CROSS-COURSE DESIGN PROJECTS FOR ENGINEERING TECHNOLOGY STUDENTS

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Abstract: *This paper describes how two classes in the Engineering Technology Department at Western Washington University, Applied Engineering Statics and Strength of Materials, have been linked together through the use of an integrated cross-course design project. The primary purpose of the project is to help students learn to utilize course material to analyze open-ended problems. In addition, various aspects of the project provide students with instruction and experience in project management, teamwork, oral, written and visual communication, creative problem solving, and business skills. Along with the goals and integration process, this paper describes the projects that have been used and the changes that have occurred. Assessment data shows that the integration of the project has been successful at meeting its goals.*

INTRODUCTION

During the 1998-99 academic year the Engineering Technology Department at Western Washington University instituted a cross-course design project in its sophomore level Applied Engineering Statics and Strength of Materials courses. These courses are required for students majoring in Manufacturing Engineering Technology (MET) and Plastics Engineering Technology (PET), and are sometimes taken by students in the pre-engineering transfer program or by students in other programs as electives. The project was designed primarily to help students develop their understanding of the traditional course material and to aid their ability to apply structural analysis techniques to open-ended design problems. In addition, the design project was intended to help students meet department student learning objectives in areas such as project management, creative problem solving, and written and visual communication skills. Now in its third year of implementation, the project has expanded to include teamwork and oral communication.

Up to this point the Applied Engineering Statics and Strength of Materials project has been both successful at meeting its goals, and has also served as a model for the development of other such cross-course design projects. After a brief background, this paper summarizes student learning objectives for the department and the classes in question, and outlines how the projects are integrated into the classes. It then describes the types of projects that have been used in the classes, and the how the classes have evolved. In addition, it also discusses the student learning objectives that are addressed, the level to which they are addressed, the assessment methods that are utilized and the results of including the project in the classes. Finally, the paper summarizes other courses in the Engineering Technology (ETec) Department that now utilize cross-course projects and the plans for expansion of these types of projects in the near future.

BACKGROUND

The Engineering Technology (ETec) Department at Western Washington University (WWU) has approximately 425 students in six different majors: Electronics (EET), Manufacturing (MET), and Plastics (PET) Engineering Technologies, Industrial Design (ID), Industrial Technology (IT), and Technology Education (TechEd). In addition, the Industrial Technology program supports options in Vehicle Design, Industrial Graphics, and Industrial Supervision, as well as a Self-Designed option. Of these programs, only the three engineering technology programs fall under the rubric of ABET. The six programs in the ETec Department are currently taught by fourteen full-time and seven part-time or limited term faculty with backgrounds ranging from Engineering to Art. WWU also offers a two-year pre-engineering transfer option. The Applied Engineering Statics and Strength of Materials sequence primarily serves students who are in the MET and PET programs. In addition, it is taken by students in the pre-engineering program who are headed to mechanical, civil, and similar engineering programs, and it sometimes serves as an elective for students in the IT-Vehicle Design major.

Before the 1998-99 academic year the Applied Engineering Statics and Strength of Materials courses were taught in the manner of traditional engineering science classes, with a basic lecture, homework, test format. The Strength of Materials class also included a bridge building competition some years depending upon the faculty member in charge. While this activity is informative and students enjoy the destructive testing aspect, student bridges have a tendency to fail at glued joints and other such areas where it is difficult to calculate expected load capacity, rather than along structural members in compression or tension. Given this, it remains open to debate whether such an activity actually reinforces course material. During the 1998-99 academic year it was decided that a cross-course design project could be added to the sequence [1]. The original notion of

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the project was to reinforce the traditional course material, but even in its first inception it was used to address other student learning objectives. Now having completed its third year the project has expanded to address additional student learning objectives from the overall ETec Department goals.

STUDENT LEARNING OBJECTIVES

The ETec Department began developing its outcomes assessment strategy in 1998 [2],[3]. Faculty in the ETec Department developed a list of desired student learning outcomes, which are shown in Table I. ETec Department faculty agreed that each of these skills is important for student success after graduation. The challenge, however, is to address all of these issues without sacrificing the technical aspects of the various curricula.

TABLE I
SKILLS THAT CONSTITUTE THE ENGINEERING TECHNOLOGY DEPARTMENT DESIRED STUDENT LEARNING OUTCOMES

▪ Analytical Ability	▪ Oral Communication
▪ Teamwork	▪ Written Communication
▪ Project Management	▪ Visual Communication
▪ Business Skills	▪ Creative Problem Solving
▪ System Thinking	▪ Ethics and Professionalism
▪ Self-Learning	▪ Technology Skills

All issues in Table I must be addressed in each curriculum, preferably more than once. One approach to teaching each of these skills is to integrate design throughout the curriculum [4]-[6]. A design project is an obvious way to address creative problem solving ability and project management skills. Depending upon the structure of the project communication skills can also be addressed, as can teamwork, business, or system thinking skills. Design also provides a good opportunity for students to develop self-learning skills and a good forum for discussing ethics and professionalism in a concrete manner [7],[8]. Moreover, design is fundamental to all forms of engineering. Design brings realistic applications into the classroom. This helps students pull fundamental concepts together and bridge the gap from theory to application, thereby addressing fundamental technical concepts as well. Since the goal is to have students graduate who are both competent and comfortable applying rigorous approaches to new technical problems, traditional material must be taught as tools for solving the types of open-ended problems they can expect to face after graduation.

PROJECT INTEGRATION

The key to making a design project a useful learning experience that develops and reinforces good student habits is to integrate the project into the class, and to do that takes thorough planning [9]-[11]. In order to develop an organized and successful program of utilizing design projects throughout engineering technology education, course designers must approach the problem as an engineering design problem, and take the time at the beginning to completely state the problem, goals, and objectives.

When designing or redesigning a course to include an open-ended project, first begin by deciding the goals for student learning in terms of technical knowledge and additional student learning objectives. Since it is unrealistic to expect to cover the majority of the topics in Table I in any one course, especially without compromising the technical content of the course, select primary, secondary, and tertiary student learning objectives. In many cases the sole primary learning objective is the technical knowledge, although this is not always true.

Once the goals for a design project have been established, there are a number of decisions that the course developer must make: Should the projects be done by individuals or teams? What will be the duration of the project? What will be the scale and scope of the project? What will be the final product from the project? Will students create reports, give presentations, and develop prototypes, or just do one or two of these? Many of these issues are related.

Setting goals and planning structure will also help with the most challenging aspect of integrating a design project into a class, which is finding an appropriate project. All of the planning in the world cannot guarantee that a selected project any term will work well. Nevertheless, the problem of finding an appropriate project is not intractable. By taking the time to determine goals for student learning in a particular class, and making decisions regarding the scale and scope of the project, and selecting team or individual projects, the search for a project is significantly narrowed.

The final step is to revise the course syllabus and structure to truly integrate the project. The project must mesh well with the course material so that topics are covered early enough to allow students to digest them so that they can use course methods to complete meaningful projects. A design project will also require the use of some class time, but if it reinforces course material it will be time well spent. All in all, the more the project is integrated into a class, the more it will provide students with a meaningful learning experience. Table II summarizes the project integration process.

TABLE II
PROCESS FOR INTEGRATING A DESIGN PROJECT INTO AN EXISTING COURSE

Set primary, secondary, and tertiary learning objectives
Set Technical knowledge goals
Select additional student learning objectives
Determine structure of project
Select team or individual projects
Determine scale and scope of project
Select a Project
Revise course syllabus to integrate project
Select design process for project
Determine what material must be covered and by when
Include design examples and open-ended problems in lecture

APPLIED ENGINEERING STATICS AND STRENGTH OF MATERIALS DESIGN PROJECTS

Design projects are integrated into the Applied Engineering Statics and Strength of Materials course sequence to address a number of different student learning objectives, including reinforcing traditional course material. Tables III and IV give the current student learning objectives for Applied Engineering Statics and Strength of Materials, respectively, with a cross-course design project.

TABLE III
CURRENT LEARNING OBJECTIVES FOR APPLIED ENGINEERING STATICS

Primary	(a) Analytical
Secondary	(b) Project Management
	(c) Teamwork
	(d) Creative Problem Solving
	(e) Written Communication
Tertiary	(f) Visual Communication
	(g) Ethics and Professionalism

TABLE IV
CURRENT LEARNING OBJECTIVES FOR STRENGTH OF MATERIALS

Primary	(a) Analytical
Secondary	(b) Oral Communication
	(c) Teamwork
	(d) Project Management
	(e) Written Communication
Tertiary	(f) Visual Communication
	(g) Business Skills
	(h) Creative Problem Solving
	(i) System Thinking
	(j) Self-Learning
	(k) Ethics and Professionalism

Each course has a set of student learning outcomes that can be measured. These in turn indicate that students are progressing towards the broader learning objectives. Tables V and VI indicate the specific learning outcomes for Applied Engineering Statics and Strength of Materials, respectively that are reinforced by the cross-course design project, including which learning objective(s) they address.

TABLE V
STUDENT LEARNING OUTCOMES FOR APPLIED ENGINEERING STATICS

Specific Learning Outcome	*Obj.(s)*
Identify external forces on an object	(a)
Draw a clear free body diagram showing external forces	(a)
Write appropriate equations of equilibrium	(a)
Correctly solve equilibrium equations	(a)
Develop safe solution to an open-ended problem	(a), (d), (g)
Develop design specifications for an open-ended problem	(b), (c), (d)
Meet deadlines for project milestones	(b), (c)
Keep minutes of team meetings	(b), (c), (e)
Write project interim reports	(b), (c), (e)
Write a technical report to document work	(b), (c), (e)
Create communication level computer graphics	(c), (f)
Assign team roles	(c)
Listen effectively at meetings	(c)
Show for team meetings	(b), (c)
Complete individual tasks	(a), (b), (c)

TABLE VI
STUDENT LEARNING OUTCOMES FOR STRENGTH OF MATERIALS

Specific Learning Outcome	*Objective(s)*
Determine internal force at any point in a structure	(a)
Determine stress at any point in a structure	(a)
Determine deflection at any point in a structure	(a)
Develop safe solution to an open-ended problem	(a), (h), (k)
Select appropriate materials to meet structural needs	(a), (h), (i)
Select appropriate materials to meet costs needs	(a), (d), (h), (i), (j)
Estimate cost of manufacturing	(d), (h), (j)
Select realistic tolerances for needs	(d), (h), (i)
Meet deadlines for project milestones	(c), (d)
Keep minutes of team meetings	(c), (d), (e)
Write project interim reports	(c), (d), (e)
Write a technical report to document work	(c), (d), (e)
Create CAD documentation drawings	(c), (f)
Assign team roles	(c)
Listen effectively at meetings	(c)
Show for team meetings	(c), (d)
Complete individual tasks	(a), (c), (d)
Prepare and give a professional design presentation	(b), (c)

These student learning objectives and specific learning outcomes have evolved over the three years that projects have been included in the class.

Projects and Project Evolution

As already mentioned, the main concern in selecting a design project is that it reinforce the course material. Thus projects for the Applied Engineering Statics and Strength of Materials course sequence need to have a significant structural analysis component, while still remaining general enough to allow for a wide variety of solutions. The projects used in the first three years of the class were: the design of a tripod extension to allow a camera to be located near ground level, the design of a telescope mount assist device to aid with the set up of a 'portable' telescope, and the design of a robot lift device to allow a robot to be removed from and replaced into its workcell, which can only be done vertically.

Throughout the three versions of the project several procedures have remained constant, but many have also evolved. Of the items that have not changed, the most important are the design process and the final proposal. In all cases students have used the design process that they learned in their introductory design graphics sequence [12],[13]. This process uses a five step approach as follows: (1) problem statement, (2) design specifications, (3) design concepts, (4) design selection, and (5) design details. The advantage of such a process is that it requires students to first carefully describe what they wish to accomplish before they determine how they intend to do so. In all cases the final product of the assignment has also been a design proposal including a full structural analysis with part sizing and material selection, a complete set of part and assembly drawings and, a cost estimate, instructions for manufacturing and use.

Of the facets of the program that have evolved three – the switch from individual to team projects, the switch to formal presentations, and the addition of quantitative assessment methods – are worthy of more explanation. While it is clear that employers prefer students to have taken part in multiple team experiences, the impetus to move from individual to team projects came from logistical problems of continuity, quality, and workload, as well as attempts to better address the ETec Department's project management learning objective. The continuity problem was caused by students who did not take the two courses in consecutive quarters. This led to them entering Strength of Materials without a project to complete. There are various solutions to this, such as giving students a partially completed project or allowing them to continue an old project, but putting such students onto existing teams is a better solution.

Team projects also solved problems of quality and workload that were created by individual projects. The workload issue is fairly clear, teammates can divide tasks, thereby allowing for more thorough and careful analysis, and the resulting fewer projects relieves the faculty grading burden as well. An increase in project quality comes hand in glove with fewer projects too. Teams are less likely to fail to produce a decent design than individual students. Although some students will elect not to take part in the team process, there are generally enough people on any given team who desire success to guarantee that a serious design is developed. Moreover, students on teams often raise each other's level of performance by both being allowed to work to their strengths and engaging in cooperative learning. Nothing can be done about students who elect to ignore the project, but students who would otherwise struggle on their own can obtain a complete learning experience on a team.

Another aspect of changing the project structure over the first three years was to have it better address the ETec Department student learning objectives. By introducing teamwork, the project better addressed the goal of having students develop project management skills than individual projects had. Alumni and employer surveys conducted by the ETec Department indicated that students needed more experience managing teams, and the Applied Engineering Statics and Strength of Materials project was a logical place to address this issue at this point in the curriculum.

With all of the clear benefits of teamwork, switching from individual to team projects was an easy choice. The value of switching from formal to informal presentations, however was not so cut and dry. Alumni and employer feedback indicated that students could benefit from more experience with formal presentations, but the tradeoff of class time for traditional course material versus student presentations had to be considered seriously. The switch from individual to team projects made the discussion possible in the first place, but the transition has been much slower. The encapsulated summary is that not only are presentations necessary practice for the students, they bring closure to each section of the class by allowing teams to see each others work and receive feedback from their peers. As such, most students seem to see the presentations as an opportunity rather than something to fear, and this is a situation that faculty should not pass up.

In addition to changes in the project structure to better meet ETec Department student learning objectives, quantitative assessment tools were developed to better measure the level to which these student learning objectives are being addressed. Table VII summarizes the projects and changes to the project structure over the first three years, as well as the future plans for the project, while the quantitative assessment tools and results are discussed in the next section.

TABLE VII
SUMMARY OF PROJECTS AND CHANGES BY YEAR

Year	Project	Teamwork	Presentation (AES/SOM)	Quant. Assessment
1	Tripod Extension (6 lb. camera)	No	None/Poster	No
2	Telescope Mount Assist (70 lb. telescope)	Yes (4 - 5/team)	None/Presentation	No
3	Robot Lift (400 lb. assembly robot)	Yes (4 - 6/team)	Poster/Presentation	Yes
4+	TBD	Yes (3 - 4/team)	Presentation/Presentation	Yes

Assessment and Feedback

Assessment data collected during the first two years of the cross-course project, primarily exams, projects, and general student feedback, indicated that the project was meeting its primary goal of reinforcing the course material and helping students make the jump from textbook problems to open-ended problems with many possible solutions. What was much less clear was how well the project was addressing additional the student learning objectives outlined in Tables III and IV, and the student learning outcomes summarized in Tables V and VI.

The assessment tool developed for the two courses is a pair of three part surveys. The first part asks students to rate their own and their teammates performance on the team in terms of both contribution, and responsible and dependable behavior. The second part asks students to rate the level to which they believe the design project helped them to develop skills in each of the targeted areas. These portions of the surveys for the two classes are given in Tables VIII and IX. The first two portions of the surveys allow faculty to assess almost all of the learning objectives and outcomes from Tables III-VI. The third and final portion of the survey consists of open ended questions that give students the opportunity to summarize their impressions of the project and give suggestions for changes in future versions of the classes. The remainder of the assessment data still comes from student work, such as the project reports and presentations, and student performance on exams, especially the final exams. With the addition of assessment surveys to the class, faculty have been able to get a much clearer picture of the areas in which the cross-course project is meeting its goals and the areas in which improvement is necessary. Feedback from the third year of the project will lead to some changes in the years that follow.

TABLE VIII
APPLIED ENGINEERING STATICS DESIGN PROJECT ASSESSMENT SURVEY

	Not At All				Significantly
How much do you believe that the design project enhanced your understanding of **course material**?	1	2	3	4	5
How much do you believe that the design project enhanced your **project management** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **teamwork** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **sketching and ideation** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **CAD and design documentation** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **meeting communication** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **written communication** skills?	1	2	3	4	5
How much do you believe that the design project provided an opportunity for **creative** solutions?	1	2	3	4	5

TABLE IX
STRENGTH OF MATERIALS DESIGN PROJECT ASSESSMENT SURVEY

	Not At All				Significantly
How much do you believe that the design project enhanced your understanding of **course material**?	1	2	3	4	5
How much do you believe that the design project enhanced your **project management** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **teamwork** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **meeting communication** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **presentation** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **written communication** skills?	1	2	3	4	5
How much do you believe the design project helped you to **integrate knowledge** from previous classes?	1	2	3	4	5
How much to you believe that the design project helped your understanding of **cost estimating**?	1	2	3	4	5
How much do you believe that the design project enhanced your **sketching and ideation** skills?	1	2	3	4	5
How much do you believe that the design project enhanced your **CAD and design documentation** skills?	1	2	3	4	5
How much do you believe that the design project provided an opportunity for **creative** solutions?	1	2	3	4	5
How much do you believe that the design project helped you understand **ethics and safety** in design?	1	2	3	4	5
How much do you believe that the design project aided your ability to **learn independently**?	1	2	3	4	5

It has been clear in all versions of the project that students have found the project helpful in understanding course material and how to apply it to real problems, and they frequently make comments to that effect. Moreover, since the change from individual to team projects no teams have failed to produce a functional design with a complete analysis. Not all of the designs have been optimal, but they have all successfully and safely solved the problem at hand. What the assessment surveys have elucidated is what students feel are areas in which the project has the most significant benefits.

In both classes students responded that the area in which they benefited the most was in the opportunity to develop creative solutions to realistic problems. In addition, students in Strength of Materials commented that the second most developed skill in the class was their ability to integrate material. Students also responded in both cases that the project had more effect upon their project management, teamwork, and meeting communication skills than it did on their understanding of the course material. They also increased their understanding of issues of safety and design ethics, and strategies for independent learning in Strength of Materials. Students on average felt that they gained less in other areas as a result of the project, but it should be noted that the remaining issues, sketching and ideation, CAD, written communication, presentations, and cost estimating, were generally distributed among different team members. On the final portion of the survey, students commented that the project team size should be limited to four people, teams should participate in private design reviews with faculty, and that the first poster session should be replace with a presentation. These suggestions will be implemented in future versions of the courses, and will also be seriously considered for other cross-course design projects. Table X summarizes the student responses from the two classes.

TABLE X
AVERAGE STUDENT RESPONSE TO ASSESSMENT SURVEY

Skill	Ap. Eng. Statics	Str. of Materials
Creativity Solutions	4.12	3.88
Integrate Knowledge	-	3.67
Project Management	3.85	3.61
Teamwork	3.85	3.53
Meeting Communication	3.62	3.56
Safety & Ethics	-	3.53
Course Material	3.41	3.52
Independent Learning	-	3.41
Sketching and Ideation	3.26	3.30
Cost Estimating	-	3.25
Written Communication	3.03	3.06
Presentations	-	3.03
CAD	2.85	3.13

Expansion Of Cross-Course Projects

The cross-course design project has been and is being instituted in other classes in the ETec Department as well [14]. A very similar structure has been instituted between the Engineering Design Graphics (EDG) I and II classes that students take when they enter the ETec Department. Currently efforts are underway to link this project to courses that follow, such as Introduction to Engineering Materials and Machine Metal Processes. The goal is to eventually provide continuity with all classes in the frosh and sophomore years through the use of a common project. There are also plans for integration of courses through design projects in required upper level and in new senior level elective course sequences.

CONCLUSION

The institution of a cross-course design project, while not without its challenges, has been a valuable addition to the Applied Engineering Statics and Strength of Materials course sequence. Design projects naturally lend themselves to including many important topics such as teamwork, project management, and communication, and being open-ended they help students make the transition from single answer problems to more realistic ones. By integrating the design project across the two classes it not only addresses many of the ETec Department student learning objectives, it provides continuity between the two classes. In addition, by spreading the project across two courses a more substantial project can by undertaken.

There have been changes over the course of the three years in which the cross-course design project has been included in Applied Engineering Statics and Strength of Materials. The most noteworthy of these is the switch from individual to team projects between the first and second years. This change has allowed for more of the ETec Department student learning objectives to be addressed and lowered the workload for all involved while increasing the quality and maintaining the analytical mission of the project. Furthermore, a new student survey has been implemented to obtain better assessment data regarding some of the student learning outcomes associated with the project. This has helped to show that the structure is successful and that the improvements required at this point are incremental. Overall this has been a rewarding structure for both students and faculty, and despite the effort and planning that is required, it is worthwhile for the increase in learning that occurs and the additional confidence that students gain during the courses.

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