Reassessing Design Goals: Using Design Projects to Meet Assessment Goals

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Abstract

The ability to set and assess desired student learning outcomes is key not only to maintaining accreditation, but to providing students with a high quality education as well. This paper discusses using integrated design projects to meet student learning objectives and also to provide assessment material for measuring the level of student achievement. A description of the approach is followed by a detailed discussion of a Machine Design course developed using this method. Machine Design is a technical elective for senior Manufacturing Engineering Technology students at Western Washington University. This course contains a reverse engineering/redesign project that reinforces technical material and develops students' teamwork, oral communication, and project management skills, as well as other desired skills. For comparison, briefer examples of other courses from freshman to senior level utilizing integrated design projects are also provided. The approach discussed by this paper has been very useful for developing courses to address specific desired student learning outcomes.

Introduction

EC2000 and proposed new TAC/ABET criteria have provided an impetus to provide a more coherent assessment of programs and the achievement of student learning outcomes.[1,2] While the assessment of student learning outcomes is challenging, it is extremely useful for educators to get a fresh look at the skills their graduates possess. Once assessment is underway, it is not uncommon to discover that graduates' skills in certain areas are not as strong as initially thought. One approach to address shortcomings in student learning outcomes is to utilize design projects and other realistic, open-ended problems. Carefully planned and integrated design projects can be used to both enhance and document student learning.

Whether it is solving new problems or finding new solutions to old problems, design is at the core of engineering. Despite this, engineering education moved from engineering design to engineering science in the years following World War II, only to begin to ebb back toward a design emphasis in the early 1980s. The movement back to design began slowly, but soon gained momentum with the addition of capstone design courses in many programs. By the late 1980s, capstone courses had become common and it had become clear to engineering educators that design education could not begin during students' senior year. Today most programs have some kind of design course at the freshman or sophomore level to introduce students to the process of solving

real problems in the face of uncertainty. These recent trends have been positive changes for engineering and technology students and engineering education. Students often find design classes to be interesting and challenging, and apply themselves more in these classes than they do in traditional engineering science lecture courses. In addition, design classes have provided many engineering educators opportunities to build closer ties with industry and to bring more real-world problems and examples into the classroom. Moreover, while design classes can be very labor intensive, they are also fun to teach.[3,4]

This paper discusses an approach for using design projects to meet student learning objectives beyond the mastery of analytical skills and basic engineering knowledge, and provides several examples of its implementation. Such projects in turn create various forms of documentation that faculty can use as assessment material to clearly demonstrate that the student learning objectives are being met. As a primary example, this paper discusses the planning, implementation, and results of using a major design project in a Machine Design class, an elective for senior level Manufacturing Engineering Technology (MET) students. In this class, students complete a quarter long reverse engineering/redesign project emphasizing teamwork, communication, and project management skills, while enhancing their understanding of course material and requiring them to make use of knowledge from previous courses, such as design for assembly. The class culminates with student presentations, including one to the Industrial Advisory Boards of the Manufacturing and Plastics Engineering Technology Programs at Western Washington University (WWU). This paper also compares and contrasts the Machine Design course to the use of design projects in other courses ranging from introductory to senior level classes, where the student learning objectives addressed by the design projects vary along with the content of each course.

Design and Student Learning Outcomes

The design requirements in EC2000 and the proposed TAC/ABET criteria require programs to demonstrate that graduates can solve engineering design problems, and that students' education culminates in a major design experience. There is no specific language in either which states that design must be a component of all, or even the majority of classes in a curriculum. There are, however, two primary reasons to include a design component in the majority of engineering science classes: design provides a necessary link from theoretical material to its application in the real world, and design presents a clear avenue for achieving additional student learning objectives beyond the development of analytical skills and basic engineering knowledge. If one's goal is to have students graduate being both competent and comfortable applying rigorous engineering approaches to new technical problems, then one needs to teach engineering theory as a set of tools for solving new problems.

There is also much more to engineering than being able to apply engineering theory to the solution of problems and the development of new products and processes. The skills that graduates must have in order to be successful include the ability to communicate, the ability to work on an interdisciplinary team, and the ability to manage projects large and small, to name just a few. EC2000 clearly indicates that programs must set their own goals as to the expected level of student achievement in these areas, and then fully document that students are gaining experiences in these areas and attaining the desired level of competency.

As part of an internal review of our own programs as preparation for ABET review, the faculty of the Engineering Technology (ET) Department at WWU developed a list of desired skills of graduates for our department student learning objectives, which are given in Table 1. The ET Department has approximately 425 students in six different majors: Electronics, Manufacturing, and Plastics Engineering Technology, Industrial Design, Industrial Technology, and Technology Education. Of these programs, only the three engineering technology programs fall under the rubric of ABET. Nevertheless, the ET faculty elected to adopt all of these desired student skills as objectives for every program in the department, except for Programming Skills which are only for the ABET accredited programs. The difference between the programs is the level to which students are expected to develop these skills. A preliminary survey of the courses in the ET Department showed that not all of our programs were addressing the student learning objectives at the levels that were generally believed. For example, faculty in the Manufacturing Engineering Technology (MET) Program found that students were not receiving as much instruction or experience in the areas of teamwork and oral communication as was intended. As an immediate remedy to this shortcoming, faculty developed the design project in one of the senior level MET design electives, Machine Design, to guarantee that some of the graduating seniors received more training and experience in these areas.

Analytical Skills Ability to: logically analyze and solve problems from different points of view; translate scientific and mathematical theory into practical applications using appropriate techniques and technology.	**Visual Communication Skills** Ability to: utilize appropriate technology to create drawings, illustrations, models, computer animations, or tables to clearly convey information; interpret and use similar information created by others.
Oral Communication Skills Ability to: verbally present ideas in a clear, concise manner; plan and deliver presentations; speak and listen effectively in discussions based upon prior work or knowledge.	**Written Communication Skills** Ability to: present ideas in clear, concise, well-structured prose; choose appropriate style, form, and content to suit audience; utilize data and other information to support an argument.
Creative Problem Solving Ability to: apply a design process to solve open-ended problems; generate new ideas and develop multiple potential solutions; challenge traditional approaches and solutions.	**Teamwork Skills** Ability to: work together to set and meet team goals; encourage participation among all team members; listen and cooperate; share information and help reconcile differences of opinion when they occur.
Project Management Ability to: set goals; create action plans and timetables; prioritize tasks; meet project milestones; complete assigned work; seek clarification of task requirements and take corrective action based upon feedback from others.	**Programming Skills** Ability to: use higher level, structured programming languages to write effective and efficient code to complete a task such as modeling or calculation, or control equipment; understand and adapt existing structured programs.
System Thinking Skills Ability to: understand how events interrelate; synthesize new information with knowledge from previous courses and experiences.	**Self-learning Skills** Ability to: learn independently; continuously seek to acquire new knowledge; acquire relevant knowledge to solve problems.
Ethics and Professionalism Ability to: understand and demonstrate professional and ethical behavior; understand social and ethical implications and interrelations of work, and respond in a responsible and professional manner.	**Business Skills** Ability to: accurately estimate production costs; calculate the cost effects of alternative designs; predict the effects of quality control, marketing, and finance on product or process cost.

Table 1: Department Student Learning Objectives – Desired Student Skills

Using Design Projects to Meet Student Learning Objectives

Using design projects as a method to help students develop a wide range of necessary skills presents numerous challenges for engineering faculty, not the least of which is deciding where to begin. In order to develop an organized and successful program of utilizing design projects throughout engineering education, faculty must approach the problem as one would approach any engineering design problem, and take the time at the beginning to completely state the problem and the goals and objectives in solving it. One cannot realistically expect to address every student learning objective in every course, but one must address every learning objective at some point in every curriculum, ideally more than once. Thus faculty need to prioritize various learning objectives for students (including technical knowledge), determine where objectives should be introduced, and where objectives should be reinforced. Again, one can treat this as the next step in the engineering design process, setting specifications (in this case student skills), and then ranking their importance. Of course, it is neither possible nor desirable to address every learning objective in every class. For example, while oral communication skills and teamwork are two of the traits of graduates most valued by employers, not every class can have team projects and student presentations. Sometimes faculty want to make sure that every student does every portion of a project so that they all reinforce analytical skills, and in many classes there is not enough flexibility in the content of a course to create the time for student presentations. It is a task for the entire faculty to determine how many such experiences students should receive, after which faculty must also reach consensus on where those experiences will take place. In some cases, however, the faculty may decide that certain skills such as written communication or ethics and professionalism are important enough that they should be incorporated into every class, in which case some part of every course must be organized to meet these goals.

Regardless of whether the impetus for selection is a personal or departmental decision, the course designers need to determine to what extent they will be addressing student learning objectives in the course. The ET Department at WWU ranks the extent to which each objective is addressed on a six-point scale, with the lowest level being that the skill is not addressed in the class. The next higher levels include small assignments reinforcing or practicing skills introduced in other courses, and limited or no new instruction on the skill. The highest levels include larger, longer assignments, frequently more than one, and significant instruction and feedback regarding the skill. Just as not every skill can be integrated into every class, not every skill that is part of the class can be addressed to the same extent. Selecting the learning objectives to be addressed and the extent to which they will be addressed will help determine both the scale and scope of assignments that one will use in the course, and the amount of class time that one must devote to instruction on the subject. Before creating a syllabus, however, the course developer must address the issue of student evaluation.

Methods of student evaluation are a personal choice, but such decisions should be made early in the course development process. Moreover, the evaluation materials themselves should be designed with the syllabus, rather than a day or two before the test or assignment is given to students. The logic behind this is that the course designer will be evaluating students on what he or she considers to be the most important concepts and methods. Therefore, if the course designer creates the evaluation materials with the course syllabus and before lecture material, he or she will create a course that is aimed toward desired learning outcomes. The exact questions do not

necessarily have to be developed, but the topics on which students will be evaluated and the relative level of importance placed upon each one should be determined. The intention is not to 'teach to the test', but to clearly define and rank student learning goals. The coverage should match the significance of the topic. Once developed, the evaluation materials should be used to determine the details of the course. The goals and evaluation materials will aid in determining what material must be covered, in how much depth it must be covered, and the time schedule for covering it. It is likely that the course will be organized in a slightly or even drastically different form than it has been in the past. This may make finding an appropriate text or texts more challenging, but the course will be more focused on stated student learning objectives.

The other question to ask is whether evaluation materials are going to be useful assessment tools that demonstrate the course is meeting its student learning goals. Somewhere in the course there should be some assignment or assignments that document the student work in each learning objective and demonstrate that the students have either progressed in the development of that skill or reinforced that skill through practice. When the course includes a design project, it will be relatively easy to obtain evidence that some of the student learning outcomes are being met. For example, a final design report may show that the course addressed creative problem solving ability, visual and written communication, and even project management and business skills depending upon the report content. In addition, copies of student presentation materials along with photographs or videotape can be used as evidence that oral communication skills were addressed as well. Documenting other student learning objectives such as teamwork and ethics and professionalism can be more difficult. Even when the design project involves teamwork the final project will not show how well the students worked as a team. Evidence of teamwork may be found by collecting other types of student work, such as progress reports, meeting minutes, and design notebooks. This will effectively create a design portfolio of student work, which can enhance evidence for other claims of student learning.

Along with copies of student work, faculty should not overlook the value of student surveys and external reviews. Student perceptions of what they actually learned and practiced in a course are valid, valuable, and easy to obtain through surveys. Schools in the NSF Gateway Coalition have created an assessment toolbox for faculty which contains easily adapted surveys and other forms for obtaining student feedback on how specific courses address student learning objectives.[5,6,7] An equally valuable, although potentially more difficult approach is to enlist representatives from industry to provide external review of student work. This can be anything from providing external reviewers for student presentations or student reports, to having the occasional observer attend student meetings. There are two levels of challenge for this approach. The first is getting anyone from industry to find the free time to donate in order to take part in student work. This is easier to solve if the project is sponsored by industry or if it can be coordinated with some other event such as an Industrial Advisory Board meeting. The second challenge is getting written feedback. Without some form of written documentation to record the opinions of outside reviewers there is no real evidence. Instead of trying to get an outside reviewer to write a letter, however, this is again an opportunity to create a short, specific survey that reviewers can fill out quickly and sign to attest to their assessment of the students' level of achievement. Outside review coupled with student feedback and student design portfolios will give a complete set of information for full assessment of how well any course is meeting the stated student learning outcomes.

A *Machine Design* Course Developed to Meet Student Learning Objectives

The ET Department at WWU began the process of developing a full student outcomes assessment plan during the 1998-99 academic year. As has been widely reported by other schools, this is a slow and difficult process.[7,8] There are numerous obstacles, not the least of which are the time required and the cultural inertia that inevitably must be overcome. We have had relatively good success overcoming the latter through the use of virtually full department participation in final decisions, coupled with pressure from multiple internal and external sources. As such, the ET Department Assessment Committee was able to develop a set of desired student learning outcomes that the faculty adopted for every program in the ET Department and conduct a preliminary survey of the level to which department courses were meeting the student learning objectives. The survey was neither complete nor ideal. For various reasons, it was not possible to obtain information from every course, and it turned out that there was variance in the faculty interpretation of the definition of student achievement levels so that only general trends could be inferred. This was still a very useful exercise. In effect, it was a trial run that has allowed the Assessment Committee to develop more focused and accurate assessment tools, and also given them more time to soften some of the faculty resistance to the mission.

The preliminary survey also showed some useful and important information that went against general ET Department beliefs. In the case of the MET program it was clear even from the preliminary survey that students were not receiving as much instruction or practice in the areas of teamwork, oral communication, and ethics and professionalism as was commonly assumed by faculty or intended in the ET Department goals. The exact reasons for these shortcomings are secondary to the issue of making changes to address the issue, although it in part stems from the use of individual rather than team capstone design projects. This approach to capstone design is used throughout the ET Department as a last chance to guarantee that every student is capable of completing a large, open-ended project. From the standpoint of certain skills, such as written communication, creative problem solving ability, and project management this approach is very effective, however it addresses these other issues at the expense of teamwork. One solution developed to address these shortcomings was to modify some of our technical electives to incorporate certain aspects of a capstone design experience, concentrating on some of the student learning objectives that were not being met by required courses. This is not a long-term solution, but it did create an effective stopgap measure until a more complete department plan is formed.

The technical elective that was offered to senior MET students in the spring 1999 term was Machine Design. As a design course, it naturally lends itself to open-ended team projects and student presentations. For the first step in the course design, faculty selected and ranked the student learning objectives for the course, which are summarized in Table 2. The primary student learning objectives for the course are the development of teamwork, oral communication, and project management skills. The secondary student learning objectives for the course are creative problem solving ability, written and visual communication, business, and system thinking skills. In addition to the development of other desired student skills, there are specific analytical skills students should develop in the course as well. The main technical objectives for the class are to have students become familiar with failure theories and standard design practices for mechanical components so that they could correctly and efficiently design or select the types of mechanical components that are found in a power transmission system.

Primary Learning Objectives	Secondary Learning Objectives	Specific Analytical Skills
▪ Analytical Skills ▪ Teamwork ▪ Oral Communication ▪ Project Management	▪ Creative Problem Solving ▪ Written Communication ▪ Visual Communication ▪ System Thinking ▪ Business Skills	▪ Correctly apply appropriate Failure Theories ▪ Correctly design or select mechanical components for power transmission systems

Table 2: Desired Student Learning Outcomes for Machine Design Course

In order to address all of the student learning objectives, faculty chose a reverse engineering/redesign approach to the design project. The reverse engineering process provides a very quick learning curve for students when they are learning the technical material and developing skills such as project management.[9] Furthermore, the redesign portion of the project provides them with an immediate opportunity to practice skills learned during the first portion of the project. As is often the case, the success of a course such as this hinges upon finding an appropriate project. The machine design project needs to fit the following constraints: (a) be complex enough to require teamwork to analyze and redesign, (b) not be so complex that the initial analysis could not be completed by midterm, (c) contain basic power transmission components, (d) not be so well designed as to not give students a reasonable opportunity to make suggestions for improvement, (e) be affordable for teams of three students in their basic course laboratory fee. In this particular case, faculty selected a cordless screwdriver with multiple speeds, a torque clutch, and a handle that could be switched between straight-line and pistol grip. The cordless screwdriver fell within the project constraints as well as any device that was readily available.

With the project selected, the next step in the course design process was to integrate the project into the course such that the student learning objectives were all addressed at the appropriate level. Project management and teamwork were linked together through the setting of goals, intermediate milestones, and individual tasks to meet the goals and milestones. For the first half of the project the instructor acted as team leader and provided the project goals and intermediate milestones. Students discussed and agreed upon individual tasks and responsibilities to meet the goals and milestones for this portion of the project. For the second half of the project students began by developing their own set of project goals and intermediate milestones, and then agreed upon individual tasks and responsibilities. Due to the small team size of three students, and the fact that all students in the class were familiar with each other from previous coursework, students did not set specific team roles such as leader or recorder. Instead, each student accepted full responsibility for a portion of the project and all major decisions were made as a committee of the whole.

Student discussions on the project constituted a portion of the approach to developing student oral communication skills as well. Part of good oral communication is the ability to clearly state ideas and to listen well during meetings. As such, the student design team met with faculty each week to discuss what had been accomplished, what had been discovered, what would be accomplished by the following week, and the plan for accomplishing it. In addition to the weekly meetings, students gave two formal presentations. The other MET faculty were the audience for these presentations. The presentations were also open to students who were not in the class, although the attendance by other students was low. Having a formal and partially unknown audience helped to motivate students to work harder to prepare professional presentations. In prepa-

ration for the presentations, students were given instruction on preparing a presentation and feedback on their plan and material in advance.

Like the primary learning objectives, the majority of the secondary learning objectives were addressed by the reverse engineering/redesign project. Written and visual communication skills were addressed through a midterm reverse engineering report, a final redesign report, and the development of communication and engineering drawings for the reports and presentations using Pro/ENGINEER. Students also kept formal design notebooks that were collected and reviewed with the project reports. Students were given feedback on their writing and drawings, but unlike the primary learning objective skills, there was no specific instruction in these areas. System thinking and business skills were also addressed through the project. Students were required to call upon knowledge learned in previous classes, specifically Manufacturing Automation and Robotics, Computer Integrated Manufacturing, and Manufacturing Economics. Students utilized a design process they had learned previously, completed design for manufacturing and assembly analyses for both the reverse engineering and redesign portions of the project, and developed a complete cost estimate for both halves as well. As with the written and visual communication, students were given feedback, but little new instruction in these areas.

Unlike the other student learning objectives, creative problem solving was addressed through more than just the course project. Certainly the redesign portion of the project did include creative problem solving, but the rest of the class repeatedly addressed this issue as well. Other than the project, and partially to work around the project schedule, the lecture material in the course was divided into thirds. The first third of the course included a brief review of structural analysis and the development of failure theories. The exam on this portion of the class was a standard engineering class test that contained several problems each with a single correct answer. The remaining two-thirds of the course were devoted to the design and selection of machine component such as gears, shafts, and bearings. In this portion of the class the majority of assigned homework problems were open-ended, and the last two exams were two halves of a large design problem during which students individually designed and analyzed a small, single-speed transaxle for a piece of lawn equipment. The specific desired analytical skills in the course were also primarily addressed through lecture, homework, and tests, but certain aspects were reinforced through the analysis of the gearbox and other loaded components in the project.

Along with providing the means to address most of the desired student learning outcomes, a design project also creates the majority of the evidence as to the level of student achievement in all areas of the course. In the specific case of the Machine Design class, the design project provided evidence of student learning through the midterm and final reports and presentations, the student design notebooks, and the student plan for the redesign portion of the project. This kind of design portfolio is standard to many design courses, and it does clearly demonstrate student achievement in many areas. In addition to what faculty collected as evidence of student achievement, however, there were several other good opportunities to collect assessment evidence that were squandered. Students were visibly more confident and comfortable during their final presentation than they were during the reverse engineering presentation. The final presentation was so strong that the MET Program Director asked the team to repeat their presentation to the combined MET and PET Industrial Advisory Boards (IABs). Nevertheless, there were two great opportunities that were missed: student presentations were not recorded, either with video

or still photography, and written feedback was not collected from either the faculty review panel or the IAB members after any of the presentations. In addition, students in the course were not surveyed other than with the standard course evaluation form. While the course evaluations let me know that the students all felt that they had learned a great deal in the class and had enjoyed the experience, they did not provide specific information as to the skills that students believed they had developed in the course. So while I believe that the course addressed the student learning outcomes I intended at roughly the level I intended, I did not collect all of the available supporting evidence to confirm or refute my belief.

Additional Examples of Using Design Projects to Meet Specific Learning Objectives

The Machine Design course discussed in the previous section is slightly different from other courses taught in the ET Department in that faculty made decisions about what aspects to emphasize and provide instruction on in Machine Design after the ET Department had completed a preliminary assessment of the MET program's level of meeting student learning objectives. Nonetheless, even though there was a reactive or prescriptive aspect to planning the Machine Design course, faculty utilize the method of selecting and ranking student learning objectives and addressing them through an open-ended design project in many courses. For the purpose of comparison, the remainder of this section briefly describes four other projects that are used in the manner described in the previous section and how they are currently evolving.

Engineering Graphics I

Engineering Graphics I is an introductory course that is required for all students in the ET Department regardless of major.[10] It is the first class in every program, and many of the students who take the course are considering getting an ET degree of some kind, but most have not yet committed to the ET Department. As an introductory class, this course covers three basic areas: design, freehand drawing to improve visualization skills, and an introduction to computer-based solid modeling. The course also needs to be fairly interesting so as not to discourage students from staying in the ET Department. The learning objectives that are primarily addressed by this class are visual communication skills, creative problem solving ability, and project management skills. This is also a class that is taught multiple times every year by several different faculty. As a result, there is some variation from section to section, although the ET Graphics Committee works diligently to minimize variation in the overall content.

Students in every section of this class complete two design projects. Since students are learning the design process and project management skills, the first project lasts nine weeks. As part of this project students complete steps in the design process every one to two weeks. These steps concentrate on presenting visual information such as design sketches, hand and computer communication drawings, and simple engineering drawings. Other steps include the definition of the design problem and setting of design specifications. The goal of this project is to lead students through a well-managed design project and to create and reinforce some good habits. The most common project is to have students design a solution to some kind of a storage problem. This is generally a very effective project because every student has trouble fitting something into a small dorm room or crowded apartment, which allows each student to personalize the problem.

The second design project is the final project in the course. Students are given three weeks to design a flashlight. This project is designed to both reinforce the skills learned in the first project, as students use the same design process and all of its steps, and lead into the following course, Engineering Graphics II. During Engineering Graphics II students complete a team-based design project to also design a flashlight, but there they concentrate more on the engineering drawings and manufacturability of their design. That course culminates in the students creating a prototype of their design. The assessment of Engineering Graphics I has shown that students are learning about the design process and developing visual communication skills. It is less clear how much they are absorbing about good project management, but that is why necessary skills are covered in more than one class.

Statics and Strength of Materials

Like the Engineering Graphics I and II courses, the Statics and Strength of Materials course sequence also makes use of a design project that bridges two courses.[11] This project is integrated across the two classes so that Statics begins with a review of the design process and Strength of Materials ends with a student design poster session with an open invitation for anyone to attend. The primary objective of this design project is to reinforce the analysis tools that are taught in lecture and to help students learn how to apply the theoretical material to realistic open-ended problems. In addition, the project serves to increase student confidence in applying the material to real problems. The design project also addresses students' creative problem solving abilities. It addresses their system thinking skills as well by requiring them to draw links to previous classes in their curriculum. Furthermore, it addresses their motivation for self-learning and business skills by requiring them to develop an estimate for the cost of producing their design. Finally, students practice skills in written and visual communication and project management to successfully complete the project, although the latter is not strongly emphasized as students are not required to develop their own intermediate deadlines or coordinate with team members. Assessment of these courses has shown that the students do become more comfortable with the core material of the class than in the standard lecture-homework-test format. This course sequence is evolving slightly this year, as we are switching from individual to team design projects. Individual projects were used to confirm that every student could complete the analysis of their design successfully, but preliminary assessment of the MET and PET programs, whose students make up the majority of the class rosters, showed that there is a dearth of teamwork in these programs at the sophomore level. Student feedback is also leading to the use of more open-ended problems as in-class examples to help students make the connection between theory and realistic application.

Fluid Power

In the Statics and Strength of Materials course sequence the design project is integrated into the lecture. In Fluid Power the design project is integrated into the laboratory. Fluid Power is a junior level class that includes an introduction to Fluid Mechanics as well as an introduction to Fluid Power. It is currently required of all MET and PET students. The primary learning objectives of the Fluid Power project are teamwork skills, project management skills, and creative problem solving ability. Students complete a small set of laboratories to introduce them to pneumatics, and then the rest of the laboratory periods are used to solve open-ended problems that require the

use of pneumatics. Projects are solicited from local industry and other faculty who occasionally need a device built or modified for a different laboratory. Secondary learning objectives for these projects are the reinforcement of written and oral communication skills, business skills, and analytical skills. Students complete a project-management-style survey and are placed onto teams to ensure that there is a balance of styles on every team. The teams are then given a short problem description from the customer who will be receiving their design and a final deadline. Teams are sometimes given a budget as well, depending upon for whom they are doing the project. The teams are responsible for determining team roles and tasks, setting intermediate deadlines and goals, and, of course, solving the problem. The amount of effort faculty exert on the teamwork skills of the students often ends up being inversely proportional to the quality of teamwork. This is not ideal, but it does address those who need the most help. During the term each student is required to turn in a weekly progress memo detailing his or her contribution to the project since the last laboratory period. At the end of the term each team does an informal presentation and demonstration of their project, and also turns in a report detailing their design. The projects do reinforce some of the material in the course, although due to limitations of time and money, the systems students design are quite simple compared to what they can expect to find once they graduate.

Manufacturing Automation and Robotics

The Manufacturing Automation and Robotics course is one of the last required classes students take before they graduate, so preparing students for their careers is a major concern. The projects in this class are part of the laboratory component just as they are in the Fluid Power course, although the projects are sometimes integrated into the course lecture material as well. As with Fluid Power, the Manufacturing Automation and Robotics course project is primarily designed to enhance students' teamwork and project management skills, and their creative problem solving ability. The course projects also put a strong emphasis on students' oral and written communication skills, and their analytical and programming skills. The course is a required course for MET students and is taken as an elective by EET students. On average the EET students comprise one quarter of the course enrollment. Students are placed into teams by both styles and skills, and each team is given a different project. Most of the projects involving designing and demonstrating an automatic assembly system using a SCARA robot, although some projects involve building devices under the control of microcontrollers instead. The projects reinforce the material that is covered in lecture, and occasionally end up as examples in lecture for certain topics. Students are also introduced to the SCARA robots by being given a simple programming task on a completed project from a previous term before they are assigned to teams and given their own projects.

As with Fluid Power, students in Manufacturing Automation and Robotics determine the team roles and intermediate deadlines, and develop the solution including the parts feeding strategy. Students are also required to turn in individual weekly progress reports and a team final report. The final report includes the team's suggestions for changes to the design of the assembly to improve its production efficiency. In the past, students gave only an informal presentation and demonstration of their project. The course has evolved, however, so that students now give a formal presentation to other faculty and students, followed by a demonstration of their project. The student effort level on these projects is very high, although some of teams learn about proj-

ect management the hard way by doing virtual round-the-clock work before their presentations. Nevertheless, informal feedback from alumni indicates that these projects are among the experiences that they consider to have been the most valuable in their education.

Conclusion

Engineering and technology education is in a state of flux. Engineering and technology educators are being asked to help students develop a wide range of skills to maintain or improve the technical content, and to develop and implement a plan to document that the level of student achievement is meeting expectations. While this is leading to many improvements in engineering and technology education, it also is creating many challenges for faculty. This paper has presented an approach for using integrated design projects to both meet desired student learning outcomes and collect assessment material that can be used to gauge the level of student achievement. The first step in the approach is to treat course design as any engineering design project. Thus faculty should begin by selecting a set of student learning objectives and determining the degree to which they will address them in the course. Once faculty have determined the course specifications, they can develop the course structure and select methods for student evaluation. Before making final decisions and developing course material, faculty should consider how well student work will document student learning and decide what supplementary assessment methods should be used to provide a complete set of assessment information. This approach is being used in the Manufacturing Engineering Technology program at Western Washington University to develop and refine courses, such as the Machine Design course this paper discussed in detail. Faculty in the Engineering Technology Department are still conducting a complete assessment of existing courses, but once this is complete and faculty reach consensus on program goals for student learning outcomes, the method described in this paper will be one of the primary methods for eliminating discrepancies between the current program curricula and curricula that will meet all student learning outcomes at the desired level.

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