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Student Team Formation and Assignment in a Multi-disciplinary Engineering Design Projects Course: a Pair of Suggested Best Practices*

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Over the 7 years in which Carnegie Mellon University's multi-disciplinary Engineering Design Projects course has been offered, the processes for forming the student teams and then associating the teams with client-sponsored projects have matured into what we believe are a pair of best practices. This paper describes our suggested best practices for team formation and associating teams with projects. Further sections describe the path we followed developing these processes and compare our processes with some benchmarks.

Keywords: Design Projects; Multi-discipline Teams; Student Teams.

THE SUGGESTED BEST PRACTICES

CARNEGIE MELLON UNIVERSITY'S College of Engineering (which retains the old name, Carnegie Institute of Technology) sponsors a seemingly conventional Engineering Design Projects course that provides an opportunity for students to have a realistic multi-disciplinary experience. The class organizers recruit students from across the university community, assign them to multi-disciplinary and diverse teams, introduce them to industry-based project management and product realization process tools, and turn them loose on sponsored projects.

In response to client, student and faculty observations of project and process successes and to further the goal of providing the students a multi-disciplinary team experience, the organizers have over the life of the course evolved the processes for team formation and associating teams with projects into what we believe to be best practices.

Team formation

The initial team compositions should be established before the class meets for the first or second time. The process begins with the Course Director obtaining the detailed class roster, which shows majors and class years along with student names. The list needs to be re-ordered by academic major, starting with the engineers (in order of declining cohort size) and continuing with the non-engineers. Within each cohort the students are ordered by class year, to further support team diversity. Based upon the number of committed projects and the desired team size of 4–6, the appropriate number of teams is set up and the process of assigning students to teams is begun.

It is important to note that at this point there is no basis for associating teams with projects. Project selection comes after the teams are formed. The students are distributed to the teams cyclically, by discipline, one at a time, until each cohort has been fully assigned. Then the next discipline cohort is distributed in the same manner, beginning with the team following the last team to which a member of the previous cohort was assigned.

Consider this example: assume that there are 11 electrical engineers (ECE), eight mechanical engineers (MEG), two civil engineers (CEE) and a materials engineer (MSE). The total number of students is 30; they can fill five teams of the ideal size of six students. The first 10 ECE will be assigned in two cycles, resulting in two per team; continuing the cycles, the 11th ECE will be assigned to team 1. Then the MEG are distributed, starting with team 2, until all are assigned. By the time all of the MEGs are assigned, team 4 has two MEG members. The two civil engineers and the materials engineer are then assigned to teams 5, 1 and 2. The starting assignments would thus be:

- team 1: 3 ECE, 1 MEG, 1 CEE;
- team 2: 2 ECE, 2 MEG, 1 MSE;
- team 3: 2 ECE, 2 MEG;
- team 4: 2 ECE, 2 MEG;
- team 5: 2 ECE, 1 MEG, 1 CEE.

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At this point two teams have five members each and three have four.

The non-engineers are next distributed, ideally with no two from the same discipline on any one team. Say the eight non-engineers include two industrial designers, one business major and five writers. Assigning one writer per team leaves three more non-engineers to distribute among teams 3–5. It seems to make sense to put the designers with the teams having more mechanical engineers, since they are likely to end up being interested in projects which provide opportunities for their two sets of skills. Similarly, the business student could fit well with the lone mechanical engineer and civil engineer. The result is five teams of six students:

- team 1: 3 ECE, 1 MEG, 1 CEE, 1 writer;
- team 2: 2 ECE, 2 MEG, 1 MSE, 1 writer;
- team 3: 2 ECE, 2 MEG, 1 designer, 1 writer;
- team 4: 2 ECE, 2 MEG, 1 designer, 1 writer;
- team 5: 2 ECE, 1 MEG, 1 CEE, 1 business major, 1 writer.

At this point the team rosters are examined to further the goal of having as diverse teams as possible. This is based upon the two dimensions of diversity that are reasonably (albeit not completely) identifiable from the class list of student names: gender and cultural heritage. Consider gender as an example. Potential shifting of people is first done within disciplinary contingents: if team 2 has two female ECEs and team 5 has no females, one ECE student could be swapped between these two teams. A second stage would involve minor rearrangement of the mix: perhaps team 1 has three ECEs, one MEG and two females, while team 4 has two ECEs, two MEGs and no females. A female ECE from team 1 could be swapped for a male MEG from team 4, resulting in team 1 having two ECEs and two MEGs and team 4 having three ECEs and one MEG. With no loss in the overall multi-disciplinary character of the teams, diversity will have been improved.

Simultaneously with this is a check and correction for possible concentrations that might inhibit the goal of having people who will approach problems differently. Perhaps one team has more graduate students (journeymen, in terms of level of experience). There appears to be value to switch people within a disciplinary cohort among teams, to better spread the more experienced students among the less experienced undergraduate students (apprentices) [5]. This might, for example, entail swapping an ECE grad student from team 2 with an ECE junior from team 5.

The last intentional perturbation is to see if there are chances to switch within a discipline cohort to get better spread of problem-solving styles on each team. Myers-Briggs type or Jungian temperament might be employed. The needed data can be obtained using some self-evaluating questionnaire, e.g. [13], perhaps during the first class session. Altogether, this process supports the concept that multi-disciplinary teams should be formed primarily on the basis of the skills sets of the participants [11], applying other criteria only after this primary goal has been achieved.

Fine tuning.

Once the teams have been associated with projects, there may be pressure to permit some rearranging of the teams. Perhaps an individual reluctantly has gone along with their team's project preferences, despite an obvious or strong affinity for some other project. Examples might be the materials engineer who really wanted to work on the one project with a strong materials-selection component but whose team expressed its preference for and got assigned to, an integrated hardware + software project. So long as the multi-disciplinary nature of the teams is not severely compromised, it may be wise to permit a small number of team trades to support cases like this.

In addition, if the inevitable early withdrawals by a few students who really wanted to take another course but elected the project course as a place holder until and unless they later were cleared from a wait list makes one team too small to be successful, one or two transfers may be warranted.

Associating teams with projects

Soon after teams are formed, perhaps in the following class session, have the project sponsors present their projects in sufficient detail that the students can form opinions about which projects they would like to work on. A ten-minute presentation followed by up to five minutes of Q&A seems to work. A reason for delaying this step until the class session after teams have been formed is that it may prove useful to have the team members get to know each other by concluding the team formation class session with a simple team building activity.

After all of the project sponsors have made their presentations, ask each team to identify both its 'would like most to do' project and its 'don't want to do it' project. Even when discouraged from doing so, some teams provide even more information, like their 'number two' and 'next-to-last' projects; this added information can prove to be useful. How well may this work? In most of the seven semesters in which this approach was used, most teams got to work on their first choice projects. Two semesters it was four out of five. So far, no team had to work on the unwanted project.

While it is more important to have variety on the team, it may prove useful to permit some minor switching, to match an available talent with a needed skill. Interestingly, people do not always take advantage of this. For example, in a recent semester a materials engineer did not change teams to get on project focusing on an application of polymers. He chose instead to remain with medical device project that his team had picked as its first choice.

CONTEXT: THE COURSE

The goal of this course is to offer Carnegie Mellon students an opportunity to experience carrying out an industry-like design project in a truly multi-disciplinary and diverse environment.

The process begins with engaging project sponsors (clients) during the previous semester and then recruiting a suitably multi-disciplinary class. The principal difficulties in achieving the course goal are constructing student teams that are truly multi-disciplinary and diverse and matching them with projects. Once the students have registered, the processes of team formation and associating teams with projects can be started. Over the seven-year life of the course the processes for carrying out these two tasks have been evolved to what appears to be a stable and successful model.

A presentation at the 2004 ASEE Annual Conference [17] discussed this course in general terms and one at the 2006 ASEE Annual Conference [18] discussed it more specifically with regard to finding appropriate projects.

CONTEXT: RECRUITING A MULTI-DISCIPLINARY CLASS

The intent is not just to have students from several engineering disciplines working together, but to have engineers work together with industrial designers, architects, technical and professional writers, business students, etc. This to a large extent mimics the modern industry experience, where a product realization team may include, in addition to a variety of development engineers, manufacturing engineers, purchasing agents, someone representing the maintenance function, a marketer, a technical writer, etc.

To achieve this goal the course is open to and advertised to juniors, seniors and graduate students in most academic departments on campus. (We have so far ignored drama and music majors.) In a typical semester the class comprises mostly seniors, some juniors, a few MS candidates and an occasional PhD candidate.

Limiting the class to juniors, seniors and graduate students enables the class (and the project sponsors) to capitalize on the special abilities of students categorized by Bransford as expert learners. [2] A student's familiarity with subject material influences how that student may digest course curriculum contents and respond to both formative and summative assessment in a subject-specific classroom. These expert students exhibit specific academic characteristics that influence how learning occurs.

Bransford identifies an academic expert learner as a person who has developed topical insights due to exposure to ideas within a specific field. These insights positively influence how the student thinks, feels and responds to subject material. [2] This is caused by an alteration in how the student perceives situational information, analyses the data and responds to the academic scenario. Such a student is able to more efficiently weed out extraneous information and focus on germane data, organize information in a practical manner and both quantify and qualify the situation. An expert learner will have stored information, which has been portioned and categorized into various organizational hierarchies that are easily accessible for situational analysis and application.

Expert learners exhibit higher-levels of subject-specific understanding. (Recall Bloom's *Taxonomy*, in which there are both low-levels of understanding based on memorization of facts and theory and high-levels of understanding based on evaluation and synthesis of ideas [1].) To apply this highly organized data to new situations (a high-level, advanced method of thinking), the student expert draws upon schemas. Schemas are informational skeletons; they are representative of different situations that can help the student determine how best to relate to a new problem situation [20]. By extracting from pre-developed schemas, the student expert can better understand and respond to new academic problem scenarios.

Although the directors of the class cannot control the variety of the student roster, different students will be expert learners in their different fields, with varying levels of experience.

The course is an elective, so there is no guaranteed pool of students. It is not listed in any academic department's registration lists of available courses, only in a fairly short list of classes sponsored by the Engineering School. It is thus necessary that we take extraordinary measures in order to attract the desired combination of students. We:

- advertise the course to all of the engineering departments by sending several posters to the Dept Head and/or to key faculty members who work with undergraduates or who have recommended the course to students in the past;
- advertise the course to the School of Computer Science, particularly to the Human Computer Interaction Institute;
- advertise the course to the Mellon College of Science, the Tepper School of Business and the H. John Heinz School of Public Policy and Management, by sending posters to undergraduate coordinators;
- advertise the course to the Departments of Architecture, Design and English, by sending posters to a known key contact in each department;
- enlist our participating faculty to advertise it to their contacts;
- urge students who have taken the course and thought it to be valuable, a good résumé item, fun, etc., to encourage their friends to take it.

We typically conduct a round of advertising just before course registration time. We have recently added a second round as the students are returning to begin the new semester: we provide the Assistant

Dean of Engineering for Undergraduate Studies with an e-mail description of the course that he forwards to all junior and senior engineering students. This generally brings in a few more students.

We get a reasonable mix of engineering students, rather proportional to the sizes of the several departments, with some extras who have been urged by participating faculty to take the course.

We get a very varied group of non-engineers, depending in part upon how many other project courses are being offered to them in a given semester. A good example of this is industrial design, for which we almost never get a person in the spring semester, when they have a large number of desirable departmental project options for their own students. The technical writers and professional writers in the English Department (both undergraduate and graduate students) appear to be strongly influenced by colleagues who have taken the course and had a good (or not-so-good) experience.

Given the selection of students who have registered for the class, the next task is to form as diverse and multi-disciplinary a set of teams as we can, ideally comprising four to six students each. Our diversity options are gender, class year (junior, senior, MS candidate, or PhD candidate) and, to a minor extent, psychological type. Our multi-disciplinary options include the several engineering disciplines and the various non-engineering majors.

We have so far found no reasonable means to recruit for diversity, beyond asking faculty with an interest in diversity to inform a diverse audience about the course.

PROCESS DEVELOPMENT: TEAM FORMATION

In the first seven semesters, team formation and project assignment were done simultaneously. Projects were described by their sponsors at the start of the first class period, after which students could question the project sponsors to learn more about the projects.

The first time the class was offered, this process ended with each student turning in a paper listing (in order) the projects on which they would be interested in working. Students were also asked to put on the paper the results of an on-line Meyers–Briggs-style test they had been encouraged to complete before the first class. Before the next class session, the Course Director formed teams based upon student preferences leavened with consideration of the students' psychological types. This enabled the student teams to meet together, with their clients, when next the class met.

The psychological type results played a sufficiently small part in the team creation process that this was not repeated again for several years, at which time it was used only for fine tuning.

Without this complication, in the second semester the process was changed to have most of the team formation occur during the first class period. After the clients made their presentations, they dispersed to the corners of the classroom and the students were encouraged to visit with each, to ask more questions. The students were asked to pick a preferred project and sign their name to a paper held by the sponsor of the project. The course director took these papers home, made some adjustments to balance team sizes and notified the students by e-mail before the second class of their project team assignments. A student taking the course for a second time was granted the priority to stay with the same project, if desired.

This same process was repeated the following semester. The general sense after two semesters was that since the teams really could not be finally formed during the class session, it was better to return to the earlier mode of having the students indicate their project preferences and the course director would form the teams after the class. One attempt at improving the process was to have the students not only indicate their preferred projects, but also to state the reasons for their choices and the strength of their preference feelings. This gave the course director more information on which to base team assignments. It also formed the basis for some consideration of creating multi-disciplinary teams, by choosing to which teams to assign students whose preferences were not strong.

This method was sufficiently successful that it was used three more times. There was, however, an undercurrent of discontent among students who were not assigned to their first choice projects. More significantly, this process did not result in the most multi-disciplinary teams that might have been possible given the class composition.

This led to a major change the eighth time the course was offered. The first order of business, carried out by the course director in full view of the class, was to form the teams. The method used was first to order the students by college and then by major. This was done using an MS Excel spreadsheet projected on a screen at the front of the classroom. This ordering first placed all the engineers before students from any other college and then within the engineers put the electrical engineers first, followed by the mechanicals, etc. Once this was done, the course director did a count off on the spreadsheet: there were four projects, so the numbers one through four were assigned moving down the list of students. All the students who were assigned number one became team 1, etc. This assured maximum diversity of academic majors on each team.

With this process, associating teams with projects was separated from team formation. The ongoing evolution of this latter process is discussed later in the paper. This process has been used since, except that assigning the students to teams has been done out of class prior to the second-class session. This has allowed time for an introductory lecture on team formation, an in-class psychological type test and a second, brief team-building activity. The current process is described in detail above.

Benchmarking

Faculty responsible for three other project courses involving engineering students working on industry client-sponsored projects were consulted, to understand how they form the teams in their classes. An important difference from the course being described is that in each of these examples the students all come from a single engineering discipline. One course lets the students form their own teams [20]. They do this while the clients are describing the projects, so there may be some 'we'd like to do this together' element.

In the other two courses [4,7], the teams are formed of students who have indicated their preferences to work on particular projects, where possible giving students their higher choices. In one course each student is given the option to name one other student who they want to work with and one student they do not want to work with.

In some similar project courses, psychological type plays a larger role in team formation [19] or in team development [3]. None of the three courses cited for comparison use psychological type information to help form teams. Student backgrounds—industry experience mainly, but also gender, foreign or US national/resident (big challenge for defense related projects), etc.—are considered.

Doepker [4] said that previously they selected teams ahead of time and then had the teams select the projects, but that this approach was full of problems. Some students did not get the project they wanted and more or less lost heart. The target team size of 4–6 meets the criterion found by Hunkeler and Sharp [5] were the most important among several criteria they considered (e.g. academic record and learning style).

Fine tuning

From time to time a situation arises in which an individual reluctantly has gone along with their team's project preferences, despite an obvious or strong affinity for some other project. Examples might be the materials engineer who really wanted to work on the one project with a strong materials-selection component, but whose team expressed its preference for and got assigned to, an integrated hardware + software project. It has been class policy to permit a small number of team switches after project matching, to support cases like this.

It is, of course, easiest to manage if, for example, on the project team matched with the materials selection project there is the class's lone Human Computer Interaction Institute student. Lacking this obviously synergistic exchange of students between teams, the best alternative seems to be negotiation among the involved parties. There have also been times when these seemingly mismatched students did not want to switch projects, but chose instead to learn all they could from the project with which their team was matched.

A dilemma

Circumstances have led us to conclude that it is best not to form the teams until the second-class session at the earliest, to minimize the impact of our experience of what may happen next.

Just as the class and the teams seem to be settling in place for a productive semester, 'the best laid plans gang aft aglay' (to quote the Scottish poet Robert Burns), as a few shoppers and others quit:

- By shoppers we mean students who have in some way or another signed up for more courses than they want to actually take, with the idea of assessing the climate of each during the first week and selecting the one that they feel best meets their needs. They may look at who else is in the class, what the specific projects are and with whom they are teamed. There are also some students who sign up for some course as a backup for another course they would prefer to take, but which appears not to be available to them. As an example, a student reasons that 'I really want class A, but I got put on the wait list for it, so I'll sign up for class B. If Class A opens up, I'll quit class B so that I can take class A. Otherwise I'll go ahead with class B'. Electives like this Engineering Design Projects course are often class B, as the potential class size is large enough that there is almost never a wait list.
- Others have less well-defined reasons for dropping a class. Two recent examples are: (1) a student discovered after classes started for the semester that the Engineering Design Projects course did not meet some need to complete graduation requirements; (2) a student discovered after classes started that the Engineering Design Projects course with which she overloaded would involve more work than she had expected and might threaten her outstanding GPA.

Hopefully none drop because they are on the wrong team. Preventing this is one reason a few last-minute individual team changes are permitted.

The impact of these losses, of course, depends upon how late the dropouts occur, how the people who drop the course have been distributed among the teams and how well the other teams are progressing along the forming-storming-norming-performing path [16] to working effectively together. The departing students are usually engineers, who are trying to optimize their programs.

If one student drops from each of a couple of teams, little harm is done to the developing teams. Should multiple students drop from one team, things can become difficult if that team is left with too few members to successfully carry out their project.

Responses to this extreme attrition can take several forms, including:

- Recruit someone to switch from another larger team. The better the teams are cohering, the harder this becomes.
- Allow the team to continue with its reduced membership. This requires agreement among the team members, the client and the coach, that the remaining team members can make an adequate contribution over the semester. Their multi-disciplinary experience is diminished, but the client anticipates a useful outcome.
- Cancel the project and distribute the remaining students among the other teams. This disappoints the client, but is better than investing energy (and dollars) in a team too small to produce any useful outcomes.

In a recent semester, one team was reduced through last-minute attrition down to two engineer members from different disciplines. After a good amount of head holding, they agreed to continue with the project—albeit with reduced expectations for the outcome. They also agreed with the client to hire, part time, an industrial design student to complement their own skills. The client reportedly was quite satisfied with the results of the project.

PROCESS DEVELOPMENT: ASSOCIATING TEAMS WITH PROJECTS

The method for associating the teams with projects has also been evolved over time, to a format that appears to be very effective. The evolution has been in a direction to better build a sense of team member belongingness and self worth (in the context of Maslow's *Hierarchy of Needs* [15]). After the teams are formed to bring together a fair mix of subject matter experts with specific learning types and a team building exercise is conducted during an early class meeting, teams work together to choose the project on which they wish to work.

As was pointed out above, in the early semesters team formation and associating teams with projects were intermingled. This had the disadvantage that there was no way to positively affect the structure of the teams. While team composition might be better matched with a particular project (i.e. more electrical engineers on a circuit-focused project), the opportunity for students to get a realistic multi-disciplinary experience was not supported.

The eighth time the course was offered was the first time that associating teams with projects was separated from the team formation process. After a brief team-building exercise for the newly formed teams, the students heard the projects described. The course director chose to do this, rather than letting each client present their own project, to assure a uniformity of presentation style, enthusiasm, etc. Each team was then asked to identify on paper one or more projects on which they preferred NOT to work. The idea was not to create expectations (which might not be met) in the teams of being assigned to their favorite project. The course director used these antipreferences to assign the teams to projects before the next class period.

This change clearly furthered the goals of multidisciplinary and diverse teams. However, asking only what projects the teams did not want to work on had the disadvantage that no indication was available of on which project each team would have preferred to work. Even though this may have minimized expectations of working on one's preferred project, there was no way to try to insure the maximum number of delighted customers (team members).

The approach which has been successfully used for three years has been to ask each team to identify both its 'would like most to do' project and its 'don't want to do it' project. Even when discouraged from doing so, some teams provide even more information, like their 'number two' and 'next-to-last' projects.

How well has this worked in creating successful team + project matches? As described above, in most of the seven semesters in which this approach was used, most teams got to work on their first choice projects. Two semesters it was four out of five. So far, no team had to work on the project they said they did not want to do. In one five-project semester, one team was asked to do their 'next to last choice' project. They objected sufficiently that this project was cancelled and the members of that team were distributed among the remaining projects. (See further discussion in the *Outcomes* section.)

Benchmarking

One course [20] uses a method similar to that used in the course being described: the newly formed teams indicate their preferences for several projects, in order. The faculty and teaching team then match teams to projects as best they can.

In the other two courses surveyed for comparison [4,7], teams are formed based upon which students want to work on which projects. In one case the students are asked to rank the projects, as they are described by the sponsoring companies. In the other each student is asked to identify five projects they would not mind working on (no ranking) and two projects they do not want or cannot (due to conflict) work on. Experience has shown that most students can be assigned to one of their preferred projects.

The process described here contrasts interestingly with the process reported by Janna [8–10]. While they are not asked what projects they would rather not work on, Janna's students are asked to make bids on three projects, so that they do not simply rank order their preferences, they are pressed to assign a value to their rank-ordering. 'If we really want to work on project A, we need to bid low . . .' While Janna has so far not encountered it, this process does have the potential for a student team to bid artificially high on some project on which they would prefer not to work.

PROCESS DEVELOPMENT: OUTCOMES

Assessment

No formal assessment vehicle has been used with this course. Four sets of feedback have been available to the faculty:

- visible team malfunctions;
- client (sponsor) satisfaction;
- formal student feedback (through the university's faculty course evaluation process);
- informal student feedback (urging their friends to take the course).

Visible team malfunctions.

Only two of these stand out. The generally accepted value of having diverse teams was reinforced one semester by a team that was slow to make project progress because of strong gender groupings. This particular team had six members: three males and three females, two of whom were extremely strong performers. The result, visible as early as the team-building activities in the early class sessions, was essentially a separation of the team into two sub-teams, one comprising the males and the other the females. Throughout the early part of the project work, team responsibilities were divided between these two homogeneous subteams. Only after intervention by the team's faculty coach did they re-unite as a single team and spread the work all around. The action based upon this incident was to be more attentive to the diversity of the teams.

The earliest sign of another team malfunction was when a strong male engineer openly questioned in class how a female Professional Writing (English) major would be able to contribute to the team's engineering design project. Sadly, this is consistent with a perceived resistance to learn from others in the current educational system, which encourages people to mistrust others working with them [14]. The faculty and the rest of his team assured the concerned student that by semester's end they would see a definite contribution and the writer elected to remain with the team. However, after the teams were associated with projects, the same individual voiced dissatisfaction that while the team had not been associated with their 'we don't want to do it' project, they had been matched with their next-to-last choice (which information had not been collected as part of the matching process) and they did not want to do that project either.

In this case he had support from other team members. The faculty decision was to drop that project and distribute the members of that team among the other projects. This resulted in one team having the more-than-desirable seven members, but this seemed better than forcing people to continue with a project on which they did not really want to work. This outcome was deemed satisfactory in that no student quit the course as a result. The only future action that was taken on account of this was that although 'second' and 'next to last' choices were still not solicited, they were not rejected.

Client satisfaction.

This is best measured by repeat business. Over the years the course has been offered there have been several companies who have sponsored projects for several semesters—usually stopping only when their champion for the course changed jobs or left the company, or when the company was bought out.

Interesting feedback has been the opinion that the work done and reported has been more valuable than the specific design proposals made by the student teams. The very complete final report required of each project team provides truly useful information should the company choose to have its own staff pursue the project further. Information is provided not only about seemingly promising avenues to follows, but also about dead end paths not worth pursuing.

Formal student feedback.

Not all of the students in this project class bother to complete faculty course evaluations for it. There appears to be uncertainty whether they are rating the entire course or their project and the several faculty members who have taught different lessons or just their team coach. In a recent semester the course rating was 3.4/5.0, which was approximately 9% below the Engineering School average.

Informal student feedback.

While there has been no attempt to collect data, each semester several students tell us that they have been encouraged by their classmates to take the Engineering Design Projects course. This seems to be the major influence among the graduate professional and technical writing students. This has been verified by their program coordinator.

There is also an occasional student who takes the course twice. (The course is offered with a different number in the fall and spring semesters, so there is no administrative problem with someone taking it twice.) Sometimes the student wants to continue work on a specific project—and sometimes the student seeks a different experience and so carefully avoids the previous semester's project and client.

Expectations met and not met

A potentially greater problem with both students and clients is the creation of expectations that do not get met. This can lead to dissatisfaction with the total experience, regardless of how good parts of it may have been. Recruiting materials for this Engineering Design Projects course, for both students and clients, are worded with the intent not to create unreasonable or undesirable expectations.

For students, the goal is to tell prospective students exactly what they may expect to encounter in the course. The focus is on:

- the real-world project experience;
- the multi-disciplinary experience;
- the range of disciplines from which students are recruited;
- the variety of clients/sponsors who provide projects;
- that each team will be supported by a client representative and a faculty coach;
- the sorts of development-related topics to be studied.

The intent is to make it clear at the start that the expectation is that each student work at a level appropriate to the number of units to be earned. This occasionally discourages a student who somehow perceived that this course would provide an opportunity to coast.

One of the most difficult expectations to deal with at the start of the course is the expectation of some of the engineers that the non-engineers will most likely have little of value to contribute to the engineering design projects. Usually this is not vocalized, although as described above the engineers on one team clearly and publicly expressed their doubts about what a technical writer would be able to contribute to the team's project work. The most negative outcome of this was to discourage the team's writer member; it is not clear that the writer ever fully recovered from this. More often, when the engineers are at worst curious about how the non-engineers will contribute, the semester ends with the team members rating the writer (or other non-engineer) as the top contributor, because of the variety of tasks undertaken by that individual (e.g. project management, preparation of presentations, coordinating the final report).

For potential clients, the need is to convey clearly:

- the skill level of the students who will work on their project;
- the amount of time and effort the students can be expected to put into the project.

For clients with experience sponsoring faculty/PhD candidate research at the university, it is important to make it clear that the students working on a project in the Engineering Design Projects course will be at a generally lower level (mostly upper-division undergraduates), will not be as highly focused on the specific topic of the project as a PhD candidate would and will not be putting in as many hours per week—this is but one of several classes each student is taking.

This latter factor disappointed an internal project sponsor (from a Carnegie Mellon University unit) in a recent semester. Her main experience was with a program in which the students work most of each semester on projects, taking in addition perhaps a single course. She had anticipated much greater student effort on the project; especially on the construction of a working prototype that she had hoped could be tested with potential customers.

SUMMARY

To further the goal of providing the students a multi-disciplinary team experience, potential best practice processes for team formation and associating teams with projects in multi-disciplinary engineering design project courses have been described. Following sections have detailed the evolutions of these processes and examined the outcomes that have driven and supported the changes.

This seemingly conventional Engineering Design Projects course sponsored by Carnegie Mellon University's College of Engineering (which retains the old name, Carnegie Institute of Technology) has been focused as an opportunity for students to have a realistic multi-disciplinary experience. What distinguishes this course from similar courses are:

- students are recruited from across the university community, starting with the engineering departments but also including other disciplines such as business, design and writing;
- they are assigned to deliberately multi-disciplinary and diverse teams;
- they are introduced to industry-based project management and product realization process tools;
- they work on design projects sponsored by industries, non-profits, government bodies, or various Carnegie Mellon units.

Successes are indicated by generally favorable student reactions and by repeat business from both client sponsors and students.

OPPORTUNITIES FOR FURTHER WORK

The biggest problem is coping with dropouts after the teams have been formed and started on their team-building and project work. Once they are under way and starting down the forming-storming-norming-performing path, the teams resist transferring anyone to another project and also really do not want to add any more members.

Possible alternate strategies are to delay team formation and team-building until after two or three classes, to allow some of the early dropouts to go away. The question is how to do this without materially slowing down project initiation? With only a 14-week semester in which to accomplish a successful project, early delays in starting the actual project work can have a major impact. But some rearrangement of early class content (e.g. instruction and team-building activities) might be possible with minimum impact.

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