AC 2009-1262: EDUCATING ENGINEERS FOR MULTISCALE SYSTEMS DESIGN IN A GLOBAL ECONOMY: THE TECHNOLOGY LEADERS PROGRAM

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Educating Engineers for Multiscale Systems Design in a Global Economy: the Technology Leaders Program

Abstract

With the rate of technological change growing rapidly and technological systems becoming increasingly complex, engineers capable of designing adaptable systems from both a systems level and a component level are needed for the U.S. to remain competitive. Most engineering schools fail to meet the growing need for engineers skilled in multiscale design: they educate engineers to handle systems issues or component issues, but not both. Furthermore, engineering education focuses on designing static, “point” solutions, not agile solutions that can adapt to change. Specifically, this project proposes the development of Technology Leaders, a transportable interdisciplinary program that will prepare engineers and technicians to lead teams in the designing and building of multiscale agile systems.

Building on prior work at the University of ___A___, ___B___ Community College, and the Learning Factory at Penn State, the Technology Leaders program will integrate three elements: a new interdisciplinary, design-focused undergraduate curriculum; the hands-on Technology Leaders Program Lab (TLP Lab); and applied summer experiences. Grounded in constructivist learning theory, the interdisciplinary curriculum will focus on design throughout the undergraduate experience by incorporating multiple interconnected real-world problems into the courses. The curriculum will be developed for both four-year university and two-year community college students. As part of the curriculum, Technology Leaders students from all years will participate together in a learning community focused on developing leadership skills, fostering a sense of belonging, and providing space for reflection and student-led curriculum design. The TLP Lab will consist of easily reconfigurable multiscale hardware (e.g., servers, motes), software (e.g., service-oriented-architecture based products, peer-to-peer networks), multiple networks (e.g., Internet, 802.11, Zigbee), and test and evaluation tools (e.g., Network Sim, emulation tools) at multiple facilities including the University of ___A___, ___B___ Community College, and industrial partners. All students will complete summer industrial internships or research experiences before graduation with Technology Leaders industrial and research partners.

The Technology Leaders Program is being implemented over the course of four years beginning in Fall 2008, with our first students graduating in Spring 2012. The first year focus is on developing the TLP Lab and integrating it into first-year courses as a means of marketing the program. To this end, the lab was built, one section of the first-year introduction to engineering design course has been completely redesigned to incorporate the TLP Lab, the Technology Leaders Community is meeting monthly, and the lab will be utilized in an introductory electrical engineering survey course. In addition to an overview of the entire Technology Leaders program, results from these initial activities are presented in the paper.

Introduction

The purpose of this paper is to describe the Technology Leaders Program (TLP) at the University of ___A___ and report on the first stage of its implementation. The TLP is aimed at preparing engineers and technicians to lead geographically-distributed teams in the designing and building
of multiscale agile systems. It is a multi-faceted program consisting of an interdisciplinary, design-centered curriculum spanning both a 4-year and 2-year institution, a wide-area distributed physical lab, a learning community, integrated internships for students, and faculty development workshops. In this paper, we will establish the motivation for such a program, define the TLP’s objectives, outline the overall structure of the TLP, and then focus on three major milestones of the first stage of implementing and evaluating the TLP. These three milestones are 1) the building of the TLP lab, 2) the development and execution of a first-year engineering TLP design course, and 3) the establishment of the Technology Leaders Learning Community.

**Motivation for the Technology Leaders Program**

The Technology Leaders Program is focused on educating both engineers and technicians about designing multiscale systems to be agile to change while collaborating on geographically-distributed teams.

The primary focus is on multiscale systems – agility, geographically-distributed teams, and educating both engineers and technicians support the focus on multiscale systems. In this context, a *multiscale system* is defined as one that consists of multiple, hierarchical levels of components. Each component is part of a greater higher-level system while also being composed of a system of lower-level sub-components. Consider two examples: a car and a sensor network.

A car is not only composed of many lower-level sub-components, it is also part of a larger system. Consider a Honda Accord LX. Moving up the hierarchy, several cars compose the car model “Honda Accord,” and several car models make up the entire line of Honda cars. The entire line of Honda cars is just one component of the entire fleet of Japanese cars, which are one component of the system of all cars driven on roads today. Drilling down the hierarchy from the Honda Accord LX, this individual car is composed of several major subsystems such as structure, power, suspension, steering, braking, interior comfort, safety, etc. Within each of these subsystems are further sub-subsystems. For instance, “power” is composed of fuel storage, an engine, and a transmission. Each of these can, of course, be further decomposed into its components.

A sensor network is another good example of a multiscale system. A sensor network is composed of (at a minimum) the set of sensors, communications equipment, data storage equipment, and software. A designer of the network is focused on integrating these subsystems into a functional system. Each sensor, communications device, data storage system, and software is one level down the hierarchy. A designer at this level could, for instance, design an RFID reader, integrate an accelerometer with necessary circuitry, develop a wireless communication device, or write software code. Another level down would be the electrical components of the sensors.

Most undergraduate engineering curricula focuses on teaching students how design from the bottom-up component level of a multiscale system. For instance, electrical engineering students learn how to design and build electrical components and mechanical engineers learn how to design gears, kinematic linkages, and heat exchangers. Systems engineering undergraduates also focus on only one level of a multiscale system; different from other engineering disciplines,
however, systems engineering undergraduate curricula focuses on top-down integration. Most engineering undergraduates get nearly all depth and little breadth; systems engineers get just the opposite. Such distinctions are not as clear ten or twenty years post-graduation, where having a combination of both depth and breadth is not only desirable, it is a necessary skill for designing multiscale systems. With the TLP, we will focus on teaching undergraduates design from both a deep, component level (in our case, electrical engineering) and a broad systems level (systems engineering) prior to graduation so that they can be more innovative and productive engineers immediately upon graduation.

While many factors are leading to the increased relevance of multiscale systems, including more advanced technologies that allow for the design of such systems and the increased rate of technological change, globalization is playing an important role. As globalization continues, the role of engineers in the United States is shifting further up these hierarchies towards more integration and coordination. In a more global economy,

> engineers employed in organizations will necessarily be required to coordinate projects having global workforces ... A typical U.S. engineer will have to become a project manager early in his or her career and will be coordinating the work of people stationed around the world, either within the parent organization or in contractor organizations.  

To be effective at integration, however, an engineer must have deep knowledge in the components that s/he is integrating. The motivation for creating an educational program focused on multiscale design, therefore, is rooted in globalization. Also noted in the preceding quote about globalization is the motivation for focusing the TLP on geographically-distributed team collaboration. As engineers focus more on integrating multiscale systems, they will work on distributed teams more frequently. Furthermore, these teams will be composed of both engineers and technicians. While engineers will tend to focus further up the multiscale hierarchy and technicians tend to focus further down, such generalizations oversimplify the reality in which the work of engineers and technicians is heavily enmeshed in the design of large, complex systems.

Due to the focus on multiscale systems, agility is an important factor. Agility, defined here as the ability of a system to adapt to changing needs over time, is especially critical for systems that cannot be completely rebuilt quickly or that have long life. Multiscale systems can be very fragile to changing needs if agility is not designed into the systems. For instance, if a camera with higher resolution is needed in an existing sensor network, changing the camera can be very difficult due to existing physical and software-based interfaces that cannot accommodate different cameras. Or, consider if five cameras are needed instead of just one: this will be difficult to implement if the existing system is not designed to be agile.

**Objectives**

The **primary aim of** the Technology Leaders program is to create a transportable interdisciplinary program that will prepare engineers and technicians to lead geographically-distributed teams in the designing and building of multiscale agile systems. We **hypothesize** that engineers and technicians with multiscale, agile system design and implementation skills can be educated by joining diverse students from multiple settings into a learning community while they
experience a hands-on design curriculum supported by a geographically-distributed lab. The specific goals of this project are to, over a four year period, :

1. **Adapt existing engineering curricula in electrical engineering, computer engineering, and systems engineering to support a new program (the Technology Leaders Program) that integrates a learning community and the Technology Leaders Lab throughout a student’s engineering education.**
   This program will enable students to learn how to design agile systems, in geographically distributed collaborative teams, from both the top-down perspective of systems engineering and the bottom-up perspective of electrical and computer engineering.

2. **Transport the Technology Leaders Program to other institutions.**
   Several activities will engage faculty from other institutions early in the development of the TLP. Notable are the faculty development workshops, the Technology Leaders advisory board, and special sessions at conferences.

The focus in this paper is primarily on the first goal of creating the TLP. In particular, we will address the first stage of implementation of the TLP which involved creating a first-year design course, the TLP Lab, and the Technology Leaders Learning Community (TLC).

In terms of learning objectives for TLP students, the program focuses on the application of skills and knowledge, progressing from routine application on simplified systems to non-routine applications on real-world systems. The overall learning goal for students in the Technology Leaders Program is as follows:

**Graduates from this program will be able to lead the designing and building of agile systems, from both a top-level perspective and a detailed, component-level perspective, on geographically-distributed teams.**

More specifically, graduates from this program will be able to:

- **Learning Objective 1)** design and build “agile” systems and components that can adapt to change,

- **Learning Objective 2)** design and build from both a systems, top-level perspective and a detailed, component-level perspective,

- **Learning Objective 3)** collaborate as an active member of a geographically-distributed technology team in designing, building, and testing agile, multiscale systems,

- **Learning Objective 4)** apply fundamental concepts from both electrical and computer engineering and systems engineering, including circuit analysis, digital logic design, systems methodology, modeling and analysis, and data and information engineering,

- **Learning Objective 5)** value the roles that a systems, top-level perspective and a detailed, component-level perspective can both play in design and the importance of designing systems to adapt to change,

- **Learning Objective 6)** apply what they have learned in the TLP throughout their careers
Structure of the Technology Leaders Program

The Technology Leaders Program curriculum consists of a four-year “university” curriculum, a two-year “community college” curriculum, a learning community, and summer research and internship opportunities. These elements are mapped to the six learning objectives in Table 1.

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
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<td>First Year</td>
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<td>X</td>
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<tr>
<td>Third Year</td>
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<td>Fourth Year</td>
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<td>X</td>
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<tr>
<td>Learning Community</td>
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<tr>
<td>Summer Industry or Research</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Four-Year Curriculum

The purpose of the first year of the four-year curriculum is to motivate, engage, and recruit students to the TLP. The first year focuses on simple, hands-on applications of multiscale systems and their design. It includes a TLP section of the first year introduction to engineering design course, and integration of the TLP lab resources into an introductory electrical engineering survey course.

The purpose of the second year is to establish interdisciplinary foundations. To contribute to an interdisciplinary team, individuals must bring knowledge from their discipline in which to ground their contributions. We are aiming to educate students to be more than just disciplinary contributors to interdisciplinary teams; we aim to educate students to be able to lead interdisciplinary teams. To do this, the students must have working disciplinary knowledge in more than just one discipline. Hence, Technology Leaders students will complete sophomore-level foundations classes in both systems engineering and electrical and computer engineering.

With interest established in the first year and disciplinary grounding in the sophomore year, students are prepared to focus directly on designing multiscale, agile systems in their junior year. Two new “design lab” courses will be created for the junior year. Both courses will fully integrate the TLP Lab, a hands-on design clinic modeled after the Learning Factory at Penn State (described in detail in a following section). The pedagogical structure of each class will be similar, involving a series of short (1-3 week) problem-based case studies. Most of the case studies will be directly from the industry partners. The two courses will be:

- **Multiscale Systems Course (fall, junior year)** – integrating systems perspective with component design perspective, modeling multiscale systems, integrating off-the-shelf components with custom design work, identifying emergent properties, interfacing between scales, sequencing the design of multiscale systems, and evaluating/testing integrated systems of components.
• **Agile Design Course (spring, junior year)** – identifying limits of a design, defining possible changes that could affect a system during its life, creating systems that measure when, where, what, and how much adaptation is needed to respond to a change, measuring system agility, integrating components and architectures that permit agility, and assessing trade-offs of building agility into systems.

After completing numerous short design case studies during their junior year, students are ready to synthesize their knowledge of multiscale, agile systems in their senior year. The two-semester capstone project will be run through the existing capstone program in Systems and Information Engineering. Technology Leader capstone teams will work on projects sponsored by a Technology Leaders industrial partner. Teams will be composed of systems, computer, and electrical engineering students. All projects will involve designing, implementing, and testing both the hardware and software for a multiscale system.

**Two-Year Curriculum**

___B___ Community College (BCC) will create a two-year curriculum to educate technicians in the design of multiscale agile systems and will also offer a curriculum designed for students who want to transfer into the four-year curriculum at the University of ___A___. The two-year technician track will include an introductory design course and also a “capstone” course where students will team remotely with a TLP capstone team in their fourth-year at the University of ___A___.

**Summer Research or Industry Experience**

All Technology Leader students must complete at least one summer internship with a company or a research experience with the Wireless Internet Center for Advanced Technology, a research lab at the University of ___A__ focused on multiscale agile systems. This can occur in the summer after their sophomore and/or junior years. The Technology Leaders industry partners will provide the industry internships.

**Learning Community**

Building on the educational literature in learning communities ⁴, the Technology Leaders Learning Community (TLC) will focus on leadership, a sense of belonging, and space for reflection. The TLC will be a 1-credit class required for all Technology Leaders students, starting in their sophomore year and continuing through graduation. As prior work has shown that “a sustainable learning community initiatives are led by collaborative leadership teams” ⁵ third and fourth year students will run the TLC with the assistance of faculty coordinators. This collaborative leadership team allows students to take ownership of their learning in the Technology Leaders program while providing the stability and resources (e.g., external speakers) of faculty.

The entire curriculum is shown graphically in Figure 1.
In the first year of the TLP, four major elements of the program are being implemented. These four elements – the TLP Lab, the First-year Introduction to Engineering Design Course, the Technology Leaders Learning Community, and Evaluation – are described in the following sections.

**Stage 1 Implementation: The Technology Leaders Program Lab**

The TLP Lab serves as an agile, hands-on design facility for students in all four years of the Technology Leaders program. In this first year, space was renovated and equipment purchased to build the lab. Students used the lab during the Introduction to Engineering Design course for both formal lab activities and as a resource for their design projects.

The TLP Lab is co-located in Charlottesville, VA, at the University of ___A___, and in Lynchburg, VA at BCC. As the Technology Leaders program is transported to additional schools, the TLP Lab will continue to grow in a wide-area, geographically-distributed manner. Instead of creating independent facilities, additional schools can create facilities that link into the network capabilities at the TLP Lab at University of ___A___ and BCC (see Figure 2).

**Figure 2 Wide-Area Distributed TLP Lab**  
As shown in Table 2, the TLP Lab is structured around four main capabilities: networking, multiscale, agile hardware, multiscale software, and development, test, and evaluation tools. The TLP Lab equipment is easily reconfigurable for a variety of hardware or human-in-the-loop experiments.
Table 2 MAST Lab Technologies

<table>
<thead>
<tr>
<th>Networks</th>
<th>Multiscale Hardware</th>
<th>Multiscale Software</th>
<th>Development, Test, Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet</td>
<td>Servers</td>
<td>Service Oriented Arch.</td>
<td>Network Sim (NS2)</td>
</tr>
<tr>
<td>CHEETAH optical LANs</td>
<td>Sensor/Nodes</td>
<td>P2P Networks</td>
<td>Satellite Systems Sim (STK)</td>
</tr>
<tr>
<td>802.11</td>
<td>SW controlled radios</td>
<td>MANET Networks</td>
<td>Emulation tools (motes, PDAs)</td>
</tr>
<tr>
<td>Zigbee</td>
<td>Mobile computing</td>
<td>Command Center Apps</td>
<td>DSP Design</td>
</tr>
<tr>
<td></td>
<td>Wireless sensors</td>
<td>Mote-based Apps</td>
<td>Math Analysis</td>
</tr>
</tbody>
</table>

**Stage 1 Implementation: Introduction to Engineering Design Course**

*Class Structure*

The Technology Leaders section of the Introduction to Engineering course exposes first year students without any programming skills to the integration of sensors into systems. Three elements formed the core of the course: a classroom experience focused on engineering design, a lab experience focused learning the basics of how to use certain sensors, and a team-based design project for real clients. The labs and projects from the first year are described in greater detail in the following two sections.

*Labs*

The focus of the labs is to build the students’ ability to analyze key characteristics in an organized manner when presented with various sensors. It also serves the purpose of familiarizing students with the basic features and constraints of the sensors they will be using for their term projects. In a real world environment, when building a sensor-based system, engineers encounter many resource constraints. It is important for the students to be able to factor in these limitations during the design process.

The sensors selected for the labs are SunSPOT wireless accelerometers, PIR motion sensors, and an RFID tag/reader. The labs were divided into two lab modules, with the first module focusing on basic features of the sensors such as range of detection, precision of the measurement, calibration, and sampling rate, and the second module focusing on building a sensor-triggered webcam system.

For the first part of the lab, students were asked to determine the key characteristics of the three sensors. Along the way they were involved in activities that raised questions on calibration, the tradeoff between sampling rate and signal fidelity, and dealing with false positives and false negatives.

For instance, with the SunSPOT wireless accelerometer, students were first asked to determine experimentally the direction of the x, y, and z axes (see Figure 3).
After calibrating the accelerometer, students were asked to predict and confirm the acceleration measurement when the sensor was rotated to different orientations. This allowed students to see the effect of gravity and calibration on the acceleration readings. Next, the sensor was placed on a pendulum as in Figure 4 to produce a sinusoidal signal.

Using the sampling software shown in Figure 5, which allowed students to adjust the sampling rate, students compared the original signal with the sampled signal from a wide range of frequencies. By observing the aliasing of the signal, although without any knowledge about the Nyquist sampling theorem, students understood the idea that there is a lower boundary as to how much they could lower the sampling rate to save power. Similar activities were performed on the PIR motion sensor and the RFID tag/reader during the first lab module.
The second part of the lab integrated these sensors with a webcam to produce a sensor triggered camera system. The lab activities called for the students to use knowledge acquired from the first part of the lab to adjust the sensor triggered systems. They varied the sampling rate and the triggering threshold to reduce the number of false positives in the system.

Projects

The main goal of the projects was to give students a design and implementation experience similar to real life engineering projects. The students were divided into six teams each consisting of five to six students. Each team was treated as an engineering company with expertise in building systems with the three sensors and webcam they used in the labs. Using their expertise, their task was to perform a technical feasibility assessment for a system that addresses the needs of their clients. Their clients were actual members of the university community, including the student newspaper, the Department of Parking and Transportation, the Systems and Information Engineering Department, and members from the university’s track and field team. Following are two examples from the set of projects.

Student Newspaper

The student newspaper has several dozen distribution boxes placed in high traffic areas around the university. To improve distribution, the newspaper staff wants to know the time distribution of newspaper demand. This information is critical in planning when to recycle the remaining day’s paper and in determining how many papers are needed for each distribution box.

The first-year engineering students were asked to build a system that could record when a paper was taken from a particular distribution box over the course of the day. The students first began by surveying three different distribution boxes to observe reader behavior. They observed that, more than 99% of the time, a single paper was taken when someone opened the distribution box. Furthermore, many readers would not take the paper on the top of the stack.

Based on this observation, students determined that they could measure when each paper was taken by measuring when the distribution box door was opened. The challenge was to design a
sensor system to measure when the distribution box door was opened. Based on the sensors’ characteristics learned from the labs and additional prototyping, the team determined that an accelerometer was most suitable for the system.

The students went one step further by determining that rather than using the given wireless accelerometer, it would be more power efficient and cost effective to use a wired accelerometer. As a result, their final design used a wired accelerometer attached to the inside of the distribution box door as seen in Figure 6. A prototype of the system was tested and it successfully time stamped the opening of the box while being extremely resistant to false positive readings.

![Wired Accelerometer](image)

Figure 6 Wired accelerometer attached to the door of the newspaper dispenser

**Department of Parking and Transportation**

One of the problems faced by the university’s Department of Parking and Transportation is that they do not have an efficient method of detecting illegal parking in handicapped parking spaces. Due to the nature of parking spaces being widely spread over university grounds, it is too costly to have a person manually check each parking spot frequently. The students were asked to create a system that would monitor the parking space and record the license plate of a vehicle when it is parked in the handicapped parking space.

After analyzing the features of the provided sensors, the students first tested a system using two PIR motion sensors. However, the PIR motion sensors recorded too many false positives as it would detect people walking in front of the parking space. The students decided to add a proximity sensor to compensate for this problem. The proximity sensor and the motion sensor complimented each other, creating a webcam system triggered only when a wide object such as a vehicle approached the parking space. They tested the system with actual vehicles and confirmed that the system was effective (see Figure 7).
Stage 1 Implementation: Technology Leaders Learning Community

In the groundwork for planning the Technology Leaders Learning Community (TLC), the steering group developed four tenants under which to base the TLC.

- **Building Community**
  The community building activities are designed as the glue that connects the other program components, with the intention of creating an interdependent community that promotes success and support.

- **Leadership Development and Career Development**
  The leadership and career development activities facilitate student growth, awareness and development as eventual engineering leaders. Career and leadership development are tied together so students can explore their career in the context of building leadership skills.

- **Finding Resources**
  The finding resources component helps all students, but especially first year students, to find the resources necessary for success in the Engineering School.

- **Introduction to the Field of Engineering**
  This final component provides an early connection to the field, in order for students to develop their “place” within engineering.

We aimed to model that which we want to teach them and not merely set these up as passive “learning” opportunities. This active community is designed to focus on interdependency and shared leadership so that students are actively engaged in constructing their own learning and development.

The Technology Leaders Community kickoff was held on a Friday afternoon in late September. All first year Engineering students were invited to participate. Twenty-six students attended the session, and 7 faculty/graduate students were present. The first session was approximately 1.5 hours and was held in a classroom. Students socialized at the beginning of the session prior to
being introduced to the Technology Leaders Program and the Technology Leaders Community in a PowerPoint presentation. Students and faculty participated in icebreaker activities to learn more about one another. Students and faculty had to find a person that they did not know, introduce themselves, and find something in common. Then that pair merged with another pair and repeated the process. These groups worked together for the main activity— a hands-on demonstration. Each group had a laptop that was connected to an accelerometer. Over half of the students had previously used an accelerometer in the TLP section of the Introduction to Engineering Design course and thus were able to teach other students how to use the device. Students then worked as a team competing with the other groups to record the highest accelerometer reading. Each group demonstrated their method for the large group. Students were engaged throughout the session.

The second Technology Leaders Community meeting took place in late October. Two career counselors from the Center for Engineering Career Development conducted a one-hour Myers Briggs Personality Inventory (MBTI) workshop. Students completed an on-line MBTI prior to the event. During the event, the presenters walked students through the different personality types and asked students to think about where they fell on the spectrum of types. Then students were given their official MBTI results and were then able to compare the official results to their earlier preferences. The presenters then facilitated a conversation with students about the strengths and weaknesses of working with particular personality types in a group. The conversation also focused on understanding the results and how to apply them to become a more effective team member and leader. At the end of the program, information was provided about the Technology Leaders Program. Forty students attended the event.

The third Technology Leaders Community event took place on the first Tuesday in November and was a trip to the Insurance Institute for Highway Safety (IIHS), where cars are crash tested. Participants received a tour by one of the IIHS engineers, and witnessed an actual crash test. After watching the crash test, students were able to go on the floor to inspect the car. This trip was open to all first-year engineering students. Ten first-year engineering students participated in this trip along with roughly fifteen students from a local high school AP Physics class.

The last TLC activity of the semester was a showcase of final presentations for the Introduction to Engineering Design class, which took place during the final exam slot for the course on the Saturday of finals week. The 3-hour period was divided into two parts. The first two hours included fifteen minute presentations by each of the 6 teams. Graduate students and faculty members, including the course instructor, acted as judges. During the last hour, there was an open session where each of the six teams conducted their demonstrations at the same time. This portion was advertised to the engineering community as an opportunity to see what the students were doing, and as a study break with free food. All of the attendees to this portion of the event were able to vote among the six projects for their “fan favorite.” This provided an incentive for students who were conducting the projects to get their peers to attend. Approximately 45 to 50 students (in addition to the 34 students in the class) attended the final hour of the demonstrations.

**Stage 1 Implementation: Evaluation**

An ongoing formative evaluation of the Technology Leaders Program (TLP) includes examining and assessing project implementation and process, and provides ongoing information on the
direction of the project. The first phase of the project evaluation uses qualitative methods to address the degree to which the various project activities, including the curriculum and the learning community, are being implemented as described in the project plan.

**Fall 2008**

During the Fall 2008 semester, a member of the evaluation team observed potential TLP students during classroom lectures and activities, lab activities, project team meetings, and monthly learning community meetings. Over the course of the semester, the evaluator completed observations, conducted student focus groups, and analyzed documents.

**Site and Sample**

Project sites included a classroom, a lab, and two auditoriums at the University of ____A____. These sites were selected for observation because they were locations of the activities associated with TLP. Participants included the course instructor and the teaching assistant, as well as the 34 first-year engineering students (eight women and 26 men) enrolled in the Introduction to Engineering Design course.

**Observations**

The number of observations depended on the students’ activities and the evaluator’s availability. There were 17.5 observation hours over the semester. Most of the observations took place in the classroom and the TLP lab, during scheduled course meetings as well as during weekend lab hours. The evaluator also observed two learning community meetings. These observations allowed the evaluator to explore students’ experiences in the classroom and lab, and their experiences as part of project teams and the learning community.

Extensive field notes were recorded during all observations, and portions of some observation sessions were recorded using a digital voice recorder. Entries included portions of instructor lectures, student and teacher dialogue, dialogue among project team members, descriptions of classroom and lab activities, and verbal and non-verbal interactions among students, the instructor, and the TA.

**Documents**

The evaluator was granted access to the student portion of the interactive class website. Through the website, she was able to access the same information that was available to the students, including: the course syllabus; project team meeting minutes, photos, and project deliverables; pre-lab worksheets and other assignments; and some PowerPoint lecture slides. In addition, at the end of the semester, members of the evaluation team were granted access to online peer evaluations submitted by students using the Comprehensive Assessment of Team Member Effectiveness (CATME) website. These documents provided insight into the curriculum as it was being conveyed to students, as well as students’ interactions with one another and with the curriculum. (See Appendix A for the protocol used to summarize the documents.)

**Focus Groups**

In addition to 17.5 hours of observations, the evaluator conducted focus group interviews with three students. To construct interview protocols, the evaluation team developed questions based on Seidman’s in-depth interviewing method, the stated goals of the TLP, and events that the
evaluator had observed in the classroom, lab and in learning community meetings. Interviews varied in length from 20 to 45 minutes. Each interview was digitally recorded and then transcribed. (See Appendix B for the interview protocol.)

Spring 2009

Presently, the evaluation team is continuing to observe learning community activities, conduct focus groups with those students who were not interviewed during the fall semester, and perform data analysis. Findings will be documented in a report and formally presented during the summer of 2009.

Closure

Aimed at educating engineers and technicians about designing multiscale agile systems on geographically-distributed teams, the Technology Leaders Program combines an interdisciplinary curriculum with a hands-on lab, a learning community, and internships. In the first stage, the lab has been built, the introduction to engineering design course has been designed and run once, the learning community is meeting regularly, and evaluation is underway. Next steps include enrolling students into the program when the current first-year students declare their majors in Spring 2009, integrating TLP content into sophomore-level courses, and further developing the community college programs.

Acknowledgments

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References

Appendix A Document Summary Protocol
Adapted from Miles and Huberman\textsuperscript{7}

DOCUMENT FORM

Date received/posted:

Name or description of document:

Source (check all that apply):

- E-mail message ___
- Course website ___
  - Team wiki ___
  - Assignments ___
  - Resources ___
- CATME site ___
- Handout ___

Brief summary of contents (including purpose, sender/recipient information for e-mail messages, and notes on significant text/quotes):
Appendix B  Student Interview Protocol

At the beginning of the session I will:

- Introduce myself and the evaluation project to the students and thank them for taking the time to participate.
- Review the informed consent form. (All scripting is provided in italics.)
  - To participate in this study you must sign a form designed to meet our human participant requirements. This document states that: (1) all information will be held confidential, (2) your participation is voluntary and you may stop at any time you feel uncomfortable, and (3) I do not intend to inflict any harm.
- Obtain signature for two copies of consent form
- Provide interviewees with copy of consent form for his/her records
  - Thank you for agreeing to participate. I have planned this session to last no more than 60 minutes.
- Begin the interview.
  - The purpose of this interview is for us to learn about you and your educational and career aspirations, your growth in design skill, leadership and teamwork experiences and thoughts about continuing in the field. If I ask you anything that you do not feel comfortable answering please feel free to tell me that you do not want to answer that question. Do you have any questions for me before we begin?
- Check the proper functioning of all taping equipment prior to the interview.
- Explain the process of taping the interview.
  - To facilitate my note-taking, I would like to digitally record our conversation today. Only our research team will be privy to the recordings, which will be stored in a secure file until they are transcribed and destroyed.
- Begin recording.

Introductory Questions

1. Tell me a little bit about yourself and how you decided to come to The University of ___A___?
2. Tell me a bit about your family – who lived with you when you were growing up?
   - What do your parents (or primary caretakers) do for a living?
   - What has been their role in your math and science achievements?
3. How (or why) did you decide to take this particular section of ENGR 162?

STEM Interest Questions

The following set of questions is about your interest in engineering:

4. What was your experience with math and science classes growing up?
5. When did you first learn about the engineering profession?
6. When did you decide that you might want to take an engineering class?
7. What supports or barriers did you encounter from the time you made this decision (to take an engineering class) until you arrived at The University of ___A___?
8. What supports or barriers did you encounter from the time you arrived at your first engineering class at The University of ___A___ until now (from August until the present)?

Educational and Occupational Aspirations Questions
The following questions are about your educational and career goals.
9. Tell me about your impressions of your experience in ENGR 162 so far?
   - Probing questions to be determined based on class observations.
10. Tell me about the skills that you feel you’re learning or improving upon in ENGR 120?
11. How would you describe your experiences working as part of a team in ENGR 162?
    - When working as part of your team in ENGR 162, what have been your impressions about team leadership so far?
    - What have been your impressions about “teamwork”?
12. Thinking ahead, what do you envision yourself doing next year, in terms of your University studies?
    - What do you think you’d like to do when you graduate?

Wrap-up Questions
13. Is there anything else you would like to add?
14. Do you have any questions for me?

At the end of the interview
- I will thank the participants for their time and insights.