Teaming Multi-level Classes on Industry Projects

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Abstract

For the past few years we experimented with teaming students from a sophomore-level class and a senior-level class to work on industry projects. The classes are “work design” and “facilities design.” Projects are selected to require the application of knowledge from both disciplines. In addition, the projects are selected from small local companies. The intent of this paper is to describe the benefits and difficulties associated with this methodology. While specific classes in this experience are typical of an industrial engineering curriculum, the lessons learned and benefits could translate to other disciplines.

Introduction

The use of Project Based Learning (PBL) has contributed to Cal Poly’s reputation of “learn by doing” for many years. As part of the Industrial Engineering (IE) curriculum at Cal Poly, students work in small groups with local companies on facilities related projects. The unique aspect of these projects is that students from a senior class and students from a sophomore class are partnered together to work on these industry based projects. These projects have been received favorably by the students, the local companies, ABET evaluators, and our industrial advisory board. As in many PBL activities, we observed that students develop better teamwork skills and better solutions to design problems. In addition, there are unique outcomes for the younger students including a higher commitment to their chosen major, and a better context for future classes. For the older students working with the younger students, the outcomes include review of lower level topics and enhanced supervisory skills.

This paper begins by reviewing the literature in the area of PBL and teams, describes the project and processes involved in these project teams, and delineates lessons learned from both the instructor’s and the student’s points of view. Areas of future research will also be discussed.

Review of Literature

Most engineering schools use team based projects, or laboratory assignments to help students develop skills necessary for their professional careers. Teamwork skills have traditionally been developed by assigning students to teams. To some extent, this approach does produce results, but a better approach was undertaken at the University of Dayton[4] where student teams were instructed on teambuilding and leadership. One of their suggestions was not only to instruct, but to give students opportunities to work on teams where students refine their skills as they mature though the engineering program. Many researchers have struggled with the difficult task of assessing teamwork and other soft skills involved in multi-disciplinary PBL teams. Plumb and Sobeck[10] put together a framework for developing assessment tools. They urge instructors to develop a rubric or protocols to track performance over time.

Teamwork in PBL is a unique case in that the teams are usually working on more difficult, time consuming problems. When PBL is used students achieve desirable outcomes. Several researchers at the University of Madrid[7], found that PBL used in the design of electronic systems increased interest in electronics, increased academic performance, and produced better design solutions. In addition, situational factors were found to influence the outcomes of PBL activities for junior engineering students[6]. These situational factors include the type of project selected, the learning of the individual student, and the ability of students to adapt to working under time pressure.

Engagement is often sited as an important component of learning in PBL. In the Civil and Chemical Engineering school at RMIT, researchers[5] examined the factors that effect engagement in a PBL environment. They examined first year engineering students and identified four factors that helped students engage in a project. The first factor is that students need "interesting work." The second is that students must understand the structure of the problem with clearly defined expectations. Thirdly, students work best when they feel connected to other students in their groups. Lastly, students require guidance and orientation to their new university environment.

Several studies have looked at team structures that include individuals from varying educational levels. Some have included graduate students on teams with undergrads, while others have grouped high school students with university seniors. At Boise State University[9], faculty, post-doc, graduate students, undergraduate engineering, and undergraduate technology students are put on teams together in laboratory courses. Although only in the beginning stages of this curricular change, these researchers feel it will be an effective method to simulate the working environment for the future graduates. Adams, Zhang and Burbank[1] placed undergraduates and graduate students together on teams with the explicit goal of preparing undergrads for graduate study and research. They observed both increasing graduate enrollment and higher quality of graduate students after implementation of these teams. The School of Electrical and Information Engineering at the University of South Australia experimented with grouping seniors with high school students on a design project[8]. The projects were university sponsored, but industry generated. The high school students reported better learning of technical skills and the older students developed management and communication skills. In addition, the younger students felt they could make more informed career choices.

Related to teaming in PBL, the use of teaching assistants (TA) as substitutes for faculty in guiding PBL experiences was explored at Deft University of Technology in the Netherlands[2]. There were clear advantages delineated, which included the ability of TA's to establish good social and peer relationships with student teams. In addition, TA's were unable to give direct step-by-step guidance, which proved to be an advantage to learning for the student teams. The researchers stress the importance of thorough recruiting and training of the TA as an important success factor. Also, Crosby, Ibekwe, Li, Pang and Lian[3] developed a tiered mentoring approach as part of a larger research project. The faculty mentor the gradate students who in turn mentor undergraduates. In turn, the undergraduates mentor high school students. These researchers state that they feel confident this type of activity will increase recruitment and retention.

PBL and teaming have clear advantages to students, and it seems that even grouping students at different experience levels can achieve excellent outcomes. This research takes these experiences one step further to look at a sustainable system to enhance learning outcomes.

The Courses and Projects

The two courses described below are only two of many courses in the IE curriculum that use PBL. These courses are the first in which we grouped senior students from one class with sophomore students from another to work on industry generated projects.

For more than ten years the senior facility design class has conducted projects for local companies. The students work in teams of four to seven students to produce an improved facilities design expressed in a report and a presentation. This capstone senior level class requires that students draw on their knowledge from many IE topics including inventory control, project management, ergonomics, quality, work design and economics. Clients are usually small manufacturing firms in the San Luis Obispo County area, but also companies in Stockton and the LA area have participated. Typically these firms are so small that they would never have had the opportunity to see IE topics applied in a systematic manner by knowledgeable individuals. An overwhelming number of the clients have been pleased with the results. Table 1 is a partial list of companies and projects. Some of these companies have hired IE's after realizing the contributions IE's can make to a company's efficiency. In addition, most companies have implemented at least some of the recommendations made by these students.

Table 1 - Sample Projects

Company	Location - CA	Company Type	Project Description
C&D Aerospace	Santa Maria	Aerospace	Redesign of an assembly cell
Hardy Diagnostics	Santa Maria	Biomedical	Design layout for a new location
Dioptics	San Luis Obispo	Distribution	Design new warehouse
Road Home	Oceano	Non-Profit	Design a homeless shelter/campus
Left Coast T-Shirt	San Luis Obispo	Screen printing	Re-layout production floor to incorporate new machine
SLO Roasted Coffee	San Luis Obispo	Food	Design new layout to incorporate new packaging process
UVS Thrift Store	San Luis Obispo	Non-profit	Re-layout and methods improvement
Moulton Logistics Mgmt	Van Nuys	Distribution	Redesign of reverse logistics area
New Life Church	Arroyo Grande	Non-Profit	Design of new youth center
Jamba Juice	San Luis Obispo	Retail	Redesign of retail location
Diamond Foods	Stockton	Food	Redesign assembly line production area
Wasco	Santa Maria	Electronics	Design of a new facility
Corbett Canyon Winery	San Luis Obispo	Winery	Re-layout of a bottling line
Fountains of Living Waters	Santa Maria	Wholesale	Layout of a new facility

Students also learn first hand, topics that are difficult to teach in the classroom. For instance, students learn the importance of positive interactions with clients, methods of dealing with project uncertainty, real deadlines where more than a grade is at stake, and team conflict resolution in real time.

The second course, Work Design, is one of the first major course IE students take. In this class students learn basic methods of time studies, continuous improvement procedure, and lean manufacturing concepts. They are also introduced to ergonomics and work station design. For many years students in this class have been applying these concepts to real life situations. Often students find a project themselves, and occasionally the instructors provide a project. Whatever the project, students are encouraged to recommend a justified improvement to an existing procedure using time studies and other quantitative measures.

Because these two courses have a history of working on real life projects for companies, a couple years ago we experimented with combining the projects and students so that several students from each class work on the same project. Generally the teams are made up of four upper level students and two lower level students. The tasks are loosely divided between facilities design and work study, but these are naturally integrated requiring students to interface for project completion.

Currently, not all students participate in these multi-level teams. Generally there are seven or eight facilities teams, of which four have students from the lower level class. In addition, there are seven or eight teams in the work design course, of which four are students participating on teams with the seniors.

As an example, a student team made up of five seniors and two sophomores worked for a local winery developing the layout of a new bottling line. Initially, the students visited the winery for a tour. This was followed by the upper level students creating a Statement of Work as learned in their project management class. This was discussed with the client and then expanded to include descriptions of tasks, deliverables, and a work breakdown structure. Work design students created process charts, and collected time study data on the processes. The facilities design students used this data to create a simulation using Promodel® (a discrete event simulation software that includes graphics) that illustrated bottlenecks and justified task automation. All the students in the group worked on research of automation equipment and developing alternative layouts for the line. The facilities student performed economic evaluation and evaluated quality issues. Work design students created lean manufacturing work stations equipped with 5S shadow-boards[11]. All students worked on recommendation for ergonomic improvement. A comprehensive report, approximately 100 pages long, a professional presentation, and a physical model of the recommended line was delivered to the client after six weeks of intense project work. The quality of the report was high and the client was pleased with the many creative cost-benefit justified ideas.

Learning Outcomes

The fact that these courses use PBL to teach some valuable topics should not be overlooked, but in addition, the students are learning topics that are unique to this multi-level teaming experiment. Below these outcomes are delineated into those achieved by everyone participating in the multi-level teaming, those achieved by the senior students, and those achieved by the sophomore students. The description of each outcome is followed by a quote from a student in the classes. These quotes were collected as part of an anonymous survey of the participating students. Summary data from this initial survey is also included where appropriate.

Outcomes for all students. Students in both classes are heavily engaged in the projects and thus are acquiring skills at a high level. They are also learning enhanced teamwork skills by dealing with individuals different than themselves.

- *Working with students in 443 (facilities design) gives the 223 (work design) students an idea of what sort of workload to expect and the complexity and various challenges of solving a specific problem within a team of people with various backgrounds and experience levels. (Sophomore Student)*
- *It was a lot of work, but I would definitely do it again. (Sophomore Student)*
- *I really thought that the class was a lot of fun and a great learning experience. (Sophomore Student)*
- *I really enjoyed working with the upper classmen. (Sophomore Student)*

When the younger students were asked “Did you learn more from this project than other projects you worked on?” 71% answered, “I think I learned a lot more working with the seniors.” In addition, 68% of the students reported that they worked “very hard” on the project.

Outcome for senior students. Seniors learned supervisor skills and had a chance to refresh their memory of topics learned as sophomores.

- *I did learn how to supervise and delegate jobs through an understanding that they were lower classmen. (Senior Student)*
- *It was tough to get them to find their own work to do (basically we didn’t want to hold their hands). Definitely learned a lot about delegation. (Senior Student)*
- *It was nice to have upper classmen in my group as they were able to guide us through the hard aspects of the projects. (Sophomore Student)*
- *I liked working with them because they refreshed my memory on how to do time studies. (Senior Student)*

Outcomes for sophomore student. Sophomore students expressed increase knowledge of the curriculum, development of mentoring relationships, and an increased dedication to their chosen major.

- *The seniors as well as the project defined my interest and choice of IE as my major (Sophomore Student)*
- *It helped give an understanding of what would be coming in the future. (Sophomore Student)*
- *I loved hanging out and working with upper classman; it helped me set some goals of what I want to be doing in the next couple years while I'm at Cal Poly. I thoroughly enjoyed it. :) (Sophomore Student)*
- *I didn't just learn about work study in class, I also gained knowledge from the project and the upper classman. (Sophomore Student)*
- *I remember during the project, I became good friends with the seniors in the group (Steve and Edgar) and they both basically became mentors to me. (Sophomore Student)*

- *After this project, I was sold on Industrial Engineering as the major for me. (Sophomore Student)*
- *It was great to get a preview of what we would be learning later on. (Sophomore Student)*
- *The upper classman and working with the company showed me how complicated and how many different perspectives IE's have to pay attention to when doing a job for a company. (Sophomore Student)*
- *Working with seniors put extra pressure on me to want to perform better for my peers. (Sophomore Student)*

When asked "Did the project change your opinion of IE as a career?" 89% answered "It made me more interested in my major." When asked "Did you feel appreciated?" 78% answered "Yes, they appreciated me."

Lessons Learned

By combining students from different class levels several important objectives were realized, but there are also some important lessons we learned. These include techniques that proved helpful and areas of caution.

<u>Project definition.</u> We, as the instructors of these classes, recruit companies to participate with appropriate projects before the term begins. These projects must be of the appropriate scope, size as well as include some level of ambiguity. Projects must include IE tasks such as time studies, ergonomic evaluation, and facilities implications. Careful selection of projects proved to be critical for student success. Some facilities projects do not have tasks for work design students, these projects are still being worked on, but no sophomore students are assigned to these teams.

<u>Company participation.</u> Companies that participate in these projects are asked to have one contact person who can communicate with students. In addition, they must attend two presentations: an interim presentation and a final presentation. It is very important that companies are told in advance of these expectations. In some projects, the companies are shocked at the shear number of questions students can generate. We, as instructors, try to encourage students to think hard before they ask too much, but sometimes communications can get burdensome for the companies. In these few cases, the companies must be able to deal with the instructor directly so that adjustments can be made.

<u>Course structure.</u> These projects work best if the two courses have lab activities that are scheduled concurrently. The groups must meet together and the difficulty of scheduling these meetings is minimized if students are guaranteed to be available at the same day and time. The two courses are separate and are run by different instructors. Each class has topics that must be addressed and lab activities that must be performed. The difficulty in scheduling should not be minimized.

<u>Timing of instruction.</u> One of the difficulties encountered when using any projects in a course is that it is not easy to cover all the topics in time for application to the project. This is especially true in a quarter system. In the senior design class this is solved by intense lecturing during the

first five weeks of class and project work during the last five week. This structure is not possible in the work design class, yet some important topics are needed at the beginning of the quarter. In order to solve this, we cover time studies very early, and this may sacrifice a logical sequence of topics.

Teamwork instruction. It is very important to introduce this multi-level teaming to the classes in a way that they understand the reasons behind the procedure. The seniors need to understand that the sophomore students are full team members. The younger students will be assigned specific tasks, but should be respected for their contribution and even encouraged to stretch themselves by creative problem solving. The seniors are also asked to consider themselves teachers and mentors of the younger students. In one group, the younger students were not treated as equals and the faculty members did not intervene in time to remedy the problem. The younger students were demoralized and hated being part of the team. In addition, the seniors on this particular team had major conflicts and the poor quality of their final presentation reflected their dysfunction. The younger students need to understand the time commitment and complexity of the project. It is possible that not all sophomore students can handle the intensity of these projects.

Assignment of individuals to teams. We have found that it is important for the faculty involved to assign teams and not to allow students to choose their own teams. For the seniors on the teams, there must be students with a mix of skills and experiences. For the sophomores, the students should be informed of the complexity of the task and have the option of working with the seniors on these more complex projects. In the sophomore class students are asked to volunteer for the facilities projects, and typically there are a greater number of sophomores wanting to do the complex projects than there are spots on the project teams.

Use of electronic communications. Because the students are in separate classes, communications is sometimes a challenge. The use of communication devices such as Blackboard or Google Groups has enhanced document transfer and simplified interactions.

Good teamwork techniques. The students on the teams are encouraged to practice good teamwork techniques. Students are required to create an agenda for each meeting and keep track of activities using project management. In addition, teams are encouraged to have team-bonding activities that increase the cohesiveness of the teams. Students also must deal directly with team conflicts. We, as instructors, have had to gather students together to openly discuss conflicts. This is quite difficult, and not all instructors are comfortable in the role of mediator.

Communication between instructors. The communications between the instructors should ideally be frequent and easy. In our classes, the instructor for the facilities class organizes the companies and the schedules, but discussion about team membership and dealing with problems along the way is the responsibility of both instructors.

The number of projects. These projects are managed as part of the regular teaching load of the faculty. There are approximately 250 students in the IE major at Cal Poly, this means that each quarter there will be as many as ten student groups working with companies. This requires

considerable coordination with the companies and motivation of the teams. This multi-level teaming may be easier to sustain if additional resources are allocated.

Procrastination. Students tend to procrastinate. Because of the nature of these complex problems, procrastination can really hurt the final product. In addition, because the projects are ambiguous by design, students have a hard time at the beginning of the project moving ahead with a solution methodology. Due to the nature of the project, if the upper classmen are procrastinating the lower classmen will be adversely affected. The way we have dealt with this problem is to push students hard to show early analysis and data collection, but we still struggle to get some students teams moving early enough.

Exposure of sophomores to seniors. Sometimes the students in the work design class are freshman; as young as 18-years old. Seniors must remember this when dealing with the younger students, they must be careful about mature activities such as drinking and partying. We, specifically warn senior students to be mindful of the age of their teammates.

Conclusions and Future Research

We found that teaming lower level IE students with upper classman led to several desirable outcomes. For the younger students they gained a greater appreciation for their choice of major, they develop mentoring relationships, and they develop knowledge of technical aspects of IE. Upper classman also acquired important skills, particularly management skills and relearning of topics. Both age groups of students expressed satisfaction in the experience. Although the activities described in this paper are done with IE students, other disciplines can realize similar benefits by teaming lower and upper level students together on project teams.

We have been able to sustain these project teams for several years. It is the hope that as we refine the procedures and prove the benefits, these multi-level teams will become an official part of the IE curriculum.

Although we have seen much success in their multi-level teaming, there are still more opportunities to refine the procedures. We are currently in the middle of a quarter where students have been asked to fill out surveys on abilities in teamwork, supervision and other observed outcomes of the multi-level teaming. We administered the survey to all students in the two classes, approximately half of them are participating the multi-level teaming while the other half are working on teams with their classmates. We are hoping to find differences in the groups dependent on the team type.

In addition to students from these two classes, it seems feasible to have students from other courses working with companies on multi-faceted teams. Currently, courses in simulation, design of experiments (DOE), human factors, and project management are working on team projects. It is conceivable that these classes could be partnered together to work on complex problems for companies with good results.

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