AC 2012-5035: ENGINEERING TECHNOLOGY INTERDISCIPLINARY PROJECTS

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Engineering Technology Interdisciplinary Projects

Engineering Technology Education Needs

Both engineering and engineering technology (ET) accredited bachelor degree programs require a capstone project or cooperative education experience for students to apply their technical knowledge in real world situations. The Association of Technology, Management, and Applied Education (ATMAE) organization in its accreditation standards require baccalaureate degree programs to include an element of industrial experience as related in the following.

> "Each program of study shall include appropriate industrial experiences such as industrial tours, work-study options/cooperative education, and/or senior seminars focusing on problem-solving activities related to industry. Industrial experiences shall be designed to provide an understanding of the industrial environment and what industry expects of students upon employment."[1]

Similarly, the Accreditation Board for Engineering and Technology (ABET) organization requires a capstone or integrating experience in its accreditation standards stating the project must provide opportunities for students to develop competencies in applying both technical and non-technical skills in solving problems.[2] Often it is the non-technical skills of teamwork, confronting issues of diversity, and communication (both written and verbal) that are lacking in traditional engineering courses but are often experienced in a capstone project.

Regardless of whether an ET program is accredited, these standards bring to light what is often the primary goal of any educational program, whereas the ultimate goal is to prepare students for employment by providing problem solving experiences similar to what they will experience in their careers. So, in many cases the most practical method of achieving this goal is to provide a short term simulation of the industrial environment where the student can be observed and given advice how to proceed by an expert in the field when necessary.

This method closely follows the circular experiential learning model first proposed by Lewin then later refined by Kolb[3,4]. In this cycle, student learning is a dynamic that flows through concrete experience, reflective observation, abstract conceptualization and active experience. In this model the advisor role is that of a mentor rather than instructor. This provides the opportunity for the advisors to share professional experiences with the students on an individualized basis, opening dialogue that is not typically found in the classroom. With this learning model problem solving is actual rather than theoretical, providing the students the opportunity to bridge theory and practice.

Following this model, learning begins with experience closely followed by observation and sense making of the experience by the students. Due to the fact that the observations come from the students, the projects themselves are much more real to the students, providing them with the opportunity to take ownership of the project. Further experimentation based on the student perceptions leads to yet another experience, embracing the circular design of the model. Learning then is a product of a dynamic dialogue primarily between the student and advisor, but also with all stakeholders (student, advisor, institution, sponsor, community, and future employers) involved in the process.

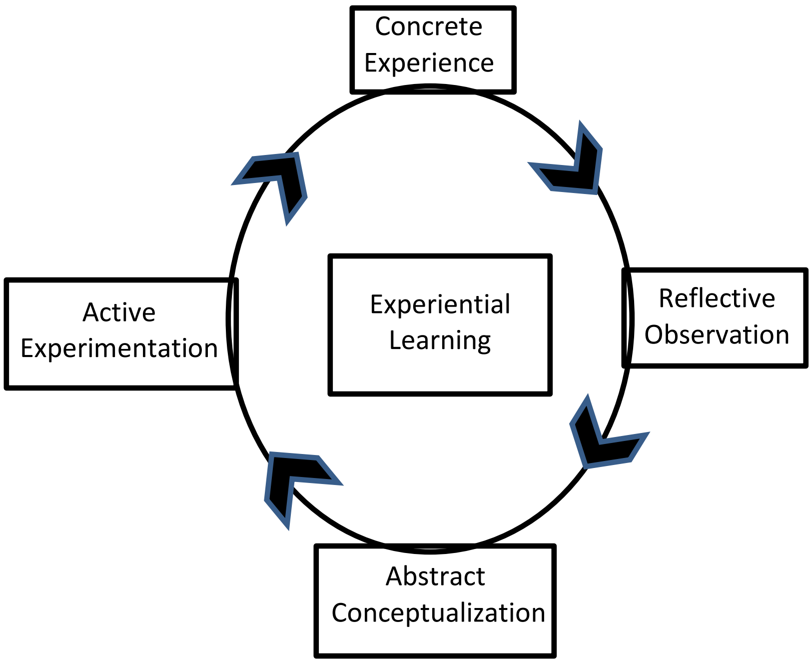

Figure 1: Kolb model of experiential learning

University Community Needs

The leading factor in the development of a capstone project for ET students is to satisfy the goals stated in the University strategic plan, where at Michigan Technological University the goal states that the education experience will enrich lives and improve our world through interdisciplinary endeavors that span engineering, sciences and arts, technology, forestry, and business.[5] Not unlike many University missions, visions, strategic plans, and goals this plan conveys good intentions, but lacks in direction or means to achieve those goals. The action plan to achieve the goals becomes a task of the departments or program areas while planning curriculum reform and revision through a continuous improvement plan. Feedback from program constituents such as industrial advisory members, students, employers, and alumni confirm that it is important to provide interdisciplinary opportunities to ET students, but they also lack in providing a means to achieve these goals.

Enterprise Program Opportunities

The fact is that ET students can navigate through four years of curriculum taking every required and elective course without any interaction in a team with students from another department or program area solving industry related problems. Most ET courses are homogeneous in their student body because of the specific content related to only their program area, and the larger courses that have several students from various disciplines are not usually designed to deliver material through activities requiring team projects. Even though the prior scenario is a possibility, there is always the option for ET students as well as all other program area students to join an Enterprise Program Team, which are advisor lead interdisciplinary groups of students joining together to work on long term projects. The Enterprise program is a way that students can experience working in a team that emulates how a company solves real-world problems, but it is not a requirement of students for graduation and most often is regarded as an extra-curricular activity that requires many hours of effort in addition to their course load. The progress towards combining the requirements of the capstone project with Enterprise Program participation will be shared at the conclusion of this paper.

Interdisciplinary capstone projects in engineering education are not a new or innovative practice as illustrated in an April 1995 Journal of Engineering Education article which reported the results of a survey that was conducted by researchers from Brigham Young University to reveal practices in engineering capstone courses in North America. [6] Of the 360 departments from 173 schools responding to the survey it was shown that 23% were interdepartmental teams as opposed to departmental or individual, and 81% were University sponsored rather than student or company sponsored, which supports the existence of interdisciplinary school sponsored approach to capstone projects. Of more interest to this study is that the survey yielded results for how projects were obtained, where 59% solicited projects from industry, 58% obtained their projects from within their department, (some projects were classified as both from industry and within their department) and 15% found them from other sources, where most of the "other" sources were reported as scientific journals or sponsored research. The origination of projects that are in need by one department in a University and at the same time provide an opportunity for students from another department to experience real world applications of knowledge while working in a diverse team providing a service to the University is worth investigation.

Service Learning Projects

Traditionally, service learning is where students participate in an organized service that meets the needs of the community, which helps foster civic responsibility, is integrated and enhances the educational experience, and at the conclusion provides a means of reflection for the students involved. Engineering Projects in Community Service (EPICS) is an initiative conducted by Purdue University reported in a 2005 article in the International Journal of Engineering Education where elements include community partners, large vertically-integrated teams of students from freshman through seniors, long term student participation, variable credit hours, multidisciplinary teams, and a start-to-finish design experience[7]. This approach is similar to the design of the Enterprise Program in that both involve students from various program areas and levels of education and experience in long term projects, although in the EPICS project the funding is provided by the University for prototype or proof of concept models and then students work with the community partner to raise funds, whereas the Enterprise Program groups are company sponsored.

The projects described in the following case studies are interdisciplinary capstone projects that are providing a service to a department or program sponsored either by the University or a company sponsor. The main service provided in these projects is the time invested in the lengthy product design process involving the evaluation of customer needs and development of design alternatives concluding with a manufactured prototype or test procedure. These projects also incorporate another element of service learning in that the student involvement impacts the University community as a whole through their efforts allowing the valuable opportunity for student reflection at the conclusion of the project. Examples of projects include installation or upgrading of laboratory equipment that may exist in departments that has fallen into disrepair, been purchased or donated by industry, or that needs to be retrofitted to serve a new purpose. As a result of utilizing this otherwise non value added equipment, the capstone projects fulfill the University sustainability strategic goal as well as departmental education needs. It is important to note here that it is critical that the projects align with the ET program student outcomes incorporating design, build, and testing of devices so that student groups are not merely serving as inexpensive labor performing menial tasks.

Capstone Interdisciplinary Projects

The capstone projects described in the following case studies include troubleshooting, retrofitting, designing, and manufacturing components for an environmental simulation test chamber, a donated die cast machine, a rotary fatigue bend tester, and the development of a CPR mattress manufacturing process for the departments of Civil, Material Science (MSE), and Biomedical Engineering. The projects involve groups of students that are composed of ET students from one or more program area working together with students from the College of Engineering and the School of Business.

In the School of Technology (SofT) the Mechanical Engineering Technology (MET) and Industrial Technology (INT) programs are two of the five program areas where each student completes a two semester capstone project sequence to meet the requirements for graduation and to comply with accreditation standards. Implementing capstone projects in conjunction with industry partners presents several challenges. Some of the challenges that may be faced include; project completion timelines that do not align with academic calendars, proprietary information that cannot be shared, and the difficulties of scheduling collaborative meetings with students and the industry project lead personnel. Budget constraints are an additional barrier, especially during a slow economy that may not allow for companies to donate resources for sponsoring student run projects. Because of these barriers and the advantages of interdisciplinary learning and service learning projects the MET program has pursued capstone projects that originated outside the School of Technology department but within the University.

Project Background – Case Study #1 Environmental Test Chamber

The Biomedical Engineering department was recipient of a donated 1986 environmental test chamber that was not being used and was transferred to the MET department. Soon after receiving the test chamber the Civil Engineering department inquired whether the chamber could be used to assist in evaluating a concrete specimen for a senior project. An interdisciplinary team of INT and MET students evaluated the condition of the SM16C Thermotron Test Chamber to ensure the chamber was operational and learned to operate the 2800 controller/programmer.

Figure 2: Test Chamber Front Right

Figure 3: Test Chamber Water Purification

The chamber needed retrofitting with a demineralized water system necessary for humidity testing, which required a demineralization cartridge and filter with necessary brackets and piping. The 2800 controller/programmer board needed replacing along with other items such as a fan blade, solenoid valve, and viewing window wiper blade. The team researched testing standards required by the Civil Engineering department students to assist in testing a concrete specimen containing a temperature sensor. Using product design tools presented in the course the students presented the best option and implemented the testing utilizing temperature and humidity sensors and made modifications to the chamber as necessary. One of the products provided by the team was a written guide for operating the chamber to run programmed temperature and humidity cycle tests.

Project Background – Case Study #2 Die-Cast Machine

Originally started in the Fall of 2008 a team of MET students had the goal of installing a zinc die-casting machine that was purchased then left idle for 2 years, for MSE students to utilize in future projects related to die design and casting of new zinc die-casting alloys. This team had to coordinate efforts with the facilities department to run utilities for the machine, the foundry faculty, and students for deciding the most advantageous location of the machine for future use. After the equipment was located and the utilities for the machine run, the students had to go through the machine and original Operators' Manual (1983) and get the machine operating, safely. To do this, there were many real world challenges that the group encountered and overcame, including scheduling, working with the skilled trades, and installing and troubleshooting the equipment.

Figure 4: Idle Die Cast Machine

Figure 5: Installed Die Cast Machine

Following the completion of this project several other capstone projects have been completed such as a group of MSE, MET and ME students who studied the correlations between defects and process parameters of die casting and a troubleshooting guide was made for cold shuts and porosity defects. In 2010, a second group of MET students worked in conjunction with the Advanced Metalworks Enterprise (AME) students to design and machine a die set that would be capable of producing tensile bars that AME would utilize to acquire material data for the company sponsor. This enabled a group of MSE students to utilize the tensile bars to evaluate the creep resistances of a new high-temperature die-cast zinc alloy.

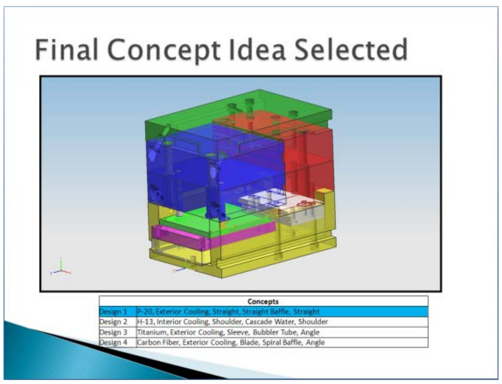

Figure 6: Concept of Unit Die and Holder

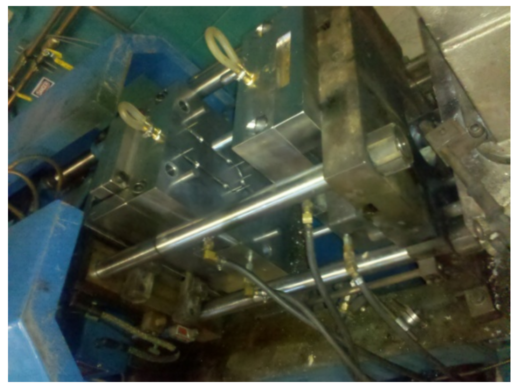

Figure 7: Installed Unit Die and Holder

Project Background – Case Study #3 Rotary Fatigue Bend Test Machines

Students evaluated the current condition of the four rotary fatigue bend machines operated and used primarily by MSE students. The MET senior design team, working collaboratively with the MSE department, made the test machines operational.

Figure 8: Existing Rotary Fatigue Bend Machines

The intent was to augment the room temperature testing functionality by designing, building, and optimizing a heating system that would provide temperature reading testing capability to 200°C/400°F. The team evaluated using either resistance heating or induction heating. Using product design tools presented in the senior design course, the students developed and implemented a design including machine modifications and sample test results.

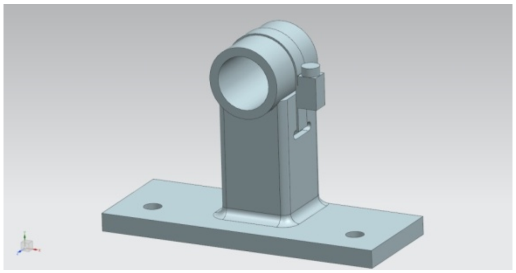

Figure 9: Final Design

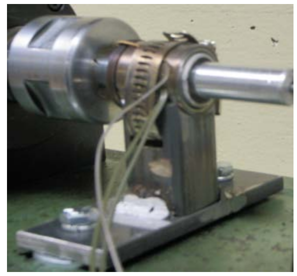

Figure 10: Installed

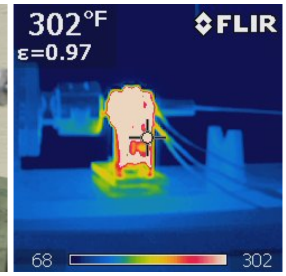

Figure 11: Operating

Project Background – Case Study #4 CPR Mattress Manufacturing Process

A senior design project from the Biomedical Engineering department resulted in the development of a CPR mattress enterprise company (CPRM) being formed by a combination of business and biomedical engineering students to design, manufacture, and market the CPR mattress to hospitals. Traditional medical practice involved the transferring of a patient who has gone into arrest to another, more rigid surface before CPR can be administered, and this process can take up to two minutes. The CPRM team had two major issues, the time required to manufacture the mattresses was excessive (1 mattress/day) and the time it took to deflate the mattress was over one minute, making the end product only marginally better than traditional methods A team of INT students working cooperatively with the CPRM students provided three process streams for production of the inflatable CPR mattress. Each of the process streams having a unique set of parameters where cost per unit, return on investment and resources vary depending on the volume of production. Manufacturing process was examined in great detail. The team found a new method of predictably cutting holes for vacuum lines in mattress foam which allowed the throughput to increase to a 20 minute cycle time without adding additional manpower or parallel processes. Additionally, the team added a vacuum manifold to uniformly deflate the mattress. This resulted in a 14 second deflation, a vast improvement.

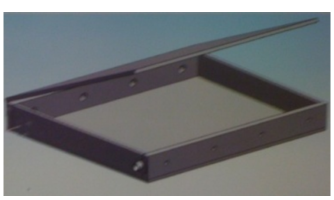

Figure 12: Mattress Drilling Fixture

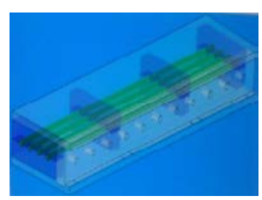

Figure 13: Vacuum Line Drilling Fixture

Figure 14: Finished Product

Evaluation of the projects - advantages and challenges/costs and benefits

The interdisciplinary capstone projects described required integration of electromechanical skill sets satisfying the high job growth area of developing procedures for utilizing and servicing test equipment as illustrated by the following US Department of Labor, Bureau of Labor Statistics, Occupational Outlook Handbook, 2010-11 Edition quote.

> "Overall engineering employment is expected to grow by 11 percent over the 2008–18 decade, about as fast as the average for all occupations. Engineers traditionally have been concentrated in slower growing or declining manufacturing industries, in which they will continue to be needed to design, build, test, and improve manufactured products. However, increasing employment of engineers in engineering, research and development, and consulting services industries should generate most of the employment growth. The job outlook varies by engineering specialty, as discussed later."[8]

Research and development engineers frequently utilize test equipment (such as an environmental simulation chambers, fabrication equipment, and mechanical testing equipment) to evaluate the successes of the improvements made to existing equipment or innovative designs, which require skilled engineering technologists to operate.

Additional benefits are the student exposure to fields like biomedical product development which require innovative manufacturing methods, and implementation of technical writing communication skills which are necessary for creation of operations and safety manuals to accompany most test equipment. Also, interdisciplinary service projects allow students the opportunity to research customer requirements, develop solutions, and solve problems with faculty and students from units outside their own department. This interaction increases the opportunity to learn to adjust to people with diverse areas of interest and backgrounds while working collaboratively to achieve a common goal.

While the educational benefits for the engineering technology student are numerous, there are always some barriers to working outside your own department. The first case study involving the environmental chamber resulted in having to adjust the capstone project team's original test because the Civil Engineering students did not have a working sample to provide at the time the team needed to run the test for their project presentation. So, communication of project time lines between departments and fall back plans need to be put in place just in case the project doesn't go as planned.

Generally, the senior capstone project costs range from $500 to $1,000 charged to the MET department, but in examples such as the case study #2, creating a new die for the zinc die cast machine, the die block material was purchased using company sponsor funds. The costs for this die to be designed and machined professionally by a die build company could easily be 10 times the cost but in the senior design project all the engineering and machining overhead was absorbed.

Future Possibilities

Currently, the SofT and the MSE Department (in the College of Engineering) are working collaboratively to staff the AME team. This enterprise addresses industry sponsored projects in the areas of fabrication (casting, metal forming, and machining), including characterization of the resultant metal structure and properties. The combination of ME, MET, and MSE students on the same project provides prospective similar to that of industry engineering teams.

AME students also participate in the conception, design, and marketing of products that they conceive. Components such as dies, permanent molds, and patterns are designed in CAD, processed by CAM, and machined in Michigan Tech facilities. Once completed, these components are transferred to the Michigan Tech foundry and the students can manufacture the products they designed and built. Experiencing the full process of product creation helps develop real-world engineering and teamwork experience that are valuable career skills.

A new procedure was started in the fall 2011 semester to allow a substitution of Enterprise Program courses for the MET degree two course sequence requirement for senior capstone design. The involvement of students in the AME team at an earlier stage in their degree is the ultimate goal so that the students will be even more invested in their senior projects, but it is too early to report the impact of this curriculum innovation. Presently, the departments of Material Science and Engineering and The School of Technology are actively marketing to underclass students for their involvement in the AME team which will eventually lead to a true interdisciplinary senior project experience.

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