Multidisciplinary Experiences
For Undergraduate Engineering Students

Abstract

Multidisciplinary (MD) team skills are of increasing importance in industry, and are required for programs that are ABET accredited. This can be challenging to provide, particularly for programs with high unit counts and a large student body. We have responded by establishing a multidisciplinary graduation requirement across the College of Engineering at Cal Poly. This requirement is mandatory. It may be satisfied by various curricular and co-curricular routes, easing throughput issues compared to having a single venue. In the paper we describe activities that satisfy the MD requirement, our general approach and assessment methods.

Industry Need

Globalization of industry is adding pressure to the need for engineers that contribute effectively in team environments. This is becoming an increasing challenge for engineering programs to embrace, as they also face expanding disciplinary material. The tendency to favor disciplinary content versus interdisciplinary content was identified 10 years ago, for example in the 1997 Professional Activities Conference of the IEEE[5], "Our education is not only essentially technical but, in recent years, has suffered from lack of breadth. It has become specialized and tends toward the high-level trade school approach." Despite the emphasis on disciplinary studies, the need to function on multidisciplinary teams remains.

Earlier still, the 1995 National Research Council (NRC) and National Science Foundation (NSF) convocation on Undergraduate Education[7] describes - "The needs of the work force are changing (American Society for Engineering Education, 1994; National Academy of Sciences, 1995) … dynamics in the labor market are putting a premium on students who have a broad knowledge of different subjects, … and the ability to work in teams. Students educated with a narrow disciplinary focus and in solitary learning styles can have difficulties adjusting to such an environment. Indeed, such difficulties are a dominant theme in the complaints voiced by business leaders about contemporary under-graduate education."

In February 2006, the IEEE updated its Code of Ethics by removing the word 'engineering' from its first point, changing "to accept responsibility in making engineering decisions" to "to accept responsibility in making decision". Here, a professional organization has broadened the view of its standards. This is in contrast to the narrowing focus of many academic departments, and further emphasizes the need for change in academia.

Expectations for ABET Accreditation

Both accreditation requirements and global industry needs are pushing engineering programs to find creative means to include multidisciplinary (MD) team skills in their curricula. The Accrediting Board for Engineering and Technology (ABET) requires programs receiving accreditation to ensure that all graduates can accomplish a range of Program Outcomes. ABET's Outcome 3D addresses MD with "an ability to function on multidisciplinary teams"[1]. It is further required that specific skills be identified and assessed via direct measures[9]. Programs also need to demonstrate that their students have a chance to practice skills associated with each Outcome. Hence a curricular mapping of some kind is needed for students to learn and practice their MD skills[4].

Consistent with ABET requirements we have defined specific skills associated with the ABET MD Outcome. Rogers[9] recommends establishing 3-5 skills for each ABET Outcome. These help answer the question: "How will you know good MD abilities when you see them"? Also see[4]. The following is an amalgamation of the skills defined by various programs across the College:

Students will…
- Recognize the value of a broad skill set resulting from a multidisciplinary team by identifying examples associated with a project.
- Rate examples of team communications and identify ways to improve team communications.
- Identify when problems occur due to poor interactions among team members and propose changes to improve team dynamics.

Skills are best phrased as learning objectives that begin with an observable action verb[6]. Studies have shown that long term retention of more fundamental skills is improved when students are challenged by learning objectives that are higher on Bloom's scale. Hence it is beneficial to use verbs as high on Bloom's scale as deemed appropriate by the program[3].

Challenges in Curriculum Development

Even when inspired to change, establishing an MD experience for every student can be challenging, particularly for programs with a large student body. Programs may also face constraints on total program units, as well as scheduling or throughput issues.

For a meaningful experience, it is beneficial for students to have differentiated themselves by disciplinary skills. Students should also interact directly in a team experience[8]. A large lecture for freshman students of different majors, passively observing an instructor would be a poor example of a 'team' experience! This lacks both differentiation and interaction.

Good examples of team projects with student design competitions have been reported by Northrup[8]. These have been designed to require student interaction. However this

example is associated with a small student body. In the College of Engineering at Cal Poly we have ~4500 students. While we have many student activities, clubs, and projects, reliance on a single venue for all team activities is not practical due to throughput issues and resources.

Furthermore our programs already suffer from an overindulgence of disciplinary content. A total of 196 quarter units are common (as opposed to 180 units). Hence the option of adding a new course to satisfy the curricular mapping for an MD experience is not viable for most of our programs.

Defining 'Multidisciplinary'

ABET leaves the definition of what constitutes 'multidisciplinary' activities up to individual programs. This flexibility is generally appreciated, but has lead to considerable debate in academic departments. Ultimately our programs have each settled on their own style of definition and disciplinary mixture.

For example, Civil Engineering defines an MD team within their discipline. The CE curriculum has a core followed by senior level tracks in which students differentiate themselves. The distinct areas of study include geotechnical, structures, water, and traffic engineering. After differentiation, students then regroup and work together on a project that is inspired by industry.

Our Mechanical Engineering Department employs industry-sponsored projects with teams of 3-5 in a two-quarter design course. The MD experience is achieved via interaction with industry contacts. The Electrical Engineering program has established a project activity in a course required by both EE and ME majors. (Note the cross fertilization with the ME students). The Industrial Engineering and Manufacturing Engineering programs offer a list of activities that their students may select from.

Approach

Given challenges in curricular development with our high-unit programs, it was difficult to answer ABET's question: "Where do your students get the chance to practice their MD skills"? We now have an answer: "Our students are MD certified." In a college-wide approach we have established a 'Multidisciplinary Certification' as a new graduation requirement for all engineering graduates. This requirement ensures that all students have an MD experience while at the same time not imposing restrictive solutions on any particular program.

To satisfy the MD requirement some programs have defined a list of acceptable activities. Other programs define a single activity. Activities include both curricular and co-curricular options. This approach allows us to take advantage of existing opportunities on campus, while mitigating the demand for increased throughput.

Example MD activities include students taking a technical elective in an engineering department outside their major. For example, a Computer Engineering student might take a Mechatronics course, offered by Mechanical Engineering. A team senior project with students of different majors is another possibility, as is a CO-OP or intern type of work experience. These latter examples would generally require some level of review by a faculty member, to judge the MD content of the experience. Club activities on campus are extensive. These are a good example of opportunities that we want to make available under the MD requirement, but that could not support the needed throughput individually. With appropriate review, an officer position in a club – or simply club membership - may also qualify. Examples of appropriate campus clubs include the solar car club, electric car club, solar house and cubesat (a cube-shaped satellite, 4 inches on a side).

Undergraduate research experiences are also applicable. Faculty engage in numerous sponsored projects across the College. These are relatively small projects and are typically unable to support large numbers of students for a team experience. However en masse, these provide another venue for the MD experience. Both local and international service learning projects (Engineers Without Borders) provide an excellent MD opportunity.

The following is an excerpt from our 2007-2009 catalog, appearing under the College of Engineering, that describes the MD requirement:

> *Consistent with ABET's requirement (3d), that students have the 'ability to function on a multi-disciplinary team', all engineering programs have adopted an explicit graduation requirement in this area. This provides students an opportunity to practice team skills. Such experience is important for practicing engineers, with the ever increasing diversity of engineering science and applications. Required activities for students are defined by each individual program, and may include items such as:*

> - *Team senior project*
> - *CO-OP or internship employment*
> - *Certain club activities*
> - *Working with faculty on a sponsored project*
> - *Project embedded in curriculum*
> - *Taking certain courses*
> - *Service learning project*

We plan to implement the MD certification via a course requirement. Programs employing a list of options for their students can implement the validation step in a senior project course, for example. In this case, the MD activity will be validated by the senior project advisor (possibly in conjunction with other faculty.)

As a specific example of an MD experience, the Electrical Engineering Department has established a project in a course that is required by both EE's and Mechanical Engineering students. This experience satisfies the MD requirement for EE ('taking certain courses', above). The project requires students to design a water pumping system, given constraints on output flow and on the electrical supply. Both electrical components (transformer & power supply) and mechanical components (motor and pump) are required. The project is intended to require skills beyond those that either of the participants can supply individually. This provides fertile ground for student learning, associated with our first skill above (to appreciate the broad skill set of a team). Here we are attempting to intertwine the team experience together with the multidisciplinary experience via this activity.

The curriculum for some programs in the College is better developed than others with regard to coverage of team skills. To help nurture programs along, we plan to make a DVD of faculty lectures on team skills to share internally. Topics such as team formation strategies and role assignments, improving team dynamics, and listening skills may be helpful.

Assessment

Methods of direct measures vary across the College. Some programs use embedded questions on common finals, others use a locally-developed exam, while others assess collections of student materials [4,9]. Many of our programs are switching to the use of local exams. Multiple-choice style questions provide an efficient evaluation process, when applicable. This approach is beneficial because the exams benchmark summative abilities (at graduation). This yields new information, beyond that already collected and observed via typical classroom experience.

To assess team skills, we are developing both essay and multiple choice questions. Students are asked to read a paragraph describing a hypothetical interaction on a team project. The hypothetical team activity may include examples of poor communication or poor team dynamics, for example. The multiple choice questions have distracters that characterize problems and offer remedies. Essay questions also include problem identification and possible remedies. Better essay responses are characterized by the number of instances they identify, by the quality of the remedies they suggest, and by the level of insight in more subtle instances. We also ask essay questions that cover students' project experiences, such as "What did the team do better than you could have done alone?" These are under development.

Both direct measures (objective questions) and senior surveys (indirect) are used to triangulate[2] on student performance. Initial assessment results to date indicate that our students are able to function on MD teams, as defined by the skills we associate with ABET Outcome 3D.

We would like to evaluate the most effective forms of instruction for team-based learning. Ideally we would like to build on the many hours of single-discipline team

experiences (laboratories) in as effective a manner as possible. Felder[4] suggests using supplemental instructional material and we may incorporate this approach as well as additional lecture topics. For example, the Computer Engineering Program introduces the concepts of learning styles and multiple intelligences inventories to precede discussions of varied team compositions. We would like to evaluate a variety of methods such as this to then be in a position to recommend effective options to our programs.

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Conclusion

We have adopted a college-wide requirement, for a multidisciplinary team experience. This requirement ensures that each student has a multidisciplinary experience during their course of study. Our approach agglomerates numerous existing opportunities across campus, thus mitigating throughput issues. Both curricular and co-curricular activities are included. At present we have formally added the MD requirement to our curricula in the College. Many programs have also established and are running their MD activities (e.g. projects). We look forward to disseminating our assessment and evaluation efforts in the near future.

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