management, stress management, and dealing with deadlines are among the skills necessary for landing a successful career in engineering. As part of the design assessment, students also have to perform a cost and failure analysis of their design. This gives the students an opportunity to evaluate the real value of their design and to critic their approach.

One major challenge for the supervisor is evaluating every individual student in every team. Certainly, some team members contribute to the project more than others. One of the methods used in assessing a student’s performance within a team is requiring each member of the team to perform individual evaluations of the other members on the team each week. The students must answer questions such as: how well the team members work together, the dedication of the team members, the total time and tasks the whole team worked together on the project, the total time and the tasks the individual worked on the project, and the communications between the team members (how long, in what form, and about what). The supervisor takes these weekly student evaluations into account (10-15% of the total grade) when assigning students’ grade.

At the end of the Fall semester, each team presents an oral proposal, submits a written proposal, and purchases the materials needed for the project.

**Spring Semester**

In the Spring semester, the students integrate the design process into their design projects and focus on product or prototype development as they select the best design solution from their three alternative design proposals.

The design process must address at least three non-technical issues (such as: economic, environmental, social, political, ethical, health, safety, manufacturability, and sustainability) related to the design. During their progress reports, students are required to consider the impact of the design approach they selected compared to alternative design approaches. Each student of each team continues to perform individual evaluations of the other members on the same team every week, and each team is required to consult their advisor on a weekly basis.

As part of their final grades, students must present their projects during the “Students’ Project Presentation,” which is an oral presentation that is organized at the end of Spring semester for students to display and discuss the results of their projects. Each design team also presents their projects at the University Annual Undergraduate Research Conference, the ASEE Southeast Annual Conference student poster competition (optional) and HBCU-UP National Research Conference.

**Course Assessment**

There was no uniform course evaluation for the old design course, because each faculty member used his/her own course evaluation. Therefore, it was hard to assess some of the program outcomes.
For the restructured (new and improved) design course, standard and uniform assessment tools as well as evaluation procedures are developed for evaluating each stages of the design process, which include: approaches to the design process, design alternatives, teamwork, effective communication, and non-technical issues that may impose constraints on the design.

At end of the Spring semester, the supervisor and the advisors evaluate the projects using these standard assessment tools and procedures.

In addition, students are given a set of questions (indirect measurements) at the end of Spring semester, which are used to assess outcomes 2, 3, 4, 5, 7, and 9 of our program mapped to the Senior Design course. Students’ answers use the four point scales: 4-Exemplary (Exe); 3-Proficient (Pro); 2- Apprentice (App); 1- Deficient (Def).

Here are some of the questions:

- This course improved my ability to apply math and science concepts to solve engineering problems.
- My background in mathematics and science is appropriate for this course.
- This course improved my ability to design experiments.
- This course improved my ability to execute experiment procedures.
- This course improved my ability to analyze and interpret data.
- This course improved my ability to identify specific project objectives based on general project and client requirements.
- This course improved my ability to gather and use relevant information.
- This course improved my ability to generate and analyze alternative by synthesizing and applying appropriate engineering knowledge.
- This course improved my ability to design a system to meet desired needs, including hardware and software within realistic constraints.
- This course enhanced my competency to function effectively in a team.
- This course helped me to communicate more effectively and present findings of engineering projects clearly, both verbal and in writing.
- This course helped me to recognize the importance of engaging in life-long learning and of keeping abreast of the latest development in the engineering field.
- This course enhanced my ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table I is the data collected at the end of Spring 2009, which summarized students’ answers to the indirect measurement questions. These questions are grouped and mapped to the program outcomes. The mean is calculated by dividing the sum of the weighted points by total population.

Table I is the data collected for 2008 and 2009 with just the mean shown.
### Table I Summary of Students’ Self-Evaluation (2009)

<table>
<thead>
<tr>
<th>Program Outcomes Performance Criteria</th>
<th>4 Exe</th>
<th>3 Pro</th>
<th>2 App</th>
<th>1 Def</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population by skill level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) the ability to design and conduct experiments as well as to analyze and interpret data</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>3.14</td>
</tr>
<tr>
<td>(3) the ability to design a system, component or process to meet desired needs, including hardware and software within realistic constraints (such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability)</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>3.00</td>
</tr>
<tr>
<td>(4) the ability to use modern engineering tools and techniques to analyze electronics and computer systems</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>3.00</td>
</tr>
<tr>
<td>(5) the ability to function on multi-disciplinary teams</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>3.14</td>
</tr>
<tr>
<td>(7) the ability to communicate effectively and present findings of engineering projects clearly, both verbally and in writing</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>3.29</td>
</tr>
<tr>
<td>(9) the commitment to lifelong learning and keeping abreast of the latest developments in the engineering field</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2.71</td>
</tr>
</tbody>
</table>

### Table II Summary of Students’ Self-Evaluation Mean 2008 and 2009

<table>
<thead>
<tr>
<th>Program Outcomes Performance Criteria</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) the ability to design and conduct experiments as well as to analyze and interpret data</td>
<td>3.04</td>
<td>3.14</td>
</tr>
<tr>
<td>(3) the ability to design a system, component or process to meet desired needs, including hardware and software within realistic constraints (such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability)</td>
<td>3.12</td>
<td>3.00</td>
</tr>
<tr>
<td>(4) the ability to use modern engineering tools and techniques to analyze electronics and computer systems</td>
<td>2.96</td>
<td>3.00</td>
</tr>
<tr>
<td>(5) the ability to function on multi-disciplinary teams</td>
<td>2.80</td>
<td>3.14</td>
</tr>
<tr>
<td>(7) the ability to communicate effectively and present findings of engineering projects clearly, both verbally and in writing</td>
<td>2.88</td>
<td>3.29</td>
</tr>
<tr>
<td>(9) the commitment to lifelong learning and keeping abreast of the latest developments in the engineering field</td>
<td>2.80</td>
<td>2.71</td>
</tr>
</tbody>
</table>
According to the students’ surveys, the program outcome of “the commitment to lifelong learning and keeping abreast of the latest developments in the engineering field” is rated lower than other program outcomes for two years. However, compared to the achievements of the old style course and the new targets set for the course, the ratings of the course objectives for the “new and improved” course are significantly improved over the old course.

At the end of the semester, the supervisor writes a Faculty Course Assessment Report which summarizes the learning outcomes mapped to the program outcomes, the changes made in the course, and the recommendations to remedy the course weaknesses. Therefore, the next faculty who will teach the course can make changes accordingly to address the issues and make continuous improvements.

Conclusions

The restructured Senior Design course provides an opportunity for students to develop technical skills as well as soft skills which are much needed for the work place. The students’ survey also confirmed that the Senior Design course helped them develop the ability to work effectively in teams, to learn project management, and to communicate effectively. Overall, it showed a significant achievement in course objectives as compared to targets set for the course.

The issues that need further work and improvement are: lifelong learning and keeping abreast of latest developments in the engineering filed. Some of the solutions we propose to remedy this problem are: attending more technical conferences, getting students involved in real-world problem solving in collaboration with industry, requiring students to take FE or GRE examinations, and getting more students involved with student chapters of professional societies such as IEEE (Institute of Electrical and Electronics Engineers), NSBE (National Society of Black Engineers), and SWE (Society of Women Engineers).

References

7. Hanson, D., Instructor’s Guide to Process-Oriented Guided-Inquiry Learning, Stony Brook University.