

## Capstone Design Courses: A Comparison of Course Formats

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### Abstract

A capstone design project course is a common component of Engineering and Engineering Technology curriculums. There are many possible formats for offering such a course, each with its advantages and disadvantages. The author has taught the capstone design course at three different universities, each with a different format (single term with a single project, multi-term with a single project and a single term multi-project). This paper will discuss the author's experiences with each of the three formats and the advantages and disadvantages of each format. Included will be recommendations to make the course more successful for each format and reasons why the single term – single project format is the least desirable of the three.

### Introduction

Many engineering and technology departments require the students to take a design project course as seniors to serve as a wrap up of the program and provide a comprehensive design experience as well as meet accreditation criteria. The classical format for this design project course is a single project to be started and completed in a single term. However, this design experience can be achieved in many different possible formats. The author has taught senior design in three formats at three different universities. These formats include the classical single term with a single project, a multi-term design course sequence with a single project and a format that had two or three design projects in a single term. Each format has advantages and disadvantages to both students and faculty. This paper will discuss these various formats, each format's advantages and disadvantages, and recommendations that may be considered to enhance the chances of success for each format.

### The single term - single project format

The classical format encompasses a single project that is defined, researched, including design activity, often including building and testing a prototype, and culminating in a final report. All these aspects are to be completed in a fifteen or sixteen week semester. At some institutions that are on a trimester system, such as the one the author attended, all this activity must be completed in ten to eleven weeks. This is an intimidating prospect to many students and faculty alike. Many variations exist to make this process less intimidating and improve chances of success. Some schools define the project topic and parameters for the students instead of requiring the students to create their own project topic. Often these departmentally defined

projects are supplied by local industry. In addition, many schools suggest, or require, that the project be completed by groups of students instead of individual effort. Regardless of the source of the project topics, the faculty must take care that the project is within the ability of the students technically and have a good chance of completion within the allowable time frame. Other disadvantages are also inherent with the single term – single project format.

Often the design project course is taken in the final semester of a student's degree program. This leads to an attitude on the part of some students of "you cannot fail a graduating senior". This attitude often results in minimum effort being applied to the project with resulting minimal learning. The pattern for getting work accomplished often is ten weeks of do-nothing then after many weeks of pleading and threatening by the faculty advisor, the last three or four weeks are a flourish of activity. The opposite is true of students who have a sincere interest in the topic of the project. They tend to spend a majority of their time and effort on the project to the detriment of their other classes. In either case, it has been the author's experience that the faculty advisors bear the brunt of both coaxing students to work and being blamed for the students' poor performance. One last problem with single term projects is that often there is insufficient time to build and test a prototype. With all these negative aspects, there are some positive points in favor of the single term – single project format.

The design project that is to be completed in a single term is usually a more concentrated effort than a project stretched over multiple terms. Some students perform better and learn more in such a concentrated atmosphere. In addition, because of the limited time frame for completion, single term projects are a good group effort activity where students can learn first hand the methods and importance of wise division of labor and group management. Lastly, with the current trend to keep degree credit requirements within limits, a single term project is often a three credit course whereas multi-term projects are often more.

The author's experience with the single term – single project course format are mixed. The shortness of the time frame for completion and motivation of the students have made this the least successful of all the formats. Most successes have been with very self-motivated individual student projects. Some suggestions to improve the chances of success: if the projects are to be ideas of the student's choosing, one key to success is to start the students thinking a term or two before the project is to be attacked about what project they will attempt. A required, therefore part of the grade, aspect of the project is to maintain a weekly meeting with each design group that includes a semi-formal progress report. The first meeting of the term lays out the ground rules and grading criteria along with the scope and intent of the project. Some faculty require a written schedule of activity for the term and a definition of the division of labor among the group members within the first few weeks. These ideas will improve the chances for success and also can be used with any of the other formats.

### The multi-term format

There are various forms of a multi-term project, but the one the author has experience with was a three-term course sequence. This format was used exclusively for projects of the students' choosing. As a result, the first course was a one-credit planning and proposal course. This course was a faculty guided self-study pattern where the students would accomplish three

goals. The first goal was to choose the individuals who would be members of the design group. The second goal was for the group to research the topic of interest to determine what information was available, past solutions to the problem, and a possible solution for their project. This full term time frame gave the students adequate time to obtain off campus materials for review, discuss the project with a faculty advisor, and give serious thought as to difficulty level, scope and appropriateness of the project topic. The final goal of the course was for the students to make an oral and written proposal to a faculty review committee. This report was to include the project problem, intended solution and scope, division of labor, and schedule for completion. The faculty committee voted and determined if the students may proceed in the following term with their project. If the proposal was accepted, the faculty advisor, with input from the faculty committee, would award a grade for the course. If the proposal was rejected, an incomplete grade was given and the students had to repeat the process. Since this course was offered in the spring term junior year, if the proposal was rejected, the students could use the summer to redo the proposal and obtain reconsideration by the faculty.

During the following fall term of the senior year the second course in the sequence was offered. This was a two-credit course with one basic goal. The design and analysis activity was the major focus. At the end of the term, the student group made a second oral and written proposal to the faculty committee that included the results of the design activities and the intent for building and testing a prototype. The grade for the second course in the design sequence was determined by the faculty advisor considering input from the faculty committee.

With the faculty committee agreement, building and testing could proceed. In this case, the final term of the design project was a one-credit course dedicated to the building and testing of a prototype. The term ended with a final written report to the faculty advisor summarizing the full design experience along with the results of the prototype testing and suggested improvements of the design. If the faculty committee did not vote for approval of the building and testing at the end of the second course, then the last one credit course was dedicated to a redesign of the project. In either case, a grade was recorded for this last term's work.

There are distinct advantages to the multi-term format. The author's experience was that students took the whole process seriously. This resulted for a few reasons. First, the specter of a faculty committee review at critical steps along the way encouraged more organized effort and more thorough work. Many students want to get right to the building and testing giving minimal attention to advanced planning or proper design. With this format, the first course stressed planning and the second course stressed designing. The "reward" of building was held for the end of the process after a number of other challenges and design reviews are over come. With the elongated time frame the work is not rushed but at the same time the required end of term proposals demanded a steady pace of accomplishment throughout the term. The consistent pace of work was also encouraged by the students' self generated schedules. The final advantage is that the grading decision is a shared responsibility among the faculty resulting in a more objective grade award. With all these advantages, there are negatives to this format.

The multiple term project course sequence requires four or more total credits. At many universities four or more credits are not available to be dedicated to this type of format. The faculty commitment is for three sequential terms. The same faculty member should be the

advisor for a given group of students throughout the whole process. Faculty turnover and sabbaticals can potentially harm student progress. Lastly, sometimes it was difficult to schedule times for the faculty review committee. Even though all the faculty on the committee were faculty advisors for the design course and therefore the meetings were considered part of the course load, faculty schedules made scheduling difficult, mostly for evening students.

The author's experience with the multiple term format is generally positive with the opinion that this is the preferred format. Just given the extended time frame of three terms relieves most of the pressure on the students and faculty advisor. With the extended time errors and wrong decisions are less devastating. In addition, when the students have to concentrate on other courses, typically before exams, there is flexibility to allow for a slackening of the pace in the design course. The stress on planning in the first course pays dividends during the design phase. The only potential problem is that students tend to think they can accomplish much grander and longer projects than is really possible. This is where the faculty advisor must make the students realize the limits of time and talent available. The other likable feature of the multi-term format is that the students often get to build and test their designs with consideration of possible improvements. The single term formats often do not have time for building and testing.

#### The single term – multi-project format

The multi-project in a single term format is the one currently used in the Purdue University Mechanical Engineering Technology Department. The intent is to provide a “cross-disciplinary approach to capstone application of the principles taught in the design, materials, mechanics, fluid power, and manufacturing undergraduate course sequences. The course utilized a student team work –oriented approach to accomplish three design projects and employed additional faculty to discuss such topics as inventiveness, concurrent engineering, teamwork & supervision, life cycle design, manufacturing cost, product safety, and professional ethics.”<sup>1</sup> A more detailed explanation is related in the paper by Bruce et al. Basically, this three credit course is divided into a lecture section and a student lab section. During the lecture, the various topics noted above are discussed. This aspect of the course could be included in any of the formats. The core of the course is in the three mini-projects that are assigned through the course. Each project ties together two or more aspects of mechanical engineering to give the students the sense of how these various fields that were taught in separate courses are interrelated and interdependent. An example: the author had the students design a soda can crusher for elderly and handicapped individuals that was to be powered by house water pressure. This project included design for strength and deflection, mechanism design, fluid power, fluid regulating and control, and safety.

There are two main advantages of the multi-project format. One advantage is that students are not stuck with the same partners throughout the course. Over the years one of the major complaints the author has received from students is that they either chose or were assigned a “slacker” for the full project experience and this adversely affected their performance and grade. The author requires that no student may have a repeating partner or group of partners for any the projects. Another advantage of multiple projects in one course is the ability to have multiple design experiences. This may be desirable for programs that do not have design throughout the curriculum where the multiple design experiences fill a void in the program. The major advantage of multiple projects in one course is the ability to integrate many aspects of

engineering together. With single project courses, some aspects of engineering may be integrated but with multiple design projects there are more opportunities to integrate more engineering aspects together.

There are two major disadvantages of a multi-project design course. Five weeks on average per project is a very tight time schedule to do design. Therefore, the projects must be very limited in scope and often there is not enough time to build and test the designs. One way to reduce the difficulty level for a project is to have the students redesign a current product or process. For example, once for a first project the author had the students design, build and test a pellet trap for indoor shooting with a pellet air gun that would be easy to remove used pellets, capture all the pellets and securely hold a standard sized target but still have the target easily replaceable. Two current designs were brought into class and tested to see the problems and advantages of each. The students were given three weeks to bring in a prototype to be tested. This redesign project was a good design experience and still allow for building and testing. Another way to make the course better may be to have only two projects.

### Summary

The inclusion of topics on inventiveness, concurrent engineering, teamwork and supervision, life cycle design, manufacturing cost, product safety, and professional ethics could be included in any of the formats. The main problem with any design course format is defining a project that is reasonable in scope for the time and intent. The main problem of single term capstone design courses is time and using the available time effectively. The major problems with multi-term capstone design courses are excessive credit requirements and faculty advisor continuity problems. Considering all aspects the author prefers the multiple term formats for three reasons. First, the stress level for all involved is lower. Second, the “luxury” three terms to complete the research, design, building, and testing provides an unrushed atmosphere where learning and experiencing design and the design process can be stressed. Lastly, only with multiple term projects can there be realistic and consequential check points to assess the students’ progress. The major problems of multiple term projects are an administrative problem that can be resolved with careful planning. Of the single term projects, the author prefers the multiple project format. Integrating the many areas of engineering are important and shorter, more intense projects are an easier format to keep students working at a steady pace and stay motivated. The disadvantages of the single term – single project course format far outweigh the advantages and therefore this is last on the list of acceptable formats.

### Bibliography

1. Bruce, R., Eigenbrod, L., Hosey, R., Stern, H., “Design Application: A Product to meet the need”, ASEE Conference 1998 (CD-ROM).

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Martin Pike is an Associate Professor of Mechanical Engineering Technology at Purdue University at Kokomo. He has over seventeen years of teaching experience in addition to six years experience in industry as a design and development engineer. He earned a BSME in 1977, an MSE in 1981 and Dr. Sci. in Engineering in 1990.