AC 2008-2759: EFFECT OF PROJECT DEFINITION ON THE SUCCESS OF STUDENT TEAM DESIGN PROJECTS

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Effect of Project Definition
On the Success of Student Team Design Projects

Abstract

Student teams carrying out sponsored engineering design projects achieve widely varying results in a single semester, ranging from research without any real design proposal, through one or more paper proposals, all the way to a functional prototype. Comparing team results with the clarity with which the sponsor defined the project shows strong correlation. This suggests that course faculty can positively increase sponsor satisfaction (and thus willingness to sponsor further projects) by working with the sponsors to develop clear and concise project definitions that provide real opportunities for student creativity.

Introduction

We have previously described[1] a course sponsored by the Institute for Complex Engineered Systems (ICES) at Carnegie Mellon University (a continuation of the former NSF-funded Engineering Design Research Center, EDRC): this is a project-based engineering design course that is open not only to Carnegie Mellon College of Engineering students, but also to the entire campus community.

Carnegie Mellon's Engineering Design Projects Course is unique because it allows teams of upper class and graduate students from several academic areas, including the humanities, business, and fine arts in addition to various engineering disciplines, to work on design projects sponsored by industries, government agencies, non-profits, or organizations within the university. The intent is to give the participating students a hands-on, integrative, multidisciplinary creative experience in the important field of engineering design.

The success of this course is attested to by several project sponsors returning for repeated semesters with additional problems to be addressed by student teams, and by some students taking the course for a second time, usually working on different projects. Students also indicate that discussions during successful job interviews have focused on this course experience.

A key to this success is providing the student teams with projects that are realistic, useful to their sponsors, and of such a scope that the students can make meaningful progress in one semester, feeling good about what they have accomplished and, at the same time, insuring that project deliverables are of value to the sponsors. Experience has shown that the student teams carrying out these sponsored engineering design projects achieve widely varying results in a single semester, ranging from research without any real design proposal, through one or more paper proposals, all the way to a functional prototype. Comparing team results with the clarity with which the sponsor defined the project shows strong correlation. This suggests that course faculty can positively increase sponsor satisfaction (and thus willingness to sponsor further projects) by working with the sponsors to develop clear and complete project definitions.

Project Success Defined

To be successful a project must achieve two goals:
• The project sponsor must receive some output they believe is of value to them
• The student team members must feel a sense of accomplishment

Value to the Sponsor:
There is obvious value to the sponsor if the students are able to actually complete a design and create a working prototype or model of the designed artifact or system. Unfortunately this is not the norm. A single fourteen-week semester often does not provide adequate time, even with six students ideally working ten hours a week, to get this far. Often the students' output is a Final Report that describes what they learned, and what they did to achieve that learning. The students are urged to make these reports as complete a record of their work as possible, including the research they did to understand the problem and possible design solutions, and decisions they made, including why they chose to abandon certain paths. Sponsors have told us that this information is very valuable if they choose to pursue the same project themselves at a later date, since it provides them guidance on what paths might prove fruitful and what paths need not be investigated further.

Any intellectual property resulting from the project belongs to the sponsor, so long as they choose to take appropriate action within a year. The university is not involved, beyond creating a student-friendly Assignment Agreement for each student that the student and a sponsor representative both sign. This agreement gives the company X, and gives the student Y. In case any issues arise, the university's Contracts Office works with the company to arrive at a mutually acceptable Agreement.

Team Sense of Accomplishment
The students need to feel that they have done something meaningful and potentially useful—that they have "accomplished" something worth while. This can come both from themselves and from the project sponsor. They will recognize if they have simply "thrashed" and gotten nowhere. It is up to the team's sponsor representative and faculty coach to try to keep the team focused as they work, to minimize the chance of this happening.

If the sponsor believes that they have gotten adequate value from the students' work, they need to give this feedback to the students. This can come from the sponsor's representative to the team. It can also come, much more strongly, by having the team present their results at the sponsor's facility to a group of interested engineers and managers. The project sponsors are encouraged to have such a presentation immediately after the course has ended.
Part of the students' sense of accomplishment comes from the grades they receive. Each student's final course grade consists of three parts, based upon input from the sponsor's representative, from the faculty coach, and from the other team members. The first two of these lead to a team grade that is the same for all the students on the team. The sponsor input is the most important; the coach may agree or may make an adjustment based upon the coach's academic experience. The sponsor representative is provided guidance, to grade on a combination of the usefulness and completeness of the design and upon the way the team worked on the project. Following a process often used in industry in determining team bonuses, the

team members are asked to rate one another, giving extra credit to a team member who contributed at a notably high level and/or less credit to a team member who did not contribute adequately. If any team member is rated especially high or low, their individual grade is modified appropriately from the team grade.

Implementation

Identifying Potential Sponsors:
Over the eight-year life of this course we have learned about potential projects in a variety of ways, including

- Current project sponsors who wish to continue with the same project or a new one;
- Former project sponsors who wish to sponsor another project;
- Companies that ICES has developed other relationships (e.g., research contracts);
- Potential sponsors identified by course faculty;
- Word of mouth.

This latter group includes companies, non-profits, and even individuals with an interest in engineering design education as it applies to product and/or process development. All of these clearly fit under the umbrella of networking. To date, we have not attempted any formal advertising, either targeted or general.

When a potential sponsor has been identified, the next step is to provide them with more details about the course and the characteristics of previously successful projects. We show our Course Description to those who are unfamiliar or only marginally familiar with the course:

The concept of the course is that multidisciplinary teams of 4 to 6 students work together on projects sponsored by industries, government agencies, non-profits, or university units. Past projects have been provided by such diverse sponsors as Eaton Cutler Hammer, Medrad, Mine Safety Appliances, Westinghouse Electric, the American Respiratory Alliance, the U.S. Federal Aviation Administration, the Carnegie Mellon Entertainment Technology Center, the Carnegie Mellon Architecture Dept., and an individual alumnus who wanted to create a restaurant offering the "perfect Southern Barbecue". The design tasks have ranged from devising a means for more easily giving injections to medical patients to simplifying the design of a unique computer game console.

As they work on their projects, student team members learn and then put into practice Teaming, Project Management, Product Realization, Ethics, and other skills practiced by product developers in industry.

A typical team may have three engineers from different academic departments (perhaps two undergraduates and a graduate student), an undergraduate industrial design student, and a graduate student in the English Department's Professional Writing program. We have also had architecture students, art students, Human-Computer Interaction Institute students, and business majors in the class. Students from all fields have had exciting experiences working together, applying all of their varied skills and experiences to address the many aspects of a "real world" problem.

Potential sponsors who at this point believe there might be basis for their participation in the course are invited to discuss what sort of project they might want to sponsor, and the level of involvement (financial and direct support) that would be expected of them as project sponsors. These areas are discussed below.

As pointed out in the above description, sponsors have represented corporations, government agencies, non-profits, and the university community. Most sponsors have been local, who can work closely with the students.

Selecting Projects:
As we discuss with a potential project sponsor the sort of project they might offer to a student team and what they can expect to receive* at the end of the project, we emphasize the importance of student experiences, including:
• The need for projects that can be brought to "successful" conclusions (see above) in one semester (or two)—including a physical or CAD prototype if possible;
• The need to engage all members of a multidisciplinary team; and
• The need for projects that can be attacked using the project management and design tools presented in class.

In addition to favorable project characteristics, we stress the need for full and meaningful participation by students regardless of their disciplines. In general, all of the members of the student team want to:
• Believe that they can contribute to the project
• Have the opportunity to be creative
• Be challenged but not overwhelmed
• Feel at the end of the semester that they have accomplished something real and tangible
• Have "fun" carrying out the project

We ask that the sponsor give serious consideration to how the results will be useful to them, and be supportive of the course, the project, and the student team

Sponsors benefit from successful projects by receiving "useful" results for their contribution of ideas, time, and money. Results are typically unencumbered by limitations imposed by corporate cultures and are typically described by company sponsors as evolutionary, as opposed to revolutionary, solutions. In addition, companies benefit by receiving regular and positive exposure on campus, as well as access to students in a situation similar to the work environment. As such, the course projects provide sponsors with the opportunity to observe student personalities, work habits, and skills as a prelude to hiring. Several project sponsors have hired students (for summer internships and full-time positions) after observing their performance in the project course environment. Likewise, students have the opportunity to learn about job openings and the culture of a given industry or corporation before accepting a job.

Getting the Student Teams Started:
When all this has been done, and the student teams are set to start work on their projects, are there specific steps that can be taken to maximize the student experience, and thereby maximize

the sponsor's value? The answer appears to be "yes." Two strong influencing factors, beyond having an exciting, well-chosen project and a client representative who works closely with the students (e.g., meets regularly with the students, communicates openly with them, keeps them on track, etc.) are:
• The expectations created by the sponsors as they describe the projects to the students
• The way the course structure leads the students to start their project work

The students first hear very brief summaries of the projects in the second class period, shortly after they have been formed into multi-disciplinary and diverse teams. During the third class period, the project sponsors present ten-minute descriptions of their projects, with some time allowed for students to question each sponsor. With the expectations thus created by the project sponsors, the student teams are asked to each identify the project they would like most to work on, and the project they would like least to work on. The course faculty will match teams with projects based upon these votes. Happily, over several years most teams have gotten to work on their first or second choice projects, and no team has been asked to work on their least desired project.

The students have already been told that as soon as possible after being matched with projects they will need to:
• Come to agreement with the sponsor on exactly what they are to do
• Propose and agree to what is wanted functionally
• Establish and rank order goals (objectives)—in discussion with their stakeholders
• Ditto for constraints

The intent of this is to prepare them for their first meetings with their client representatives, which take place a week later (after a team-building activity) by focusing on the need to agree to a clear, well-understood definition of the project—what the sponsor wants them to accomplish in their semester of work.

In order that the students in a project-based course learn the concepts and methods being taught, and also to help insure the success of the project, it is necessary for the students to keep their focus on design processes. The students are eager to get started, and if left unchecked they will begin right away "tinkering" or "playing" with the project. The students need to be presented a methodological approach in order to avoid this free-for-all. By providing guidance to the desired content of the periodic status reports (every other week in the subject class), it is easier to keep the students focused on the processes. It is also easier to detect if a student team is moving away from the direction necessary to successfully complete the project.

Early in the semester student teams may rebel against adhering to strict process guidelines, as it appears to them that they have reduced ability to be creative. They will usually discover later that following the recommended process allows them to be most creative when they need to be—when they are actually executing their design.

The Value of a Good Experience:

Several benefits accrue when a project sponsor and student team have a "good experience" — when a project is "successful". Beyond the outcomes described earlier, a sponsor having a good experience is an invaluable aid to obtaining future projects. Once a sponsor has had a "successful" project experience, it becomes much easier to enlist them to sponsor another project. This is especially true if the sponsor's representative who worked directly with the students has had a good personal experience. Such an individual either finds another project in their own organization, so they can remain involved with the course for another semester, or they become our advocate, encouraging their management to find another project to sponsor—even if someone else will be the person to work with the students.

Historical Examples

The Range of Project Definition Experiences:
Over the eight years this course has been offered, we have seen possibly the full spectrum of project definitions. Important examples are:
• A project that is so tightly defined that there is little or no room for creative contributions by the students; all that remains to be done is to implement the design.
• A well-thought out, well defined project, with clear and understandable Objectives and Constraints.
• A partially-baked project that is sufficiently clear in the client representative's mind that over the first few weeks the Objectives and Constraints emerges and is pinned down.
• A project that seems well defined, but for which the client representative modifies the project definition a few weeks into the project.
• "Come visit our facility, talk with engineers, and figure out a project to do."

The experiences of student teams working in these several modes indicate that there is a positive correlation between the degree to which the project is well-defined at the start and provides opportunity for creative contributions by the students, and the results the students obtain—including satisfaction with the overall experience.

Example Project Experiences:

Company A
Company A has been a sponsor for several years. Their projects have come from their Advanced Development organization. Each problem has been a real problem of interest to them, but for which they had not yet found time and dollars to undertake.

Over their time of sponsorship, two different senior development engineers have been the primary client representatives; the first continued until a promotion brought him additional responsibilities, after which his place was taken by the second.

Each of their projects has been brought to the students well defined but with plenty of room for student contributions. An example: "devise to means to provide safe wireless connectivity to operate a device inside a cage that blocks radio signals." The environment was defined, the users were defined and described, any unusual issues (e.g., working in a harsh environment) were described, and the goal was clearly stated. The students were shown the manufacturing facility

and the use environment, and given the opportunity to speak with potential users. Apparatus with which their device would interact was made available to the students, to examine and to test with. Throughout the semester the client representative stayed in very close communication with the students.

The results for these projects have included several functional prototypes, which could be shown to others in the sponsoring company as proofs of concepts. At least one has led to a patent application, as an innovative solution with true potential for the company.

Company B
Company B has also sponsored several projects. Most have been well defined, but one semester their representative actually said to the students that they should "Come visit our facility, talk with engineers, and figure out a project to do." This was entirely too ill defined. The result was as might be expected: the students, who started out knowing nothing about the company or its products, floundered. It was not until the semester was nearly half over that the client representative helped the students pin down something on which they could work. In the end they provided the client with some useful research results (useful if the client were to undertake the same project), but that was all. Happily this happened only once; since then they have sponsored several very successful projects.

Company C
Company E posed the question, "What sort of sensor might people wear that would do something useful for them?" The students appeared to be thrashing about, considering sensors to measure different types of inputs (e.g., acceleration, heart rate) as well as different ways people might (and perhaps do) wear sensors. The appearance was that the problem was too wide open for fur students to adequate work in fourteen weeks.

Lessons Learned

A guidebook[2] was developed principally to provide the students concrete examples of what we were looking for from them. Students generally do well from examples. Good examples exist in our Lire database[3] a repository of former projects, but— some students have tended to find the worst of examples and use them. The information would decay as students used previous semester examples (often the worst ones) and then continue this semester after semester. A guidebook was also developed so that corporate sponsors had an understanding of what to expect as a typical result from the course. It would provide context to our descriptions. Otherwise, their expectation was likely to be different from what we knew the students would be able to produce. Some sponsors would expect a working prototype of a product. Some expected almost complete specifications such that they could begin mass production the day after the final exam.

The guidebook contains standard status update reports. Our projects differ from semester to semester and within a semester. If the status updates are open-ended as well, it is hard to determine how well a project is progressing. Many early experiences were with student status reports that would "snow" us and try to dazzle us with lots of information while in the end being very off track. If the projects are not standardized, the status reports have to be in order for the faculty to effectively manage the entire class toward success. A potential down-side of this is

that the students may slavishly follow the examples provided to them. This was observed in one set of Status Update Reports after the guidebook was distributed, where the students copied precisely the format presented in the guidebook, without fleshing that information out with specific detailed information about their current status, good or bad.

It is difficult to temper the sponsors as well as the students. There needs to be enough intellectual merit to the project to engage the students. Too many times the sponsor would be looking for "slave labor". We began to realize that when the sponsor would claim that their project was "different" from what was presented in the guidebook it meant a red flag. As a product design class, the sponsor would claim that what their project was about was not a "product" exactly. Special is ok, but we wanted to emphasize similarity among the projects. This will allow for reproducibility of the results from students such that they can extrapolate an approach to doing project work in the future. To just do the project would be useful, but not as intellectually significant. Sometimes the sponsor cannot understand how to phrase their project as a product. This is not always a slave labor project, but can happen with a new sponsor that does not understand how to describe their need. The hardest product to describe is the "version 2" product-- to extend an existing product or product line to produce a new product.

All sorts of efforts to create something can be viewed as design projects. Creating a new college course, or even writing a professional paper, can be regarded as a design project, to which standard design methods and tools can be applied. Thus learning and then using good design methods and tools on any design project provides useful learning that can be applied to future projects. In a course like this, it is the process that is most important to the students. This can be difficult for them to understand; it can be difficult to get experienced engineers to understand the value of focusing on the process they are using instead of just on the immediate project.

Conclusions

It seems clear that there is a positive correlation between how a project is defined to the student team that is to work on it in a project class, and the success of the student team in achieving the goals of the project.

This implies that course faculty can positively increase the value of the experiences of both the sponsor and student by working with the sponsors (a) to insure that proposed projects provide real opportunities for student creativity, and (b) to develop clear and concise project definitions. This can have the further benefit of increasing the sponsor’s willingness to sponsor further projects).

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