Integrating Courses Through Project Based Learning

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Abstract

Integrating three courses (one sophomore level, two senior level) through Project Based Learning (PBL) within the Industrial Engineering curriculum at the California Polytechnic State University, San Luis Obispo is presented. Three courses (IME 443 Facilities Planning and Design - senior level; IME 420 Simulation - senior level; and IME 223 Process Improvement Fundamentals - sophomore level) were linked by various mechanisms: Common industry projects, common students in two of the three courses; senior students having access to sophomores in their teams to carry out time consuming tasks such as time studies, and sophomores having access to seniors as team members, and as coaches and mentors. "Industry partners" opened their doors to a group of students to identify "process improvement opportunities". Each student team included students from each of the participating classes. Scheduling of courses back to back in the morning provided students longer periods of class time to visit companies for their project work. One of the unique opportunities in this project was for the faculty to model collaboration around complex problems with no easy solution (integration of course), just as the students are required to do. Student interest is high. Faculty development is also enhanced by the enjoyable collaboration experience.

Introduction

Integration of courses though project based learning in the Industrial and Manufacturing Engineering (IME) department at Cal Poly, San Luis Obispo, has increased engagement for students and faculty alike. Many benefits have come from this effort including enhanced relevance of course topics for students, mentoring relationship between students, and faculty enjoyment through collaboration. This paper describes this experiment, the planning necessary, adjustments that were made during the implementation, and the assessment of the experience from both the students and the faculty point of view.

Three courses, eighty students, three faculty, and eleven projects were integrated through project teams during Winter quarter 2012. Others have found the advantages of integration to be many. Froyd and Ohland[1] found that the integration across the curriculum for freshman students increase retention and engagement for students and enhanced faculty development. Integration of older students with younger students has also contributed to retention and persistence[2]. The mentoring relationship developed helps younger students see the whole of their curriculum and develop mentoring relationships for future success. The older students also have the opportunity to gain skills in supervision and instruction. In addition, older students refresh their skills learned previously in the curriculum.

Project Based Learning (PBL), in its manifold forms, is a distinguishing feature of a Cal Poly education and a fundamental enhancement of the University's "Learn By Doing" ethos. It is commonly acknowledged that project-based learning (PBL) is an effective tool in inspiring and engaging students[2,3,4]. "Project Based Learning involves an academic effort which asks students to produce authentic work products that arise from behaving as professionals in their chosen disciplines."[5]. Traditional deductive instruction, beginning with theories and progressing to applications in a lecture hall setting has been the mainstay of engineering education and will likely remain so for some time to come. More recently, however, educators have come to realize that there is great benefit in supplementing the traditional method with inductive learning methods, including PBL[6,7,8,9,10]. The PBL approach employs a problem as the driving force for learning the fundamental principles that are required to find a solution. Moreover, this approach provides a context that makes learning the fundamentals more relevant and, hence, results in better retention by students[4,11,12].

It has been our observation that PBL is not some panacea that always results in better student learning[5]. Indeed, a poorly designed PBL project can result in a very negative experience for students, providing little or no learning value. Some of the factors that result in a successful PBL experience are known, but have not been adequately quantified, while the importance of other factors may remain relatively underappreciated.

Previous experience has indicated that PBL teams responding to real world clients tend to be more highly motivated, which is linked to greater learning[13,14].

Description of the experience

The faculty involved in this experience have many years of experiences with teaching and with project based learning in particular. The instructor of the facilities class has been integrating course for several years[13,14,15]. The difference in this current experience is that there are three faculty members collaborating. In order to implement this some significant pre-planning was necessary. First the schedule of classes was arranged. Next the faculty met for at least an hour each week for the quarter before implementation. Lastly, projects with local companies needed to be defined and visited before the quarter began. In addition, we aimed to use an innovative learning model to increase project work time and to enhance learning.

Courses within the curriculum

Industrial Engineering students at Cal Poly are required to take 196 quarter-units to complete their degree in IE. Courses are taught over a 10-week quarter. Three courses that were linked through the common project are listed in the Table 1.

Table 1: Industrial and Manufacturing Engineering Integrated Courses

Course number	Name	Level	Enrollment	Overlap number of students
IME 223	Continuous Improvement Fundamental	Sophomore	32	None
IME 420	Simulation	Senior	27	24 in IME 443
IME 443	Facilities Planning an Design	Senior	45	24 in IME 420

The courses were linked by various mechanisms: Common industry projects, common students in at least two out of three courses; senior students having access to sophomores in their teams to carry out time consuming tasks such as time studies, and sophomores having access to seniors as team members, and as coaches and mentors. Each student team included a pair of students from each of the participating class.

Schedule

All three classes are four unit courses. Students meet for three hours a week in a lecture setting and three hours a week in a lab in each class. In order to link courses, the department was asked one year in advance to schedule these classes with overlapping times to better enable project work across the classes and class levels. The senior lecture classes are back to back in the mornings, in the same classroom with access to the adjacent computer lab, and the sophomore lecture overlapping with one of the senior classes (see Figure 1). The facilities class has the additional responsibility of leading the larger team and mentoring the sophomore members. The facilities and process improvement fundamentals (sophomore group) lab were scheduled concurrently to minimize barriers.

Scheduling of courses back to back in the morning provided students longer periods of class time to visit companies for their project work. Instructors "borrowed" time from each other early in the quarter to cover material needed to initiate the projects.

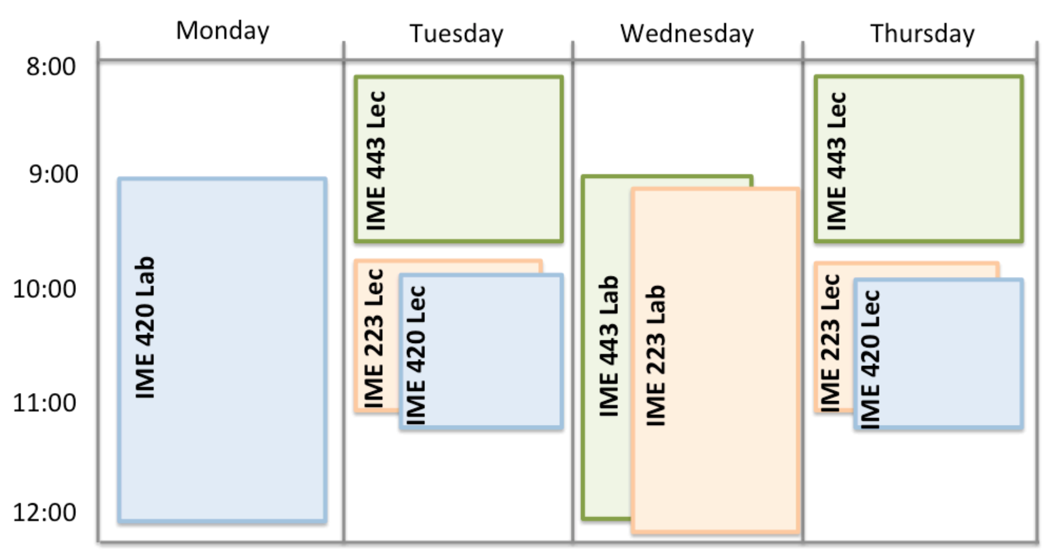

Figure 1: Schedule for maximum overlap

Projects

Three faculty members had weekly meetings in Fall quarter to organize collaboration, and to secure real-world projects. Since each student team was going to be working on a different project, there was a need for approximately15 projects to accommodate all the students expected

to enroll in three classes. This was a big undertaking. We started visiting local companies mid fall quarter. Due to the culture of Cal Poly – having great relationship with industry – 11 projects were lined up by the beginning of winter quarter. As shown in Table 2, three companies participated in more than one project, reducing the communication load on the faculty members.

Table 2: Eleven Industry projects

Company	Product or industry	Location	Project
Voler	Cycling apparel	Grover Beach, CA	1) Examining piece-rate systems in the sewing department
			2) Examining waste in the cutting, sublimation, printing, sewing process
ifixit	Repair parts and tools for Apple products	San Luis Obispo, CA	3) Efficiency evaluation of warehouse, picking and shipping
			4) Layout of kiting room for maximum flexibility and efficiency
Melfred- Borzall	Direction drilling equipment	Santa Maria, CA	5) Evaluation of Work in Process throughout the facility
			6) Reorganization of assembly area for maximize efficiency
ATK	Structures for space systems	Goleta, CA	7) Evaluation of tool tracking system
Save-on-Crafts	Online craft store	Watsonville, CA	8) Efficient warehouse operations
CED	Electronics distributor	San Luis Obispo, CA	9) Efficient warehouse operations
Zurn	Plumbing supplier	Paso Robles, CA	10) Shipping and receiving redesign
Cal Poly Library – Special Collections	Museum quality storage of artifacts	San Luis Obispo, CA	11) Design a layout to consolidate the collection

Learning model

We envisioned a learning model (Figure 2) structured to build supportive relationships among community members (students, staff, industry members, and faculty), across disciplines, to enhance one's whole development and to value diverse viewpoints. A key ingredient of the model is significant, authentic engineering design experiences (i.e., those with clients, a range of disciplinary viewpoints and real-world applications).

Each of us has experimented with various learning models in our courses for many years. The model in the diagram below is a representation of our shared understanding. Often this ideal model is not achieved, but it is our goal. This is similar to the idea of the flipped classroom or "inside-out" educational model[16]. The students are required to prepare before coming to class. Often they watch a video lecture or read an assigned chapter in the book. Class time is spent reviewing or applying the material to problem sets or to the projects. The assessment of the concepts is seen in the projects. One important component is weekly meetings with student teams to challenge and integrate ideas. These weekly meetings also reinforce the concepts of teamwork and the human systems we all function in.

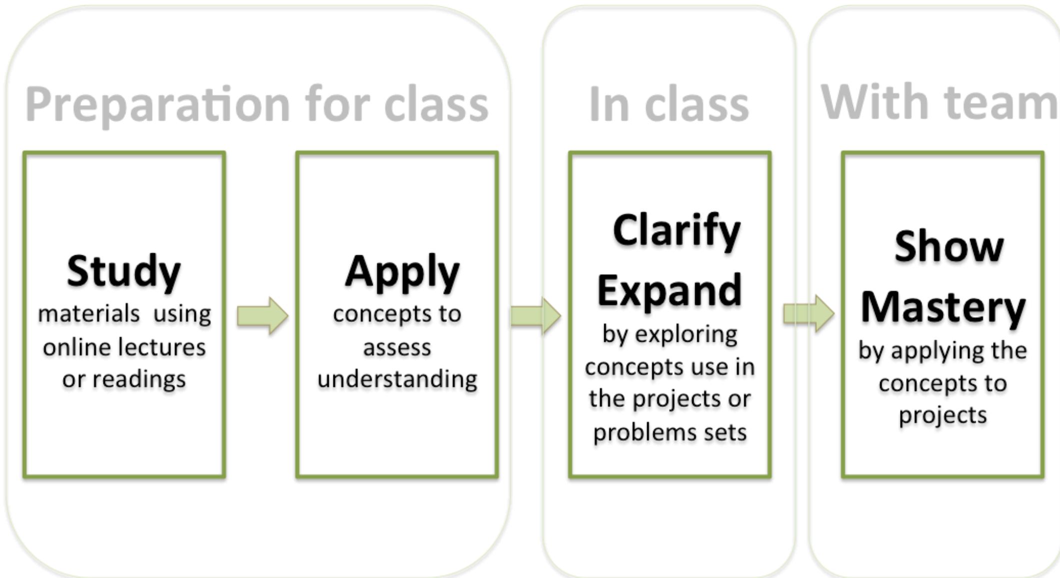

Figure 2: Learning model

In some ways this model is old. We have always expected the students to come prepared, but we realistically knew that they did not. In addition, we inadvertently reinforced this by repeating the material from the book in the lecture. In this new application of the model we are diligent about the need for preparation. If a student comes unprepared, his or her peers often express displeasure in helping someone come up to speed. Time in class is more flexible in that students work independently or in groups and the instructor circulates to answer questions. Not every class is in the mode. The two senior classes are almost exclusively using this model, while the sophomore class is using it about half of the time.

Adjustments

The preparation we invested in ahead of time was important for a joint understand and the built capacity to deal with the implementation of this complex integration. Below we site a few of the mid-courses corrections we employed.

Team Contract – an example of an assignment adjusted
Students in the IME223 class are required to complete a team contract as an initial part of their project experience. The purposes of the team contract include establishing a team relationship and foundation of trust, and clearly setting expectations and team goals at the beginning of the process. This is not a new requirement for IME223 and feedback from prior classes that completed the team agreement indicates it did meet the objective of establishing a relationship of trust to begin the project. The importance of this agreement was evident to the team cohesiveness and thus emphasized by all instructors. The content includes a team name, team rules, a weekly meeting time and place, and a summary of a bonding activity. In this quarter one team included "Must visit the client at least once a week" and "Must work with IME443 students". Another team had the rule "All teammates will take this project as serious as if it were a part-time job."

Many of the rules are about meeting management, and treating their teammates with respect. Another requirement of the IME 223 class is a bonding activity. They were encouraged to include their senior team members. Some of the reflections from the bonding experiences include; “After the bonding experience, we felt more comfortable around each other and there will be more bonding activities in the future” or “This was a great experience, as it allowed us to meet one another as a regular person rather than a classmate that is depending on you”; “We were also able to assess our individual skill and how we could contribute to the group dynamic.” This all re-enforces the importance of building the initial relationship prior to the pressures that the project will bring.

Laboratories – adjustments for project applications
IME223, Process Improvement, labs have traditionally pre-defined activities that the teams complete to practice skills before applying that skill to their project. These lab activities in the sophomore class have been in place for many years, but are currently independently being revised. The new versions of the labs are more self-directed which is ideal for the integration with the projects. Ideally the skill practiced in the lab can be applied to the project, but if the particular project does not have this application, the traditional lab assignment can be used. This flexibility is a bit ambiguous and students felt a nervous about their grade. The instructor recognize this and is allowing students to demonstrate mastery thought several avenues.

IME 420 Simulation lab activities
Student time in the lab building Pro-Model simulations has increased. The practice models have been replaced with simplified models of their projects. This has allowed real time case studies of the applications. Providing rich discussion in simulation applications.

Pushing application of Simulation in Facilities projects
Since we are familiar with the content of each course, the students are encouraged to apply concepts. There is really no excuse for them not to create a valid model in simulation that can help them develop a more efficient solution in the facilities class.

Thinking about projects differently
There were two tiers of customers: internal customers (student team members), and an external customer (real world customer). Both students and faculty members felt additional pressure to meet not only the external customer’s needs, but the internal customers’ as well. In IME420, Simulation class, the instructor made changes in the delivery of material to better prepare students for the term project. Although each team’s model had different needs, in general students needed to learn about higher level modeling concepts such as bringing external data into their models early in the quarter. Another change was in the way the term project was woven into the course assignments. Rather than asking for a proposal at week 3 followed by a progress report in week 7, the students were asked to start building individual term project models starting week 4. They met with team members to discuss overall deliverables to the company, and tried to incorporate these in their models throughout the quarter.

Assessment

We are currently gathering assessment data from both students and faculty. The student feedback will be both qualitative and quantitative. The initial qualitative feedback is very encouraging and included as comments from the sophomore students below. The quantitative student feedback is in process. The initial reflection from the faculty is also included.

Table 3: Sophomore student feedback

“I am excited to work on this project, and being able to see where our group could actually help this company become better and efficient. “
“Overall, I enjoyed the tour and getting a better understanding of all the aspects that go into producing these pieces of clothing. I think it will be very rewarding to be able to help a smaller company like this improve production. And I am looking forward to benefiting from the hands-on/learn-by-doing experience.”
“Our group will be spending a lot of time in the sewing room, analyzing and gathering data. We want to get to know the procedures and processes well and perform time studies so we can access what exactly needs to be changed. We plan to propose beneficial changes to Company X that will help them become more efficient and prosperous in the future.”
“I believe this assignment will be very exciting and I feel extremely lucky to be a part of it. It is also nice to have the mentors from the other class to guide us as were work.”
“It is important for our team to keep in mind that we will be supplying the Special Collections and University Archives Department with the facts they need to propose an increase in funding and support. Our data will help them preserve and maintain a precious Cal Poly treasure.”
“Overall, the 2 hour visit was very informing and I learned an incredible amount about the special collections library. It was very interesting to see the rare irreplaceable times they have in their collection. I look forward to working with them throughout the quarter and hope that my team and I can create a more productive special collections library.”
“Overall, the mindset of the employees seems very open and excited for change, so I am excited to get back there and start taking down data.”

In order to assess the students we decided to administer two surveys. These surveys were first administered to students during fall quarter who were taking one of the senior courses and the sophomore course in the traditional mode. We plan to administer the same surveys to the students who are taking these integrated courses. The result will be available during for the final draft of this paper. The first survey Situational Intrinsic Motivation Scale (SIMS)[17] measures motivation in three different dimensions: amotivation, external regulation, identified regulation, intrinsic motivation. This survey has been useful in identifying motivation for a specific activity or group. We will use a Chi-Square test for the two groups to see if there is a difference in the motivation profile between the traditional and the integrated course. The second survey is the Course Valuing Inventory (CVI)[11,12]. This survey assess through self-report the value of the course to the students. It measures four characteristics of value: Course Value, Content Learning, Personal Learning, and Behavioral learning. Others have used this survey to identify problem based-learning as a way to enhance perceived value[12]. Again we will look at the group who took these classes using the traditional method and compare their assessment of the value to those who took it with this integrate approach.

Faculty Reflections

Since the three of us have experience radical, unexpected benefits from this course integration and collaboration, the following reflections are included as the potential benefit of faculty development.

From one faculty member:
By mid quarter, the instructors' role have changed from "I know it all" to "let's find the answer together" mode. This new role might be difficult to accept by all faculty members. In addition, since students did not have prior modeling (in the simulation class) experience, they tried to build very complicated models early in the quarter that caused some dissatisfaction with their own abilities.

The reader might wonder why a faculty member would volunteer to add such complexity to his/her teaching load since there is no institutional support for such innovations in academia. Our experience shows that faculty members get non-monetary rewards in many different levels. Reviewing student reports and models become like a design review – rather than simply checking for the correct model.

Since students work on the same project in at least two courses, there is improved and deeper learning taking place. There is efficiency in having students work on the same project if we stop being individualistic, and look at it from systems point of view. When three faculty members join forces to find 11 company projects, if one has closer relationship with industry that would help the other faculty members.

From another faculty member
When I first started teaching five and a half years ago after 19 years in industry I felt extremely isolated. I was used to working in teams and collaborating on the vast majority of my work. The solitude and individuality of the instruction process (preparation, teaching, assessing, advising) was quite a shock to me. The only interactions I had with other faculty were the weekly department meetings. And contrary to what I had anticipated about interactions with students, my office hours were rarely visited and class time was highly directed (i.e. lecture format). While I have adjusted to the characteristics of the profession, both in my understanding and by more actively seeking involvement to increase teamwork and collaboration within my teaching, it wasn't until this opportunity to formally link classes that I have experienced true collaboration within in my responsibilities here at Cal Poly. In addition to enhancing my personal experience this collaboration has already started, and I know will continue after the classes are completed, to improve my instructional skills. While developing the plans for our classes we discuss how we deliver content, why we deliver content, and observations of our students learning experiences. Basically this has been a weekly exchange of best practices in our individual experiences that provide guidance and creativity to improve our personal content management and delivery. The interaction with the students in the class has also increased. The reality of an actual client with actual problems has heightened my sensitivity to make sure the students have a depth of understanding and are applying the skills delivered each week to make meaningful progress, meaningful examination and analysis for their client. In addition to the responsibility I feel to the client I feel a responsibility to my co-collaborators and to the students across all three classes to ensure successful team dynamics, which, in my opinion, is as important a learning outcome as topical skills. This experience has re-enforced my belief in the benefits of the "inside/out teaching" method. I have been slow to take the time to develop what 'inside/out' would mean for my classes. This prototype of integrated project based learning almost requires 'inside/out' in order to be successful. I can see that it is imperative I spend limited and valuable class time to expand the students learning not to deliver content that they can easily obtain themselves.

From the last Faculty member
I have so enjoyed this experience. I believe that we should be prepared to do almost everything we ask students to do. I usually apply this to homework assignments and computer software, but now I think it is important in teamwork too. We ask out students to work on teams and tout the benefits of multi-disciplinary work, but we as faculty rarely work together. This experience has made me a better mentor to my students because I can see the synergies and the extra work involved in team projects. I have also enjoyed re-learning the topics in the two other courses.

Conclusions and Lessons learned

Although this experience was surprisingly beneficial to students and faculty, there are still improvements that can be had. In addition we outline below the salient issues that should be addressed for implementation at other universities.

For Faulty

1) Dedicate time to plan and design the situation. Although there was significant mid-course corrections as will implemented this project, the time spent together in planning contributed greatly to our ability to quickly adjust and to enjoy our time together.
2) Faculty openness is necessary. Although we all have had success in the classroom, we found it necessary to let go of our attachment to the way we have always done things this was quite a challenge. If faculty are not willing to examine their assumptions inside the classroom, this experience could be very frustrating.
3) Have fun together. We found, just as we instruct students that spending time sharing a meal in a "team bonding activity" can help our faculty team function smoothly, it helped us also. We consistently enjoyed out planning session. Because there was no increase compensating in this endeavor, this enjoyment was necessary
4) It was helpful to attend each other's classes. Although we did not do this all the time, knowing what the other faculty was covering helped encourage student integration.

For Student and projects

1) Encouraging students to behave as a team across classes. Some of the older students needed encouragement to include the younger students in activities, but once they did, the team flourished.
1) Start project work early. Given our 10-week quarter, student need to be encouraged to start work on the project early. Tours during week two and weekly questions about progress serve to encourage early progress.

Assessment of student engagement and motivation will be measured and results will be presented. These results will guide design in the future. It is hoped that this experiment in integration will continue each Winter quarter.

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Biographical Information

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Lizabeth Schlemer has been teaching at Cal Poly, SLO for 18 years. She is a graduate of Cal Poly herself, and she holds a Masters in Industrial and Systems Engineering and an MBA from University of Southern California, and a PhD in Educational Research from University of California, Santa Barbara. She has 10 years of work experience at Unocal Corporation where she

held positions of increasing responsibility. Most of her current research activities center around engineering education and enhancing engagement through valid contexts like project based learning and community service. She teaches a wide range of subjects from Engineering Economy to Facilities Planning and Design. She has developed good relationships with local industry and provides her students with opportunities to participate in real projects for real clients.

Sema E. Alptekin, PhD

Sema Alptekin holds a PhD in Industrial Engineering, as well as an MS and BS in Mechanical Engineering from Istanbul Technical University. She has been a Professor for over 17 years in the Industrial and Manufacturing Engineering Department at Cal Poly State University in San Luis Obispo, CA, including 6 years as Department Chair. She worked at the University of Missouri-Rolla before joining Cal Poly, and was a Visiting Scholar at UC Berkeley as a member of the BISC group in the EECS Department in 2003-2005. Her current research interests include applications of soft computing technologies in the design of intelligent systems. She has been serving as the Director of Honors Program at Cal Poly.

Karen R. Bangs

Karen Bangs holds a BS in Industrial Engineering from Cal Poly SLO and an MBA from University of California, Irvine. She is in her 6th year of teaching at Cal Poly. Before joining Cal Poly she spent 19 years in the semi-conductor industry working at Skyworks Solutions Inc. (formerly Conexant Systems Inc. formerly Rockwell Semiconductor Systems). Her responsibilities included Industrial Engineering analysis, Operations Finance and Supply Chain Management. She teaches a wide range of subjects from Introduction to Industrial and Manufacturing Engineering to Human Factors to Quality Engineering. She also led the Women In Engineering Program 2007-2010.