Session 2230

Teaming in Engineering Design Courses

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Abstract

The ability of new engineering graduates to work in teams is a skill that is highly valued by industry. It is reported by campus interviewers and engineers at NASA and in industry that students who have had experience in working in teams as undergraduates more readily adapt to the industry environment and usually advance faster than students who have no teaming experience. Teamwork exercises can be integrated into all levels of the undergraduate experience, but the primary curriculum element that features teaming the design element. This paper discusses the goals of the teaming experiences in the author's design courses and the course features that help these objectives to be met. Aspects of multi-institutional teaming are included in the discussion.

1. Introduction

Capstone design courses are where important parts of the transition from the classroom to real world engineering should take place. The more like the real world we make our design courses, the better is for our students. In creating effective design courses, we should learn from those with experience, both experienced design instructors and design engineers in industry. Teaching design is iterative (like the design process itself) and a what works often depends the institutional learning environment, the design instructor, the available resources, the students, and student interactions with other faculty members and engineers from industry and government.

This paper presents a set of goals and practices that were learned by the author while teaching at the USAF Academy in 1981-82 and while collaborating with 40+ design instructors as part of the NASA/USRA Advanced Design Program from 1985-95. The current multi-disciplinary multi-institutional design activities discussed are part of the Texas Space Grant Consortium's Advanced Design Program - an outgrowth of the NASA/USRA program.

2. Goals for Teaming Exercises in Design Courses

The typical student in a capstone design course is within one to three semesters of graduation. Many students today have come through 16+ years of education in which almost every course was characterized by rules such as (1) do your own work, (2) working together is cheating, (3)

report students who collaborate, etc. The emphasis has been on the work of the individual - with the goal of each student learning the same things from a course.

Of course, no two students will ever learn the same thing from any given experience. Furthermore, in industry, teamwork is the standard mode of operation. The industrial environment usually does not favor the individualist who tries to do the whole job. Thus, in preparing students for industry, we should prepare them to work in teams.

The design course goals listed below overlap, and the overlap is intentional. It is much better to include an aspect of a goal more than once when stating course goals than to miss stating it.

Goal 1: Students will gain experience working in teams. In my design courses, this implies that the students, as members of teams, will gain experience in many team activities, i.e.,

Cooperatively develop a formal proposal in response to a request for proposal - In this activity, students must work to define the real problems associated with a purposefully vague Request for Proposal (RFP). In design, the most important step is to be sure that you understand the problem and are solving the right problem. Many a design has gone astray because of faulty problem definition. Problem definition requires ideas and thought by all members of the team.

Cooperatively develop ideas (brainstorm) about the definition of and possible solutions to their design problem - As they brainstorm, students learn to share ideas, to combine ideas, and to use the ideas of others as springboards for new concepts. Again, students learn to use the combined intellects of the whole team.

Conceive, analyze, and evaluate candidate solutions to their design problem - Here the individual can shine. Various members of the team propose and analyze candidate solutions, presenting them to the team. The team as a whole evaluates the candidate designs.

Cooperatively choose among design alternatives - Teamwork is extremely important in this step of the design process. Team members must present the pros and cons of design alternatives and then choose among them. Members of the team must agree on one or two of the design alternatives. All subsequent team activities will focus on the design alternatives chosen in this step.

Create and present formal mid-term and end-of-term oral design presentations - Teams prepare oral design presentations at mid-semester and at the end of the course. They must present the technical aspects of their work in formal design reviews. Typical team design presentations are about 45 minutes long. Each team member must present a part of each presentation.

Write, edit, and produce formal mid-term and end-of-term written design reports - Teams written design reports at mid-semester and at the end of the course. They must document both their technical work and the management of their work. Each team member must write part of

the report and then the report must be integrated to read as a coherent document. Typical team design reports are about 100 pages in length.

Create posters /models that illustrate final designs - The team is required to develop materials to help "sell" their design to company management and the public. Usually a small subset of the team develops the model and another subset develops the poster.

Conduct peer evaluations of all team members (including self) - Each member of the team is required to evaluate the work of every members of the team. These peer evaluations are used in determining relative grades of members of the team.

Receive grade credit for their work based both on individual and team contributions - It is made clear at the beginning of the semester that the grade of the individual members of the team will be based on both the effort of the individual and the quality of the work (design presentations, reports, models, and posters) done by the team.

Goal 2*: As a result of working in teams on a project, some very important skills will be developed by the students. Students will:*

Develop the ability to find, interpret, share, and evaluate information pertinent to their design task - Design projects require the students to find, understand, and evaluate large quantities of information about many subjects. Every member of each team must find pertinent information, understand it, and interpret as related to the design objectives.

Develop the ability to find appropriate experts, to ask appropriate questions, and to communicate their findings to teammates - The team will often have to consult experts, both inside the university and in industry. Team members must ask questions to obtain pertinent information, understand it, and interpret it for the team.

Develop the ability to define the "real problem(s)", given a vaguely stated design goal, and then to refine and often redefine the "real problem(s)" - Team members must develop a "needs statement" for the design proposal. In this statement, they must succinctly state the design need that their project will attempt to meet.

Develop the ability to break large design problems into smaller problems, to use the team's resources to solve the smaller problems, and then to synthesize solutions of smaller problems into candidate designs - As part of their analyses of candidate designs, team members must develop physical and mathematical models which, when analyzed, will provide information used to evaluate the appropriateness of the candidate design.

Develop the ability to choose cooperatively from among candidate designs in a logical and consistent manner - Teams must learn to evaluate design alternatives as a group. Agreement is highly desirable to ensure a well working team.

Develop logical and consistent presentations of their work - Teams are evaluated twice per semester on the quality of their oral presentations and written reports. They learn to work together to ensure the quality of the final presentations and report.

Goal 3: *As a result of the overall design experience, student teams will develop the ability to define problems, to make assumptions, to develop solutions, and then to evaluate those solutions* ***with a the amount of guidance from the instructor decreasing as the semester progresses.*** *The decreasing level of guidance is very important, since one of the most important parts of teaming in the design environment is to learn to depend on the team and not on the instructor*.

At the first of the semester, the instructor is coach, guide, friend, consultant, and information source for the team. By the end of the semester, the team has taken over its own guidance and the instructor has become more like a "contract monitor" in the research world.

Goal 4: *When possible, student teams will coordinate their designs with designs being produced by students at other universities*.

We often use design projects that are related to design projects being done at other universities. When this is done, we have found it advisable for the instructors to uncouple the designs as much as possible. Students working on highly coupled design projects will often use the fact that they have asked for information but not yet received an answer from another school as an excuse to delay working on their design.

3. Course Features Which Can Facilitate Meeting Design Goals**:**

The following course features can be used to meet the design goals stated above. They are not the only way to meet the goals. These are course features which work in one academic environment with one particular instructor. They may or may not work in other environments. If they work, use them and if they do not - change them or discard them.

1. Choose a variety of design topics and let students choose the project on which they work (sometimes it is necessary to "guide" choices to avoid a team which is too large). Students work harder if they are strongly interested in the problem. Sometimes, with a very interesting problem, a major concern can be assuring yourself that your students are not failing their other courses because of the time they are spending on the design project.

2. Use small teams. Some instructors are comfortable with larger teams, but small teams (2-4 students) work best for me. On larger teams, a student can "hide" and not really be part of the team. On small teams, the contribution of each individual is vital.

   I do not have more than one team working on a single project. I tried multiple teams working on the same project in 1984 and discovered the academic equivalent of industrial espionage. One team put a library call on every reference checked out by the other team.

3. Issue a Request for Proposal (RFP) -- with administrative boilerplate as well as a technical problem. Detail deliverables, presentations, evaluation procedures, management

requirements, etc. Make the RFP a miniature version of those the students will see out in industry.

4. Have the entire class brainstorm every problem. This means that students working on all of the projects contribute ideas to each project. This way there are many ideas to consider.

5. Have teams determine their own structure. Provide the work of previous teams for reference. Using the work of earlier teams as an example of how things should be done is strongly encouraged. Provide information about effective teaming but do not force teams to follow particular procedures. Allow teams to make mistakes and to learn from them.

6. Require that each student team develop a written proposal -- with both technical and management plans. LIMIT THE LENGTH OF THE PROPOSAL (20 pages or less) -- force teams to be brief. Again, suggest that they look at the work of earlier student groups. Teams like the idea of having a short proposal, but about half of the teams find the 20 page limit confining.

6. Provide resource files of specialized information. For the first few years I taught design, each design class started with the same reference set of information -- the university library. Students were gathering good information, using it, and discarding it at the end of the semester. I began collecting such information in a file drawer (now 18 file drawers) and making it available to students in subsequent years. I allow students to search through the files, borrow materials, and place materials back into the files (wherever they think that they belong). I avoid doing the research in the files for the students. They will get many ideas by searching through the files. Teams sometimes miss a really good reference because they didn't look in the files. I point this out to them at a point later in the semester.

8. When possible, coordinate projects with those at other universities in the region. Students can share materials, ideas, etc., across the Internet. A larger school can share resources with a smaller school and really enhance the design experience at that school. However, if the projects are interdependent, a troublesome situation can arise. Students at one school will ask for information from a team at another school. Then the team will use the fact that the information is not immediately forthcoming as an excuse for procrastination.

9. When possible, bring teams from rival schools together for mid-semester design reviews. For several years in the late 1980s, the University of Texas had a very successful arrangement with Texas A & M University. We held a common mid-semester review. Student teams from the other university would make up most of the audience for the mid-semester reviews. The friendly competition was a strong motivational factor that resulted in higher quality presentations and reports.

10. Involve engineers from industry and government as consultants. These engineers answer student questions, provide reference documents, track the design, give feedback to the teams, and attend the final design review. The facts that (1) "real engineers care about the work", and (2) "real engineers critique to the final presentation" are very strong motivating factors. The effect is even greater if the outside engineer attends an early class meeting and discusses the importance of the design with the class.

11. Require mid-semester formal oral and written reports (actually about 60% of the way through the semester). The objective is to have teams to bring their work together, to identify holes in their work, and to get a first draft of the final report into the computer. Have the students on the other teams provide written feedback about the oral presentations.

12. Require end-of-semester formal oral and written reports. Also require posters and models (when appropriate). The final written report must include an executive summary, a technical report, and a management report.

13. Require each student to submit a peer evaluation at the end of the semester. Team members are required to evaluate every member of their team (including themselves).

The information in this paper is presented for those who do not yet work with teams but want to do so. The creation of teaming experiences for your students is a design problem. You must first define your problem, brainstorm, gather information, propose candidate solutions, analyze and test the solutions, revise them, etc. What works for one instructor in a particular environment may not work for another instructor in a different environment.

References:

1. NASA/USRA Advanced Design Program, Universities Space Research Association, 3600 Bay Area Blvd, Houston, TX 77058, contact: Mr. Jack Sevier.

2. Texas Space Grant Advanced Design Program, Texas Space Grant Consortium, 3925 W. Braker Lane, Suite 200, Austin, TX 78759.
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