

## **AC 2007-1936: FACILITATING MULTIDISCIPLINARY TEAMS IN A SERVICE-LEARNING ENVIRONMENT**

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# Facilitating Multidisciplinary Teams in a Service-Learning Environment

## Abstract

Today's engineers have to be able to work with colleagues of different backgrounds, both from different engineering fields as well as those from fields outside engineering. To better prepare graduates for this environment, universities and colleges are placing an ever increasing emphasis on interdisciplinary learning. The rise of interdisciplinary and multidisciplinary engineering programs at many universities illustrates this trend. However, there are many obstacles to effectively functioning on multidisciplinary teams. Most disciplines have specific languages that may make collaboration difficult. Disciplines also tend to have unique methods or tools for designing that may be contradictory. The EPICS program at Purdue University is a service-learning program that is highly multidisciplinary, and faces many of these issues. In an attempt to address these issues, the program has adopted several strategies. Those strategies, which are discussed in this paper, are the incorporation of multidisciplinary leadership in the use of advisors and teaching assistants from various disciplines, the use of inclusive language in the course outcomes, and the use of National Instruments LabVIEW to provide a common technical medium in which students can work.

## Need for Multidisciplinary Teams

In their report *The Engineer of 2020*<sup>[1]</sup>, the National Academy of Engineering highlighted thirteen different attributes that an engineer in the year 2020 will need to be effective. One of the driving factors in the development of these attributes is that “the population of individuals who are involved with or affected by technology...will be increasingly diverse and multidisciplinary.” This highlights one of the biggest pushes in recent years, which is for engineers who are able to function effectively on multidisciplinary teams.

Often in engineering, when the term multidisciplinary is used, it refers to different branches of engineering. A multidisciplinary team might have electrical, mechanical and industrial engineers on it. However, when students become practicing engineers, they will no longer be working solely with other engineers. Quite often, they will need to work with peers without a technical background. For instance, their coworkers may have a business or management degree. The people designing the casing or packaging may have degrees in the arts. Psychologists may help with the design of the user interface, and advertising and marketing specialists will introduce the product to the world. Engineers will need to be able to effectively work with and communicate with people from a wide variety of backgrounds, not only those with engineering backgrounds.

The need to train engineers to be able to function on multidisciplinary teams has been recognized by both industry and academia. The Accreditation Board for Engineering and Technology (ABET) lists “an ability to function on multi-disciplinary teams” as one of its outcomes that engineering students must meet<sup>[2]</sup>.

Within the field of engineering education, there has been recognition for the need for instruction in multidisciplinary teaming. In a special report in the Journal of Engineering Education outlining the research agenda for the new field, attention is given to the need to understand the engineering thinking in a multidisciplinary environment<sup>[3]</sup>. In an article published in ASEE *Prism*<sup>[4]</sup>, a survey of industry representatives showed that there is a strong need to emphasize multidisciplinary, team-based, and collaborative problem-solving.

As a result, many programs have been instituting multidisciplinary learning experiences in their engineering curriculum. For instance, the Colorado School of Mines<sup>[5]</sup> instituted a capstone course in multidisciplinary engineering design in 1994 with the intended purpose of “enhancing our students’ abilities to: 1) solve complex, “real-world” problems with numerous technical and non-technical (social, environmental, ethical, etc) constraints in a multidisciplinary environment.”

## **Service-Learning**

In a recently published service-learning text<sup>[6]</sup>, Lima and Oakes define service-learning as a pedagogy that integrates service within a local, regional or global community with academic learning. Hatcher and Bringle<sup>[7]</sup> developed one of the more concise and complete definitions of service-learning:

*We view service-learning as a credit-bearing educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of the course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.*

Many disciplines have imbedded service-learning into their college curricula as well as many K-12 schools. Service-learning is aligned very well with the ABET Criteria<sup>[2]</sup>, as well as the National Academy’s Report on the Engineer of 2020<sup>[1,8]</sup>. Engineering is a relative late comer to the service-learning movement. While there is a growing momentum within engineering education, the community has been slow to adopt the pedagogy on a large scale.

### Components of Service-learning

Service-learning has distinct and important components. These components are not necessarily unique to service-learning, but taken as a whole, they are what makes service-learning.

1. *Service* – A service is provided to an underserved area or people. In engineering, it may involve direct contact with people through educational programs for children or the elderly or project work, such as a solar power system for a remote village in the Andes Mountains or research and data analysis such as environmental data.
2. *Academic content* – Service-learning is a means to learn engineering principles and content more effectively. In service-learning, the service is directly linked to course studies to help students learn that material more effectively. For example, in a design course, the service

provides an environment to apply design with community and human constraints. In an engineering science course, the service would reinforce or build course concepts.

3. *Partnerships and reciprocity* - Service-learning involves partnerships with students, faculty, the community, and in some cases industry. Students performing service-learning should not do something *for* the community, but rather *with* the community. Each partnership member contributes to the project's goals and each benefit from it. When service-learning is done well, the partnerships become reciprocal. In reciprocal partnerships, all partners contribute to the work, all receive benefits from the work, and all learn from the work and the other partners.
4. *Analysis or Reflection* – In service-learning, the discipline of recording, analyzing and reflecting on the learning that is taking place is important for several reasons. One of the most important is connecting the service to the academic content. This can be difficult since service-learning presents technical challenges in untraditional ways. To make these connections, instructors may guide students through activities to analyze and reflect upon their work, how they are accomplishing the work, the implications of their work, and its connections with the academic course content and the larger social issues. These kinds of activities are called metacognitive activities or reflection and have been shown to improve learning<sup>[9]</sup>, not just service-learning. Reflection activities are also designed to help participants process their experience. Students may have their own biases and prejudices reinforced rather than challenged during their service experience and reflection/analysis will help them process these experience and result in positive learning. Reflection will also help connect the student experiences, learning and service, to the broader issues of society and the engineering profession. It is also a goal of service-learning to promote civic engagement and for engineering students this has both personal and professional components.

Service-learning offers an excellent opportunity for multidisciplinary work because the contexts often necessitate multidisciplinary approaches. If an electromechanical device needs to be designed for children with a disability, the project requires students with electrical and mechanical engineering skills as well as students with expertise in children development and disabilities. This context provides a rich environment where students with the different skills can be empowered to take meaningful and potentially leadership positions within the teams. The different dimensions of the pedagogy, including the reciprocal partnerships and reflections, introduce additional opportunities for students with diverse skills and majors.

### **Engineering-Centered Service-Learning Program**

The need for multidisciplinary design experiences motivated the creation of the Engineering Projects in Community Service (EPICS) program<sup>10</sup>. The model that guided the creation of the EPICS program was to involve each student for several semesters or even years on the same long-term project, so that each student would experience varying roles over the course of the project. Long-term community partnerships with EPICS has enabled this type of student experience.

The EPICS program is built around the concept of long-term partnerships between student teams and not-for-profit organizations in the community. Community service agencies face a future in which they must rely to a great extent upon technology for the delivery, coordination, accounting, and improvement of the services they provide. They often possess neither the expertise to use nor the budget to design and acquire a technological solution that is suited to their mission. They thus need the help of people with strong technical backgrounds. Moreover, the community service agencies will ultimately deploy the teams' systems.

Each team and its community partner work closely together to identify and solve the partner's technology-based problems. The projects fall broadly in four areas: education and outreach, access and abilities, human services, and the environment. Over 80 projects are active in the current academic year.

The curricular structure of the service-learning program enables each student team to maintain a long-term relationship with its community partner and to successfully design and deliver products that have significant technical complexity and significant community impact. The program is implemented as a track of courses, where a team corresponds to a division or lab section of the course. Each team is large – 8 to 20 students – and vertically integrated – composed of freshmen, sophomores, juniors and seniors. A student may be a member of a team for up to four years, registering for 1 to 2 credits each semester. When seniors graduate each year, returning students move up a year and new students are added to the team. Many teams have developed formal training processes for new members. The large team size, vertical integration, and credit structure enable each team to continue with a core of returning students each semester and year. In effect, the teams function as a small engineering design firm, with the community partner as its customer. This enables the teams to tackle and complete projects of significant size, complexity and impact in the community. Some teams have been in operation for ten years and have delivered a series of projects to their community partner.

From an educational point of view, the long-term continuity enables the students to experience the whole design cycle, from problem definition through support of fielded projects. An entrepreneurship initiative takes this cycle one step further by providing opportunities for students to learn about and pursue the commercialization of their projects. The long-term continuity also enables each student to experience different roles on the team, from trainee to design engineer, to project or team leader.

Complementing the long-term structure of the teams is the multidisciplinary nature of the teams. Started in electrical and computer engineering the program has spread rapidly both across engineering and outside engineering, to computer science, sociology, and many other disciplines. Each team advertises for the students and disciplines it needs each semester for its project. The multidisciplinary nature of the team adds an important educational dimension and has proven critical to the quality of the products that the teams develop and deliver.

### **Problems Facing Multidisciplinary Teams**

Even with the compelling context of service-learning, many obstacles remain to creating a truly multidisciplinary learning environment. First of all, language is not always used in a way that

allows for the inclusion of all members. Each discipline has its own specific jargon, which may not be understood by all members of the team. Electrical engineers may start talking about Bipolar Junction Transistors (BJT), Metal Oxide Silicon Field Effect Transistors (MOSFET), and Operational Amplifiers (OP-AMP), leaving most of the members from other discipline out of the conversation because they have never heard these terms before.

Also, some of the ways the problems or desired outcomes are worded may unintentionally discriminate against members. Many courses that attempt to integrate multiple disciplines originated within one specific discipline. Therefore, many of the objectives of the course may be worded in a way that caters to members of that discipline or discriminates against members from other disciplines, however unintentional it may be. This will limit the opportunities to draw in members from outside the original discipline.

Not only does the language sometimes bring about conflict, but the technical language in which the work is being accomplished can bring about problems. Each discipline has its own set of skills and methods that are commonly used. This can cause conflicts when those methods do not mesh coherently. For instance, one discipline may be very hands on while another tends more toward theoretical design. When members from two such disciplines are brought together, there can be a serious clash of styles.

Faculty are also not equipped to facilitate and assess contributions from diverse student teams. Evaluating students who come from very different disciplines fairly and appropriately presents challenges for faculty and can create tension within the student teams.

### **Multidisciplinary Leadership**

One way that we have tried to encourage and foster multidisciplinary teams in the EPICS program is to provide leadership from different disciplines. The program is broken down into several teams that work with different community partners. Each of these teams has one to three faculty advisors along with a teaching assistant (TA). These advisors and TAs provide some of the leadership for the teams, as well as a technical resource for the students.

In the fall of 2006 semester, the program had faculty from 11 different disciplines (electrical and computer engineering, mechanical engineering, biomedical engineering, civil engineering, computer science, engineering education, chemical engineering, communications, audiology, computer graphics technology, and library sciences) as well as staff from the university and local industry with a variety of backgrounds. In addition, the program had TAs from seven different disciplines (electrical and computer engineering, mechanical engineering, biomedical engineering, civil engineering, computer science, computer and information technology, and sociology). This diversity provides a voice for those disciplines within the program, ensuring that their specific needs are met. This highly diverse spectrum of expertise provides a number of additional benefits.

### *Recruitment*

First of all, most of the faculty advisors will also be teaching courses in their respective disciplines. This provides a great way for recruiting students from those disciplines. The advisors can spread the word about the EPICS program to students in their discipline first hand. This is a much more effective way to recruit students than the traditional ways of posting flyers or holding information sessions, because students will hold their professors' opinions in higher regard.

Another factor that aids in recruitment efforts is that students from many disciplines receive academic credit toward graduation for participation in the program. Students may participate for either one or two credits and for as many semesters as they choose. Credits count for different areas in different majors. For example, in mechanical engineering, it counts as a technical elective. In Electrical and Computer Engineering, it may count as the capstone course. In Liberal Arts, it counts as ethics and social responsibility core requirement. Students in electrical, computer and interdisciplinary engineering, computer science, and audiology may also take the course in their senior year to fulfill their capstone requirements. This is a strong selling point in the recruitment process.

### *Technical Support*

In addition to the recruitment opportunities the advisors present, if a student knows that a faculty member from their discipline is a part of the program, they will be more likely to join because that faculty member will be able to provide support for the student. Many students do not feel that they are capable of doing the work necessary for many of the projects undertaken, so knowing that there is a faculty member available who can help with the technical work is a great comfort to many students.

Along with the technical support provided by the advisors is the technical support that is provided by the TAs. While TAs are assigned to specific teams, they are required to hold office hours that are open to all students within the program. This provides a great deal of technical expertise the students can draw on to help with their projects.

Advisors and TAs are also paired up on the teams to provide complimentary skill sets. This is done to give the students direct access to the most assistance. For example, if the advisor for the team is from mechanical engineering, a TA from electrical and computer engineering would be teamed up with that advisor to give the students as much support as possible.

### *Skills*

Finally, all TAs are required to lead "skill sessions," which are one to two hour sessions intended to teach some skill the TAs feel would be beneficial to the students. Since the TAs for the program come from a variety of backgrounds, there are a wide variety of skills that can be taught. This gives the students the opportunity to acquire new skills that they wouldn't be able to in their traditional disciplines.

During the fall of 2006 semester, skill sessions were conducted on keeping a lab notebook, an introduction to soldering, an introduction to LabVIEW, an introduction to Java, an introduction to the mechanical engineering machine shop, professional ethics, communication, and entrepreneurship. These are all valuable skills for students to have, regardless of discipline. In very few programs would a student be able to get a basic introduction to all of these skill sets in the span of one semester.

## **Learning Objectives**

Another way in which we have tried to encourage and support the multi-disciplinary composition of the program is to develop a set of common learning objectives that are appropriate for students from all disciplines. The outcomes of the course align with ABET, but are written using language that is not engineering specific. We have found that the use of the phrase “technical knowledge” is perceived as only pertaining to the engineering or technology students, and not students from all over campus. Furthermore, using the phrase “non-technical” to describe all other disciplines and expertise devalues the knowledge and expertise of those disciplines. So instead of using the terms “technical” or “non-technical” when referring to knowledge, we use the term “discipline”. In addition, we have explicitly stated that the ability to appreciate contributions from individuals from multiple disciplines as an outcome. With this in mind, our course outcomes are stated as follows:

- **Discipline Knowledge:** ability to apply material from their discipline to the design of community-based projects
- **Design Process:** an understanding of design as a start-to-finish process
- **Lifelong Learning:** an ability to identify and acquire new knowledge as a part of the problem-solving/design process
- **Customer Awareness:** an awareness of the customer
- **Teamwork:** an ability to function on multidisciplinary teams and an appreciation for the contributions from individuals from multiple disciplines
- **Communication:** an ability to communicate effectively with widely-varying backgrounds
- **Ethics :** an awareness of professional ethics and responsibility
- **Social Context:** an appreciation of the role that their discipline can play in social contexts

Because students participating in the program come from a variety of disciplines, semester classifications, and number of semesters that they have participated in the program, it would be difficult to define specific learning objectives that would be appropriate for all students in the program. In addition, since students enroll for only one or two credit hours (where typical courses are offered for three credit hours), the learning is spread out over multiple semesters. Furthermore, it is considered a best-practice to allow students to participate in the development of their own learning objectives in consultation with their advisors. Therefore, we have provided a set of example learning objectives which the students can draw from and modify in developing their own learning objectives. The following are example learning objectives that have been provided to the students for the various outcomes:

## Outcomes and Associated Learning Objectives

| Outcome              | Learning Objectives   |
|----------------------|---|
| Discipline Knowledge | Incorporates material and ideas from previous coursework in at least one design   |
| Design Process       | Describe activities, decisions, and artifacts produced during the design process phases of own project.   |
| Lifelong Learning    | Recognizes need for knowledge outside of coursework in at least one design  |
| Customer Awareness   | Describe how the project will benefit the community.  |
| Teamwork             | Identify through oral and written reflection the values and behaviors he/she believes are necessary for the team to complete their tasks for a particular semester.               |
| Communication        | Create reports documenting design of projects in enough detail to reproduce the project; reports should contain, on average, no more than one grammar or spelling error per page. |
| Ethics               | Identify 2 moral values/considerations essential to the design of the project.  |
| Social Context       | List and explain the three sociological orientations or "social maps" as a way of understanding the social context of the project partner.  |

## National Instruments LabVIEW

Many of the teams within the program work on projects that require some form of computer programming. However, with great amount of diversity within the program, there may be few students who have the necessary programming skills to accomplish the necessary work or students with skill in different languages. One possible solution to this problem is the use of National Instruments LabVIEW.

LabVIEW is a programming language and environment developed by the National Instruments Corporation. It was originally developed as a tool for researchers with little or no programming experience to allow them to create programs that would measure and analyze data, as well as them to automate repetitive processes. Over the last 20 years, LabVIEW has grown in popularity in industry, but has not yet had much of an impact in academia.

National Instruments lists three main uses for LabVIEW: data acquisition, data analysis, and data presentation. LabVIEW, however, is much more than a software package for data manipulation; it is a fully functional programming language, with most, if not all, of the same capabilities as those languages traditionally taught in the academic realm, such as C and Matlab.

Unlike those traditional programming languages, LabVIEW programs are written graphically in the LabVIEW environment. In other words, instead of writing lines of textual code, the programmer uses graphical blocks, referred to as Virtual Instruments (VI's), representing different functions and connects those blocks together to develop the code.

The LabVIEW programming environment consists of two windows, the "Block Diagram" and the "Front Panel." The Block Diagram is where the code is generated. The Front Panel allows

programmer to develop the user interface. This allows the user interface to be developed along side of the actual code for the program. The programmer can add different inputs (buttons, switches, dials, text, etc) and different outputs (lights, numerical indicators, text indicators, graphs, etc) to the Front Panel and connect those different inputs and outputs to the code in the Block Diagram.

An additional feature that makes LabVIEW great for both student and professional teams is that the ease with which it integrates with hardware. All of the National Instruments hardware products can be controlled using LabVIEW by simply adding the correct VI into the program. LabVIEW programs can also be downloaded onto FPGA's (Field Programmable Gate Arrays) and any 32-bit microprocessor. With this capability, students who wish to use microprocessors in their projects can create and debug the code at a much higher level before burning it onto the processor.

### *Applications to Multidisciplinary Teams*

As mentioned before, one of the issues that often face multidisciplinary teams is the lack of a common technical language and skills. This is quite prevalent with teams that are working on software projects, or projects that involve some software component. Computer scientists and computer engineers often have a lot of programming experience in a number of different languages, whereas electrical or mechanical engineers may have little experience programming, most of which was likely done using Matlab. This poses a significant problem, because those students with little programming experience will not be able to contribute to the project or understand some of the work being accomplished on the project.

Since programming in LabVIEW is visual in nature and doesn't require an extensive knowledge of syntax, it allows for students to learn and start contributing to a project at a much quicker rate. Within the service learning program, several teams have used LabVIEW as a major part of their projects. Students had little to no experience using LabVIEW or with programming in general, but in the course of a year were able to learn the program and finish their projects.

For the past several semesters, a short, one-hour course has been offered to students in the program as an introduction to LabVIEW. In informal questionnaires used for the improvement of the course, students responded that LabVIEW, when compared to other programming languages, was very easy to use and understand, and very user friendly.

Because it is easy for students to learn, it is highly suited for teams with members of various backgrounds and skill levels. Students with limited programming background can quickly get up to speed and start contributing to the project, while students with a more proficient background in programming can apply their previous knowledge to this language. This provides a common language with which students from various disciplines as well as from various skill levels can understand and contribute.

## *Examples*

One notable example of multidisciplinary teams using National Instruments hardware and software is a team working on building a miniature version of the Mars rover complete with functioning mission control center and Mars landscape. The project is being designed for a children's museum local to the university.

The project is very intricate, requiring a great deal of programming. First of all, there needs to be a user interface allowing control of the miniature rover as well as outlining the four different missions the user can choose from. The actual missions must also be programmed, in addition to all of the wireless communication that needs to take place between the computer and the rover. Finally, the location of the rover will be tracked using a camera, which requires a good deal of image processing.

The project was started in the fall of 2005 and is on schedule to be completed in the spring of 2007. During that time, the team has had a variety of disciplines working on it, including mechanical, electrical, computer, and aerospace and aeronautical engineers, and including members ranging from sophomore through senior.

Another example of the integration of National Instruments hardware in a multidisciplinary learning environment occurred with the Teams in Engineering Service (TIES) program at the University of California, San Diego. The goal of the project team was to provide for its client a reliable, automated, remote, self-sustained, and wireless water quality prototype, measuring both chemical and physical properties. The remote sensing floating prototype incorporates a solar panel, voltage regulator, battery, datalogger, weatherproof enclosure, sensors (pressure, temperature, dissolved oxygen, pH and conductivity), and wireless transmitter and receiver. This project was designed for a local non-profit group looking to establish a river park along a section of river. However, that section of river did not meet EPA standards. The partner required a system that could monitor and record water quality levels for both evidence for creation of the park as well as an educational/research tool for local K-12 schools and universities.

For the project, the program was able to acquire equipment from National Instruments to implement the water quality monitor. Students learned preliminary programming using LabVIEW in various courses at the university and then were able to fully integrate those skills in real-world projects within the program. In multidisciplinary and vertically integrated teams, as most teams within the program are organized, LabVIEW has been an incredibly useful tool due to the ease of learning the programming language to construct prototypes for real clients.

## **Results**

The results have been very positive. Students from 20 academic departments are participating in the set of courses that currently enrolls over 300 students a semester.<sup>10</sup> Course ratings have been at or above a 4.0 out of 5.0 for the overall course. Students continue with the program with a retention rate of 79% of students who are eligible to take the course again (e.g. students not graduating, leaving for co-op or study abroad). Academic credit in so many disciplines demonstrates the credibility the program has in the diverse departments. The formalization of a

multidisciplinary curriculum committee will help insure that the program continues to develop its multidisciplinary nature.

## Conclusions

Multidisciplinary skills are becoming a necessary part of the education of engineers. The increase in globalization as well as the rapid advances in technology requires engineers to be able to work effectively alongside peers from various disciplines. In recognition of this, efforts have been made to make an engineering-centered, multidisciplinary service-learning program more diverse in its disciplinary representation. To do so, we have recruited more advisors and teaching assistants from diverse disciplines, modified our outcomes and learning objectives to eliminate discriminatory language, and increased the use of tools, such as National Instruments LabVIEW, that allow for better collaboration between the different disciplines.

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