AC 2010-1302: IMPLEMENTING AN INTERDISCIPLINARY ENGINEERING PROGRAM – RECRUITING STUDENTS, BUILDING COURSES, DEVELOPING A COMMUNITY

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Implementing an Interdisciplinary Engineering Program – Recruiting Students, Building Courses, Developing a Community

Abstract

Traditional undergraduate engineering disciplines, due to their focus on single disciplines, cannot meet the growing need for engineers skilled in multiscale design: they educate engineers to handle systems issues or component issues, but not both. Furthermore, many interdisciplinary programs in engineering are more focused on developing knowledge and skills in multiple component-level domains (e.g., mechatronics focuses on developing component level knowledge in electrical, mechanical, and computer domains) than in component-level and systems-level areas.

These observations serve as the basis for the Technology Leaders Program (TLP), a transportable interdisciplinary program being developed at the University of the Blue Ridge and Central Community College. The TLP is designed to develop in students 1) disciplinary grounding in a component-level domain (electrical and computer engineering) and a systems-level area (systems engineering), 2) integration skills whereby students can design integrated systems of electrical and computer components, and 3) critical awareness of the need for this combination of knowledge and the opportunities and limitations for its application. Building on the Learning Factory model at Penn State, the TLP integrates three elements: a new interdisciplinary, design-focused undergraduate curriculum; the hands-on Multiscale Agile Systems Technology Lab (MAST Lab); and summer internships. Development and implementation of the TLP began in 2008 with the first class of students entering the program as sophomores in 2009 and graduating in 2012.

The purpose of this paper is to report on four dimensions of developing the TLP at the University of the Blue Ridge:

1) a formative evaluation of the first year of TLP development; results from this evaluation indicate many successful components of the TLP, such as the first-year course and the establishment of the Learning Community, and several areas needing improvement such as the communication between the lead personnel at the two institutions and more advanced planning and announcement of Learning Community activities ;
2) the recruitment of the first class of TLP students and key factors attracting students to the program; recruitment was challenged by major declaration not occurring until the summer after the first year, so many students only learned about the TLP from a video sent to them over email; in spite of this, fifteen students, representing a diverse mix of genders, ethnicities, and academic performance are currently in the program
3) the sophomore-level disciplinary grounding courses in electrical engineering and systems engineering and the impact of the TLP on these courses; TLP students take four existing sophomore courses, with the twist being that systems majors take two fundamental electrical and computer engineering courses in addition to their two sophomore systems courses, and vice versa. The instructors from all four of these sophomore courses worked together to link course materials in meaningful ways for both the TLP students and the other students in their courses.

4) the TLP Learning Community and students' expectations for the Learning Community; while the Learning Community existed during the 2008-9 academic year as a marketing and recruitment tool, the focus of the community has shifted greatly in the 2009-10 year now that there are students enrolled in the TLP; a needs assessment of the students shows that the TLP students recognize room for growth with their current leadership skills, a strong interest in the TLP summer internship partner companies and what interns do in their organizations, and a desire to learn more about effective job and internship interviewing skills.

In addition to reporting on these four areas of the TLP, we will also look ahead to upcoming challenges including the development and staffing of two new courses for third year TLP students.

Introduction

The primary purpose of the Technology Leader Program (TLP) is to prepare students for a world where both component-level and system-level knowledge are necessary to be leaders in technological fields. Such a purpose necessitates an interdisciplinary approach. For example, single disciplines such as electrical, mechanical, or chemical engineering typically aim to prepare students to perform component-level work in that discipline; that is, students learn how to "roll-up their sleeves" and do technical analysis and design work within that discipline. Disciplines such as systems engineering, on the other hand, aim to prepare students to perform integration work by equipping students with a holistic perspective and tools such as decision analysis, risk analysis, and modeling in general. The TLP aims to integrate both the component- and system-level knowledge by focusing on an interdisciplinary program between two existing majors: electrical engineering for the component level and systems engineering for the systems level.

The TLP curriculum is built on a theoretical model of interdisciplinary knowledge developed by Boix-Mansilla[1]. Through empirical studies, Boix-Mansilla identified four components of interdisciplinary knowledge as represented in Figure 1.

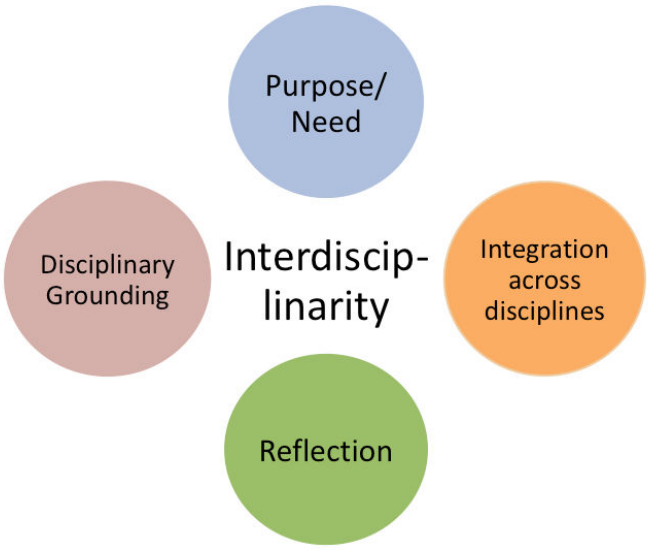

Figure 1 Boix-Mansilla Model of Interdisciplinary Knowledge

The four components are:

- **Purpose/Need**: the recognition of a need for more than one discipline to approach a problem effectively
- **Disciplinary Grounding**: the development of skills from multiple disciplines
- **Integration**: the complimentary use of the skills from multiple disciplines to approach a problem
- **Reflection**: the recognition of inherent limitations from each discipline and from their integration in the context of the problem being addressed

The overall structure of the TLP curriculum is shown in Figure 2. The colors used in this figure are linked to the colors used in Figure 1 to show how the Boix-Mansilla model of interdisciplinarity is implemented in the TLP.

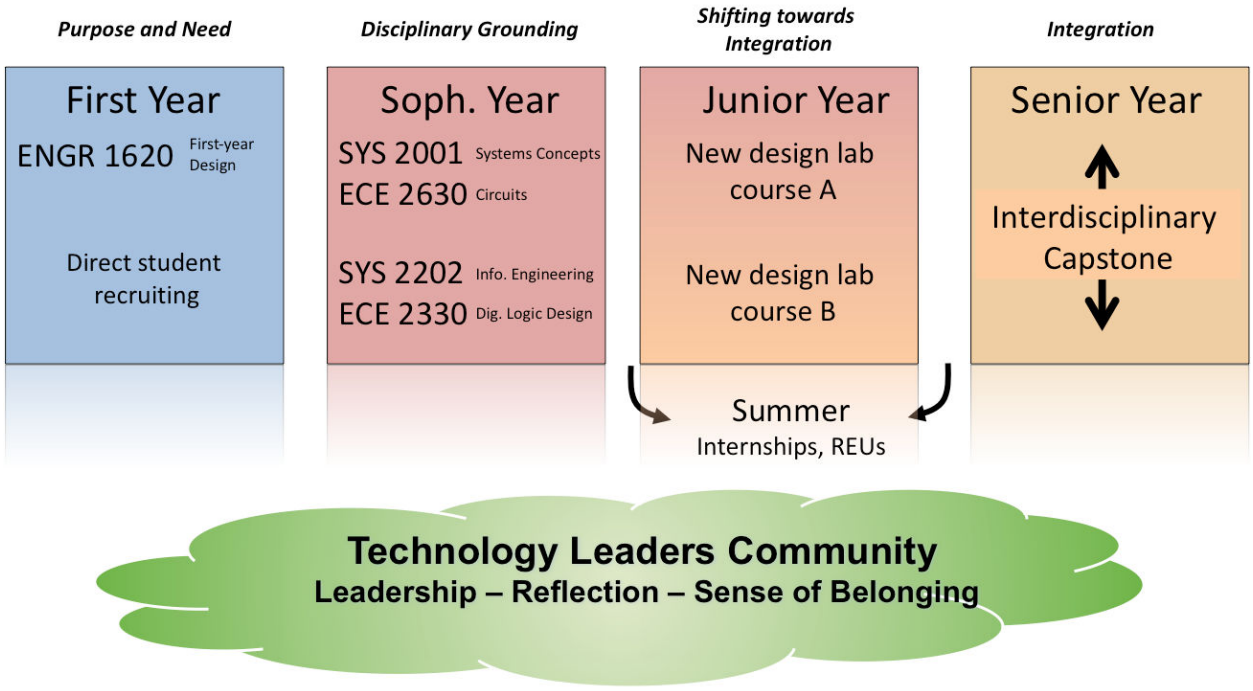

Figure 2 Technology Leaders Program Structure

In the case of the TLP, purpose and need are initially established through first-year student recruiting efforts and throughout internships and the TLP Learning Community. Disciplinary grounding is primarily accomplished in the sophomore-level courses. Integration is focused on initially in junior courses and more fully in internships and capstone projects. Reflection, while present throughout, is most directly addressed in the TLP Learning Community.

First-Year Students

Students do not declare majors until the end of their first year at the University of the Blue Ridge, so the focus of the TLP with first-year students is to expose them to the program and stimulate interest. To this end, a section of the Introduction to Engineering Design course (ENGR 1620) has been designed to focus on the integration of sensors into useful systems for actual clients with whom teams of students work. The TLP section of ENGR 1620 was taught first in 2008 and again in 2009. Direct student recruiting efforts also occur in the first year, including an open house and talks in relevant first-year courses. More details about the TLP experiences for first-year students are presented in the Evaluating Year One section of this paper.

Sophomore Year

During their sophomore year, electrical and computer engineering (ECE) students in the TLP take two systems engineering courses in addition to their normal ECE courseload while systems engineering (SYS) students in the TLP take two ECE courses in addition to their normal SYS courseload. The first cohort of TLP students is completing this course sequence in Fall 2009 and Spring 2010. More details about the impact of the TLP on these courses are presented in the Building Courses section of this paper.

Junior Year

Two new TLP courses are being designed for TLP students in their junior year. These courses will focus on short (2-3 week) real-world projects (from industry and research labs) in which students learn about the integration of electrical, computer, and systems engineering. In addition, the second course will focus on designing agility and adaptability into these systems.

Senior Year

During their senior year, TLP students will work together on two-semester capstone teams on industry-sponsored projects.

TLP Learning Community

The TLP Learning Community (TLC) meets every two weeks with all TLP students attending. Topics and activities range from community building to industry speakers, with an underlying theme of providing a space for students to connect as a group and learn from each other. More details about the TLC are presented in the Developing a Community section of this paper.

Internships

TLP industry partners speak to TLP students in the TLC and coordinate with students for internships. The role of the TLP is to provide opportunities for TLP students to meet people from relevant industries; the final responsibility of getting an internship rests with the students.

More details about the TLP are presented elsewhere[2].

Technology Leaders Program Timeline

The TLP began in Fall 2008 with efforts focused on developing the first-year courses and establishing the infrastructure for the sophomore experience, which includes courses, the TLC, and internship experiences. Students applied to the program in April 2009 with the first cohort of seventeen students starting the program in August 2009.

In this paper, we present results from the evaluation of the TLP after its first year (2008-9) and then describe three core activities from following year (2009-10). These three activities focus on recruiting students, building courses for the students, and developing a community among the students.

Evaluating Year One

Ongoing evaluation of the TLP began in 2008. These evaluations were designed to inform the principal investigators and decision makers about the implementation of the TLP, determine progress toward first-year goals, and inform improvements in the quality of the TLP program.

The evaluation findings from the first year of the program (2008-9) used quantitative and qualitative methods to provide answers to a set of evaluation questions. Among the first year goals were to:

1. develop and implement an introductory course to engage first-year students and interest them in applying to the TLP program, and
2. develop and implement a co-curricular set of activities, as part of the TLP Learning Community.

To evaluate progress toward the first goal, a member of the evaluation team observed potential TLP students during classroom lectures and activities, lab activities, project team meetings, and learning community meetings, primarily during various activities in the UVA Introduction to Engineering Design course. The evaluator completed over 22 hours of observations, conducted student focus groups, analyzed documents, and collected numerical data.

The evaluation team found that students were highly engaged with the content of the course, adhering closely to the design development process as set forth in the curriculum and devoting several hours each week to team project work. Indeed, when the instructor covered aspects of the design process in class, through a combination of lecture and in-class activities, student project teams immediately implemented the practices discussed. Students also enthusiastically participated in class discussions and lab activities. Lab activities, during which students worked with groups outside of their project teams, were particularly successful in familiarizing students with elements of multiscale agile systems design, as they provided students the opportunity to gain hands-on technical experience and also hone team problem-solving skills.

Open-ended responses from end-of-semester course evaluations indicated that students found the course "challenging," "energetic," and "worth the effort." Several students noted that they would have preferred to spend less time in the classroom, and more time on team project work. Among the students who took part in individual and small group interviews, all reported that the course increased their understanding of engineering practice. They also said that they planned to continue with engineering coursework, and pursue careers in engineering.

The process of working on design teams appeared to enhance engagement and interest in course material. However, students who took on administrative roles linked to accomplishing project-related tasks maintained these roles throughout the projects. These roles were linked to the accomplishment of project-related tasks and can be categorized into four types: managerial, technical, organizational, and research, as shown in Table 1. While all of the administrative roles involved some leadership and some oversight, students in the managerial role appeared to gain the most in terms of leadership experience. This suggests that students may not have engaged equally in each phase of the design development process, nor engaged equally in leadership development work.

Table 1 Behaviors within Administrative Role Categories

Role category	Examples
Managerial	- Agenda-setting - Initiating discussion - Assigning tasks - Writing/editing project deliverables
Technical	- Generating technology-based ideas - Manipulating technical equipment (e.g., lab computer, accelerometers, sensors)
Organizational	- Documentation (e.g., taking notes and meeting minutes, scanning illustrations) - Uploading minutes, memos, and reports to class website
Research	- Field site observations - Gathering information on-line

In response to the feedback regarding student roles within the teams, new procedures were implemented in year two. More specifically, students rotated through three pre-defined roles during the first month of the course such that each student experienced each role. These roles were "managerial", "organizational", and "research" from Table 1; "technical" was not included because its main relevance came later in the projects. After the first month, each team wrote their own team contract in which, among other things, the division of roles was established for the remainder of the term. The evaluation team will assess the effectiveness of these new procedures at the end of year two.

Concerning the goal to start the TLP Learning Community (TLC) meetings during the 2008-9 year, an engineering faculty member and an education faculty member co-developed TLC meetings for year one of the program. Because no students were in the TLP at this point, the main objectives of the TLC's during year one was to stimulate interest in applying to the program. As shown in Table 2, six learning community meetings were held over the course of the 2008-2009 academic year – four in the fall semester and two in the spring semester.

Table 2 TLP Learning Community Meetings

Meeting Date	Title
9/26/08	Technology Leaders Program Introduction Community Meeting
10/29/08	Leadership That Fits Your Style: Myers-Briggs
11/6/08	Site Visit: Insurance Institute for Highway Safety Crash Test Facility
12/13/08	Final Project Demonstrations from Introduction to Engineering Design Course
2/26/09	"Visual Prosthetics and Neural Engineering," Guest speaker:
3/10/09	"What Do I Want To Do With My Life?" guest speaker from TLP industry partner

The most successful learning community meeting, as evaluated by the number of attendees, was a session during which students in the Introduction to Engineering Design course demonstrated their final project at the end of the fall semester. The meeting featured final team

project demonstrations from the TLP section of ENGR 1620 with attendees to the demonstrations including classmates and community members. Knowing that guests would be asked to vote for their favorite project, many ENGR 1620 students invited friends and family members to attend, lending a festive air to the proceedings. The event was not only well attended (45 attendees in addition to the 35 students in the class), but also provided a fun, informal forum in which to promote the TLP among first-year students.

In spite of the general success of the first year of learning community activities, there remained a need for improved planning and communication. With the exception of the final project demonstration session, each of the learning community meetings was advertised via an e-mail message sent from an engineering faculty member to all first-year engineering students. The spring learning community meetings, in particular, were announced on relatively short notice, which may have contributed to low student attendance. Low attendance at the spring meetings may also have been due to the fact that there were no associated requirements for attendance, as during the fall in which students in the ENGR 1620 Introduction to Engineering Design class received class credit.

The major shift for the TLC from year one to year two is that students have committed to the TLP program for year two. This allows the TLC to shift from primarily being aimed at stimulating interest in the TLP to its originally intended purpose of building community among students in the TLP. More details about these changes are presented in the Developing a Community Section of this paper.

Recruiting Students

The ENGR 1620 Introduction to Engineering Design section and the TLC meetings were the primary mechanisms used to "get the word out" about the TLP and stimulate interest in it. To apply to the program, students checked a box on the same form used to declare their major. The results from the major declaration forms were first available for review by TLP faculty during late May, after the students had left for summer break.

One hundred and fifty-five students of roughly five hundred and fifty total first-year students checked the TLP box. Even though the form clearly stated that the TLP is only open to electrical, computer, or systems engineering majors, sixty-three of the students that checked the box were not pursuing one of these majors.

After reviewing the names of the remaining ninety-two students who expressed interest and had declared an appropriate major, it was clear that many of these students had never attended a TLC nor were they in the TLP section of ENGR 1620. That is, they knew very little about the TLP besides its name! Because students had left campus for summer break, a video was prepared in which the TLP was described. After sending this video to all ninety-two students, twenty-one applied, twenty-two indicated that they were not interested, and forty-nine never responded. All of the students who applied were accepted to the TLP, but four dropped from the program after having difficulty fitting the second year courses into their schedule. The remaining seventeen students enrolled in the TLP as second year students in Fall 2009.

Roughly 18% of eligible students expressing interest at time of major declaration enrolled into the TLP. Of those students who were attracted to the program based on its name alone (i.e., those that checked the box on the major declaration form) *and* who watched the video that provided more details (n=43), 49% (n=21) were still attracted after watching the video.

As shown in Table 3, the seventeen students represented a diverse mix of the three majors, of ethnicity, and of gender. Two of the seventeen students dropped from the program mid-way through the fall term, with the final numbers for category shown in the far right column of Table 3.

Table 3 Technology Leaders Program Students

	Enrolled in August 2009 n=17	Enrolled in January 2010 n=15
MAJOR		
Computer science or computer engineering	3	3 (20%)
Electrical engineering	6	6 (40%)
Systems Engineering	8	6 (40%)
GENDER		
Female	8	6 (40%)
Male	9	9 (60%)
ETHNICITY		
Asian	5	5 (33%)
Black / African American	3	3 (20%)
Hispanic	2	2 (13%)
White	7	5 (33%)

Of the seventeen students enrolled in August, the most common reason cited for joining the TLP related to the hands-on, applied curriculum and connections to industry and internships. Other frequently cited reasons included an interest in the interdisciplinarity of the program and a desire to be part of a smaller group of students and faculty than otherwise possible.

While we recruited a good mix of students with the approach used this past year, we hope to increase the number of students who know what they are signing up for when they "check the box" on their major declaration form. Current TLP students will be enlisted to help with this process, which will consist of a TLP website, a short video describing the program, an open house, and more announcements in courses that first-year students commonly take.

Building Courses

Courses must be designed or altered for students ranging from first-year to seniors in the TLP. While the primary focus in this section is on the design of the sophomore courses, each year provides a different type of challenge in course design.

Building Courses Summary

The primary first-year course, ENGR 1620 Introduction to Engineering Design, is discussed in the Evaluating Year One Section. A single faculty member led the re-design of an existing ENGR 1620 section to incorporate more electrical engineering component work (for this course, sensors were the main components) into a course that already focused heavily on systems engineering and design. This faculty member is heavily involved with the TLP.

The sophomore courses, two existing systems courses and two existing electrical engineering courses, includes students both in and not in the TLP. A primary challenge is working with multiple faculty, most of which have no connection to the TLP.

The junior courses are to be two new courses designed specifically for the TLP. Major challenges with the junior courses are staffing the courses and creating the content from scratch. These are the only two completely new courses created for the TLP

The senior course is a two-semester capstone course in which TLP students will work together on teams with actual clients from industry. This course fits nicely into an existing capstone program structure at the University of the Blue Ridge and only requires the identification of appropriate industry projects with a strong electrical, computer, and systems engineering mix.

Building Courses: Sophomore Courses

Because the main goal of the sophomore courses is to provide grounding in both electrical/computer and systems engineering disciplines, the TLP could operate without making any changes to the existing sophomore courses. The courses are already designed to provide such grounding for majors in those fields. That said, the TLP could provide opportunities to help each course better meet its disciplinary objectives for all students enrolled in the courses (most of which are *not* in the TLP). With this primary goal – to help the four sophomore courses better meet their existing objectives through integrating TLP content or using TLP resources – the faculty involved in teaching these courses met twice during summer 2009 (3 hours each) for "course re-design mini-workshops" and once during fall 2009 (1 hour) for to follow up.

The four courses are:

- **SYS 2001 Systems Engineering Concepts (fall)** – systems engineering methodology, basic tools of systems engineering such as modeling, decision analysis, and project management.
- **SYS 2202 Data and Information Engineering (spring)**– tools to model, store, manipulate, and exchange information, including Unified Modeling Language, relational models, SQL, XML.
- **ECE 2630 Introductory Circuit Analysis (fall)** – elementary electrical circuit concepts and their application to linear circuits with passive elements.
- **ECE 2330 Digital Logic Design (spring)** –number systems and conversion; Boolean algebra and logic gates; minimization of switching functions; combinational network design; flip-flops; sequential network design; arithmetic networks.

The three meetings were facilitated by a course design consultant from the Teaching Resource Center at the University of the Blue Ridge. Five faculty teach these four courses, with only two of the five involved with running the TLP. At the first workshop, the consultant led the faculty through exercises aimed at getting all participants to understand the four courses (not just their own course) and at establishing course design principles. The second workshop was more directly focused on developing tangible ways for the material in the four courses to build on each other and/or be integrated, keeping in mind that most students do not take all four courses (only the TLP students do).

While there were a few areas where the technical areas could build on each other (e.g., sensitivity analysis from a systems engineering course being applied to a circuit designed to operate an alarm in an electrical engineering course), most of these could not be applied in class because all students were not taking all of the courses. Instead, such technical connections were identified as good topics for the TLP Learning Community, where the TLP students taking these four courses could be guided through seeing these points of integration. In the sophomore-level classes themselves, several common examples were identified through which material in each class could be explained. For example, a vending machine example is used to explain the concept of functional requirements in a systems engineering course and to focus on applications of logic in the digital logic course.

In addition, term projects for Systems Engineering Concepts were selected that included the evaluation of systems with significant electrical and computer components. These projects were selected to better develop the ability for systems engineering majors (in the TLP or not) to design systems that contained both technology components and system integration issues, an objective that is completely aligned with the objectives of the TLP.

A reality of university teaching assignments – that these assignments can change not only from year-to-year but also just days before a semester starts– makes efforts to emphasize relationships between related topics from four sophomore courses challenging. This became clear at the fall follow-up meeting, as the assigned instructors for the two spring courses had changed since the summer workshops. We handled this by shifting some efforts to integrate topics from the sophomore courses to the TLP Learning Community, a forum which has the ability to adapt to changing course instructors more effectively than does making direct changes to the sophomore courses.

Developing a Community

During the 2008-9 academic year, the TLP Learning Community (TLC) was focused on recruiting students to the program along with some career development and exposure to the engineering field. For the 2009-10 year, the program became more structured with additional meetings since students were officially a part of the TLP. The goal of the TLC is to build a community of students focused on developing into engineering leaders. The objectives of the TLC are: community building, leadership and career development, exposure to the engineering field, and helping students to find resources. A needs assessment was conducted at the beginning of the fall semester with the following key themes emerging:

- Students were attracted to the program due to the connection with hands-on activities and projects long with connections to "real world" work in classes and internships
- Students were looking for an opportunity to get to know professors and other students
- Approximately half of the TLP students rated their leadership skills as competent, sharing that many had leadership experiences outside of engineering, but not engineering-specific experiences. Students shared that they wanted to learn more about how to listen to multiple perspectives, compromise, gain confidence as a leader, and consistently make good choices when in a leadership role
- Students reported that they were interested in learning more about team decision-making, conflict management, and structuring a team
- Students were also interested in career development skills (e.g., resume/cover letter writing, internship search strategies), with interviewing skills being the most popular request

The TLC met eight times during the course of the semester, on alternating Wednesday and Friday afternoons. Students in the TLP were required to attend seven of the eight sessions. The first introductory session in late August was set up to provide students additional information about the TLP and to begin to build community between students and faculty affiliated with the program. A graduate assistant facilitated icebreaker activities, and then participants were broken into small teams for a team challenge. The team challenge required teams to retrieve a "treasure" from a room that was outfitted with sensors to detect intruders and secure the treasure. A small prize was awarded to the most successful team.

The second meeting of the TLC for the semester continued to focus on community building as well as the leadership development and finding resources objectives. Students were divided into small groups to perform a needs analysis for the TLP website and to begin to design the page. In addition, the TLC facilitator emphasized team decision-making techniques as groups reached places where decisions were necessary. Students were engaged throughout the exercises and submitted final designs for the website two weeks after the TLC.

Faculty members affiliated with the TLP facilitated two meetings of the semester (one in September and one in December), focusing on integrating topics from the two engineering courses in which the students were enrolled (one systems engineering course and one electrical and computer engineering course). One of the professors brought with him various electrical devices that remotely monitor body movements of Parkinson's patients to use as examples during his talk. The other professor focused on vehicle air bags from a systemic perspective, considering different stakeholder needs and how these needs affect electrical component design. These meetings supported the objectives of learning more about the engineering field, as well as well as finding resources to provide additional academic support.

Two meetings of the semester also focused on visits from internship partners, which supports the objective of career development, learning about the engineering field, and finding resources. An employee of SAIC came to visit the TLC in November to talk about his career experiences and how his experiences shape views on the importance of the skills that are a focus of the TLP.

While this visit was not focused on recruiting, it did give students exposure to an engineer working in industry and the opportunity to begin to build a professional network. The other planned meeting with internship partners was not able to come to fruition, but a professor in the department of systems and information engineering who is a core TLP faculty member and the former President and CEO of an internship partner spoke. He focused on his experiences in designing systems for on-board collision avoidance in airplanes and also on the overall role of internship partners in the TLP.

Because students expressed a need for more information about interviewing for jobs and internships, members of the TLC attended a school-wide presentation titled "The Art of Interviewing" by a professional speaker, which aligned with the career development objective of the TLC.

One session of the TLC for Fall 2009 focused on mentoring. Four seniors volunteered to mentor TLP students on projects in their systems engineering course. In the systems engineering course, all TLP students worked on teams with other TLP students and a few non-TLP students. The seniors were provided with the project assignment, project descriptions, and project work already completed by the teams before meeting with TLC students. The mentors were also given a mentoring tip sheet to help prepare them for working with the TLC students. During the TLC meeting, the mentors met with their assigned project teams. Mentors and mentees asked questions and mentees received helpful advice about their projects. At the end of the meeting, there was a conversation about what was helpful about this process and tips for mentoring. TLP students were engaged throughout the one-hour meeting and showed insights such as "it really helped that the mentors had read through our project work and the instructor feedback prior to meeting with us" and "the mentors were really good at listening to our problems" during the de-briefing. TLP students were then assigned a team from the first-year Introduction to Engineering Design course to mentor where they could apply these insights.

The TLC concluded the semester with a "study-break" at a local pizza place during final exams. Plans for the spring term are to bring two to four speakers from TLP internship partners to recruit the TLP students for summer internships, engage the TLP students in recruiting the next cohort of students, and continue to reinforce connections between their sophomore electrical engineering course and systems engineering course.

Moving Forward

In this paper, we have presented an evaluation of the first year of the Technology Leaders Program and reported on three core second-year tasks necessary to implement the TLP – recruiting students, building courses, and developing a community. Student recruitment during the first year was successful in attracting a diverse mix of fifteen students. A community has begun to develop through the TLC, the two sophomore engineering courses, and the grouping of TLP students together on teams for the systems engineering course project. A task that this first cohort of students will undertake (as part of the TLC) is to plan the recruitment of the second TLP cohort during the spring term. The goal is to inform all first-year students about the TLP so that they will be able to make a knowledgeable choice about applying to it when they declare their major (as opposed to the prior year when a video was sent to interested students *after* they expressed interest in the program). Design and implementation of courses has been successful

for the first-year and sophomore-level courses. A significant challenge with the sophomore-level courses is to maintain connection to the TLP even as faculty teaching these courses changes. The most significant course-related challenge, however, is staffing and creating the two new third-year TLP courses.

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