# Capstone Seminar: A one-credit Hour Course Covering the Design Process Implementation

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***Abstract*— This Innovative Practice Work in Progress Paper describes a one-credit hour senior design seminar course. The course is taught concurrently with the actual Senior Capstone Design Experience I course. The development of this course is of a great importance of reminding students of the design process elements since the coverage of this topic in a typical engineering curriculum takes place in the freshman year. This helps students incorporating the design process elements while working on their actual capstone projects in their Senior Capstone Design Experience course. The instructor of the course approached students through picking a specific technology and introduced it during one lecture. Each team was required to find a potential problem that can be solved using this technology and provide statistics that show the importance of the problem. Afterward, the teams incorporated the design process elements in their proposed solution to the problem and pitched it to the instructor as a pretended investor. Individual assignments were also developed to ensure that all students are assessed based on individual and team effort. The paper discusses the need of the course, lectures' content, and assignments. In addition, it provides student feedback about the course, ABET related student outcomes along with their assessment artifacts and recommendation.**

***Key Words*—Senior design seminar, senior capstone, capstone projects, design process, realistic constraints, ethics dilemma.**

## I. Introduction

THE Engineering senior capstone design experience is an essential element of all engineering curricula. It is considered the major culminating design experience that students employ what they have learned in their earlier courses. The offering of the course varies from one university to another. Some institutions offer the senior capstone design experience course as a one-semester course and others as a year-long course sequence.

At Ohio Northern University, the senior capstone design experience is a year-long two course sequence that is common to all engineering programs. The first course in the sequence is a one credit hour course where teams are required to carry out the literature survey about their specific projects, present a proposal of the alternative designs and show the selected design based on selected criteria and toward the end of the semester, they have to order the appropriate parts and components to be ready for the second course in the sequence. The second course in the sequence is a two credit hours course where teams construct and test the prototype [1]. This two course sequence has no associated lectures and different teams are advised by different instructors.

Discrepancy in the advising of the teams is a well-known problem in the literature. For example, Karen Davis reported electrical and computer engineering and computer science seniors at the University of Cincinnati express dissatisfaction with inconsistent levels of interaction and feedback from faculty advisors [2]. Also, Gregory Watkins, from California State University at Chico mentioned that senior exit surveys repeatedly identified advisement of capstone projects as a problem area in the curriculum [3]. This problem is augmented by the fault assumption from advisors, that seniors are well aware of the engineering design process. However, the engineering design process is typically introduced in the freshman design sequence but is rarely used in the sophomore and junior year where most of the core engineering courses are taught. Hence there is a need for a refresher at the senior level.

At Ohio Northern University, students majoring in electrical engineering, computer engineering, and computer science are required to simultaneously take a one credit hour course called senior design seminar with the first course in the sequence of senior capstone design experience. The aim of the capstone seminar course is to give students an overview of the design process while they are working on their actual capstone projects. The design process is presented in details starting with the identification of the need or problem statement, objectives of the design project, literature survey and background, design specifications and realistic constraints, alternative solutions, the selected design solution based on a decision matrix, a detailed level block diagram, design implementation, design testing, and design prototyping. The course also teaches students how to manage projects through the development of project schedule and project budget. In addition, students are required to consider system reliability, think about legal and ethical issues, be innovative and learn from their failure, effectively communicate technical ideas, and work productively in a team environment.

For the above mentioned elements to be meaningful, a set of team assignments were created to cover the course topics. For

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the team assignments, students were divided into multi-disciplinary teams consisting of 2 to 3 students. The instructor picked a specific technology and introduced it during one of the lectures. Each team was required to find a potential problem that can be solved using this technology and provide statistics that show the importance of the problem. Then, the teams incorporated the design process elements in their proposed solution to the problem and pitched it to the instructor as a pretended investor. Individual assignments were also developed to ensure that all students are assessed based on individual and team effort. These individual assignments include finding examples for every realistic constraint covered in class, solving problems on system reliability, analyzing an ethical dilemma, and completing an online module on learning-from-failure.

The paper is organized as follows: Section II covers course structure and coverage. Section III explains the course implementation. Course reflection is covered in section IV. Section V maps the course to the related ABET student outcomes. Finally the conclusion remarks are given in section VI.

## II. Course Structure and Coverage

The structure of the senior design seminar is a one-credit course consisting of 50 minutes lecture each week. It is offered in fall semester of the senior year. The course exposes students to many concepts. It reviews and teaches students the design process [4-6] which includes the following:

***Problem identification***: Students must be aware of the importance of problem identification to be stated clearly to avoid working and building something that does not meet the original need. The problem statement must include the answers for who, what and why questions.

***Project Objective***: The objective statement summarizes what is being proposed to meet the need. It includes the description of the input and output of the proposed system. Implementation description is not part of the project objective.

***Literature Review***: The literature review requires a research of basic engineering and scientific principles, technologies, and existing solutions that are related to the given problem.

***Requirement Specifications***: Requirement specifications concentrate on what the proposed system must do. These requirements are considered the mission statement of the project.

***Realistic Constraints***: Students must be aware of the importance of the realistic factors that constraint their project. Realistic constraints include economic, energy, environmental, health and safety, political, manufacturability, functionality, security, reliability, social, culture, just to name a few.

***Concept Generation***: Concept generation consists of exploring the concepts for the problem solutions through research, brainstorming and other activities. Typically, this results in multiple alternative solution.

***Design Alternatives and Selected Solution***: This step consists of evaluation of the alternatives and the selection of the best solution based on both engineering judgement and decision matrix that incorporates preselected criteria.

***Prototyping and Construction***: Prototyping and construction require partitioning the whole system into subsystems, constructing each subsystem and ensuring that the inputs and the outputs of each subsystem are well defined.

***System Integration***: This step requires that all the subsystems to be integrated to form the whole system. Inputs and outputs of the whole system are defined.

***System Testing***: In this step, the system is tested and must operate and function per the stated requirements and specifications.

***Delivery and Acceptance***: The designed system is presented to the customers with all the deliverables. The customers accept the final product if the project satisfies their expectations.

***Maintenance***: Maintenance requires writing a user manual for the designed project on how it operates, how to trouble shoot the system and how to maintain it.

In addition, the course covers the characteristics of an outstanding oral presentation. Ethics and ethics dilemma analysis are covered and students are assigned ethics cases to analyze them.

## III. Course Implementation

The following activities were implemented in the recent offering of the senior design seminar course. In the introductory lecture, the instructor divided students into teams that consist of two to three students from multiple disciplines. The teams were formed differently compared to the teams in the senior capstone design experience sequence. This gave the members of each team the opportunity to share experiences and ideas that they gained from their respective capstone projects.

The instructor introduced the following project statement to start the course: "*When farmers spray their fields for weeds, they are wasting abundant amount of spray because they spray the whole field. A local farmer asked if there was any way to adapt a sprayer with a camera system that could see the difference between the crop and the weed and only spray when a weed was detected. This would allow the farmer to save money and also it would allow people to feel better about the crop because it would not be getting sprayed with all those pesticides.*"

Students were asked to discuss the feasibility of the above project statement among their own teams and share their findings with the class. Not surprisingly most teams concluded that this project is not feasible due to the complexity of farm fields and the variety of crops and weeds. However, the instructor shared with the students information about blue river technology [7], which was a National Science Foundation (NSF) funded company that uses image processing and deep learning techniques to solve agricultural problems that are very similar to the above mentioned project statement. The hope from this exercise was to ignite curiosity among students to seriously investigate the technology used by the mentioned company. At the end of the introductory lecture, the instructor asked students to individually browse the company's website and write a one-page report that answers the following questions:

- What lessons have you learned from browsing the website?
- Do you think this company will be sustainable without NSF funding?

On September 6, 2017 and while the students were doing their first individual homework assignment, John Deere released a news [8] that they have bought blue river technology for a hefty amount of money. This announcement dramatically increased the students' interest to learn more about the company and its technology. In fact, a number of students were enthusiastic enough to send the instructor emails about the news release upon reading it.

The second lecture covers project objectives and objective tree. Objective tree shows the selected criteria for a given project and the weight of each criterion. At the end of this lecture, the instructor asked the teams to find a problem that could be solved using image processing and deep learning. Teams had to state the problem and support it with statistics, state the objective of solving this problem and create an objective tree. This served as the first team assignment in the course. The list of topics that were picked by the different teams was as follows: Hydroponics, expansion to multiple crops, detecting illegal growth of marijuana, painting road lines, automated sandblasting of boats, irrigation, and sport fields maintenance.

After the second lecture, the instructor started alternating between individual assignments and team assignments. All team assignments were on the fictitious projects that were suggested by the various teams. For the second team assignment, teams were tasked to find two alternative solutions to achieve their proposed objective, compare between them based on their selected criteria to build a decision matrix, and pick the better solution. For the third team assignment, the teams were asked to create a work breakdown structure for their fictitious projects assuming that they are going to do the first prototype within a year. Finally, the fourth team assignment was to prepare a poster that includes the following: problem statement, project objective, functional block diagram of the selected solution, design drawings, schedule, and a test plan.

A lecture was reserved for the different teams to pitch their ideas in an oral presentation. The pitch was restricted to six minutes with one extra minute reserved for questions.

The oral presentation was graded based on a 10% for each of the following elements: problem statement, objective, alternative solutions, functional block diagram, design sketch, schedule, test plan, pitch, visual, and on time delivery. This activity concluded the course team assignments.

The remaining course work was all individual assignments. For the second individual assignment, students were tasked to find one example for every realistic constraint discussed in class. For the third individual assignment, students were asked to take an example of a project discussed in class and partition it to subsystems to form the functional decomposition. The fourth individual assignment was on testing procedures. Students selected a unit from their respective capstone projects and wrote a document for the unit testing procedure in a systematic way. Individual assignment five was on reliability. Students solved problems on finding the equivalent reliability of a system that is created out of various units with different reliabilities that are connected in cascade and in parallel. Individual assignment six was to solve a case study on ethics. Finally, at the end of the course, students were asked individually to take an online module on "Learning from failure". This module was developed by the KEEN network to emphasize the importance of learning from failure in the minds of future entrepreneurs [9]. It included a graded exam that students had to take.

The grading policy of the course is as follows individual assignments were given 40% followed by the group assignments 30%, oral presentations 20% and the online module 10%. These percentages essentially divide the course grade equally between group work that is captured by group assignments and oral presentation and individual work that is captured by individual assignments and the online module.

## IV. Course Reflection

To evaluate the effectiveness of the course, students' evaluations from a previous offering of the course were compared with the evaluations of the most recent offering of the course that follows the implementation described in the previous section. In the previous offering of the course, the same instructor used the same lecture material that is described in section II but had a different format for the course assignments. The list below defines the differences:

1. Teams were generated from members of the same capstone project.
2. All assignments were team based.
3. All assignments were related to students' capstone projects.

The idea was that students could utilize the material they learn in this course to fulfill the requirements of their senior capstone design experience sequence. However, there were a number of issues such as aligning the time schedule of this course with the requirements of the capstone experience sequence. Hence, students were not able to benefit, as intended, from the required assignments in this course to build their final documents for their capstone projects.

At the end of the semester students evaluate the course based on twenty five statements. The first fourteen statements cover the course and the remaining 11 statements cover the instructor. We picked that last statements from the course and instructor sections that points to the evaluations overall:

1. Overall, the course was well-organized.
2. The instructor's overall teaching of the course was effective.

Students were asked to rate these statements between 5 and 1, where 5 represents strongly agree and 1 represents strongly disagree. A total of 17 out of 24 students took the survey in both years when the course was offered in its current and previous formats. The body of students in both years represented seniors from computer science, computer engineering and electrical engineering. Table I shows the result of this survey:

TABLE I

MEAN SCORE OF STUDENTS EVALUATION TO THE SELECTED STATMENTS

| | Q1 | Q2 |
|---|---|---|
| Initial version | 3.2 | 3.5 |
| Revised version | 4.4 | 4.8 |

As shown in the table, there was a clear positive shift in the students' evaluations between the two years. We hypothesize that this shift in the students' evaluation was mainly due to the different assignments format. The team assignments gave students the opportunity to test most of the topics learned in the class in an interesting way. The instructor felt that students were eager to learn about new technologies such as image processing and deep learning and finding new applications that can utilize these technologies. Also the combination of individual and team assignments allowed the instructor to assess the grade of each student based on their individual work as well as their team work. Overall, the authors believe that the current implementation of the course is successful based on the students evaluations and its learning impact on students.

## V. Related ABET Student Outcomes

For ABET accreditation purpose where assessment and evidence of student work are required, the course activities that were described in the previous sections can help in fulfilling some of the stated ABET student outcomes. For convenience, student outcomes are mapped to the different course assignments below:

(1): An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics (team assignments 1 and 4, individual assignment 5).

(2): An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs (team assignment 2).

(4): An ability to communicate effectively with a range of audiences (oral presentation).

(5): An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (individual assignment six).

(6): An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately (individual assignments 1 through 4).

(7): An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty (team assignment 3).

## VI. Conclusion

This paper describes the structure and implementation of a one credit hour capstone seminar course that covers the design process. The purpose of the capstone seminar course is to remind students about design process topics that are typically covered in their freshman sequence while they are applying this knowledge in their senior capstone design experience sequence. The most recent offering of the course implemented a number of team assignments that were based on fictitious projects proposed by students to solve a problem with an important need. The restriction on the proposed projects was to utilize a technology that was introduced by the instructor in the introductory lecture. The course also included a number of individual assignments that helped the instructor to assess students individually and an online module that emphasize learning from failure. The structure and implementation of this course could be easily adopted by other programs in various engineering fields.

The impact of this course on the seniors' use of the design process was clear in the quality of their work. At the end of the senior year, students conclude their capstone design experience by oral presentations, poster session, and written reports. The poster session is attended by faculty and industry representatives. This year, there was significant improvement in the quality of the various formats of presentations as evident by the rubrics used by the evaluators. In the future, we are planning to move the course to the spring semester of the junior year and study whether introducing the course earlier will have a more positive impact on students.

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