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# **AC 2012-5168: ECE/SYS INTEGRATION: A STRATEGY FOR EVALUATING GRADUATES FROM A MULTI-YEAR CURRICULUM FOCUSED ON TECHNOLOGY SYSTEMS INTEGRATION**

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# **ECE/SYS Integration: A Strategy for Evaluating Graduates from a Multi-year Curriculum focused on Technology Systems Integration**

## **Abstract**

In 2009, a group of seventeen students majoring in electrical, computer, or systems engineering became the first class of Leaders in Engineering Program (LEP) students at East Central State University<sup>1</sup>. The LEP is an undergraduate curriculum focused on developing knowledge and skills that address both component-level design (electrical or computer engineering) and system-level integration.

The current situation for majors in electrical and computer engineering at East Central State University is that the curriculum is focused on developing strong technical skills to design and analyze electrical or computer engineering components. For systems majors, the curriculum is focused on developing rigorous skills for approaching a problem from a systems perspective and for modeling the performance of systems under conditions of uncertainty. The objective of the LEP is to develop systems engineering graduates with the ability to work on technology-oriented projects and electrical/computer engineering graduates with the ability to integrate their domain-specific designs into larger systems.

The purpose of this paper is to describe the research plan for determining how well the LEP is able to accomplish its objectives for graduates. The initial group of seventeen students is in their senior year during the 2011-12 academic year and all are completing capstone design projects. Five of the seventeen students decided to drop out of the LEP at various times during the last two years. Statistical baseline data to be gathered includes the types of jobs each student pursues after graduation, the type and number of internships each student completes during their summers, and their overall academic success. Interviews with faculty advisors of LEP capstone projects will provide information on the performance of LEP students relative to their non-LEP peers on real world projects. Finally, a performance activity will be used to directly observe if and how LEP students approach systems integration problems differently from their peers.

## **Introduction**

Engineering majors at East Central State University are similar to those at other schools throughout the nation – students choose to major in one area and they follow a curriculum that is largely specified but has a few electives of various types sprinkled throughout. The primary commonalities to all majors are a set of math, physics, chemistry, writing, and technology and society courses. With this structure, it is not surprising to learn that students in different majors develop different sets of rigorous technical skills and that these skills do not overlap significantly. The problem, of course, is that nearly all real world problems require knowledge and skills from more than just one of the majors.

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<sup>1</sup> a pseudonym

This general predicament has led to the creation of numerous interdisciplinary programs within engineering. This paper is about a plan to assess students knowledge and skills in one particular interdisciplinary program, the Leaders in Engineering Program (LEP), which is about more than just interdisciplinarity; the LEP is about educating students with both the bottom-up, component-level design skills associated with most engineering majors and the top-down, integration-focused skills associated with systems engineering.

In particular, the LEP is an interdisciplinary program between Systems Engineering (SYS) and Electrical and Computer Engineering (ECE). Table 1 highlights how different, yet complementary, the two majors are.

**Table 1 Systems Engineering and Electrical and Computer Engineering Majors**

<b>Systems Engineering Majors</b>	<b>ECE Majors</b>
<p>The Systems Engineering undergraduate degree at East Central State University is focused on applying systems thinking to projects and programs that involve technology, people, and policies while utilizing operations research-oriented analysis approaches as appropriate. SYS graduates are good at handling complex problems and making evidence-based recommendations as to how to improve system performance. Implementation of these recommendations is not a primary focus of the SYS degree; when implementation is addressed it is focused on information systems.</p> <p>Given a problem, SYS graduates are primarily educated to be skilled at recommending solutions and requirements for those solutions.</p>	<p>The Electrical and Computer Engineering undergraduate degrees at East Central State University are focused on the analysis and design of ECE components and, to a lesser degree, systems. Like many other ECE programs, the primary focus is on analysis of ECE components. Given a certain set of requirements, an ECE graduate should be able to create a design to meet those requirements.</p> <p>Given a recommended solution / requirements for that solution, ECE graduates are primarily educated to be skilled at creating and analyzing a design that implements the recommended solution.</p>

It is with these large differences between the majors that the LEP aims to educate engineers capable of both creating the high-level strategic recommendations and implementing those recommendations for technology-based systems. The motivation for the LEP is to develop systems integrators capable of systems analysis and strategic decision-making as well as more implementation-focused component design work.

The purpose of this paper is to describe a plan for assessing how the LEP has affected its first cohort of students. In this paper, we present the LEP's objectives and curricular structure, review relevant literature, explain results from prior assessments of LEP students, and then describe the assessment plan.

## The Leaders in Engineering Program

To fulfill its goal of educating students with both rigorous systems integration and detailed electrical and computer component design skills, the structure of the LEP is built around a model of interdisciplinarity developed by Boix-Mansilla<sup>1</sup>. The essence of the Boix-Mansilla model is captured in four dimensions:

1. **Purpose:** students must understand the reason why multiple disciplines are necessary to solve a given problem
2. **Disciplinary Grounding:** students must have fundamental knowledge from all of the disciplines needed
3. **Integration:** students must know how to integrate the different worldviews, approaches, and tools used by the different disciplines
4. **Critical Awareness:** students must be able to reflect on the appropriateness and utility of taking an interdisciplinary approach for a given problem.

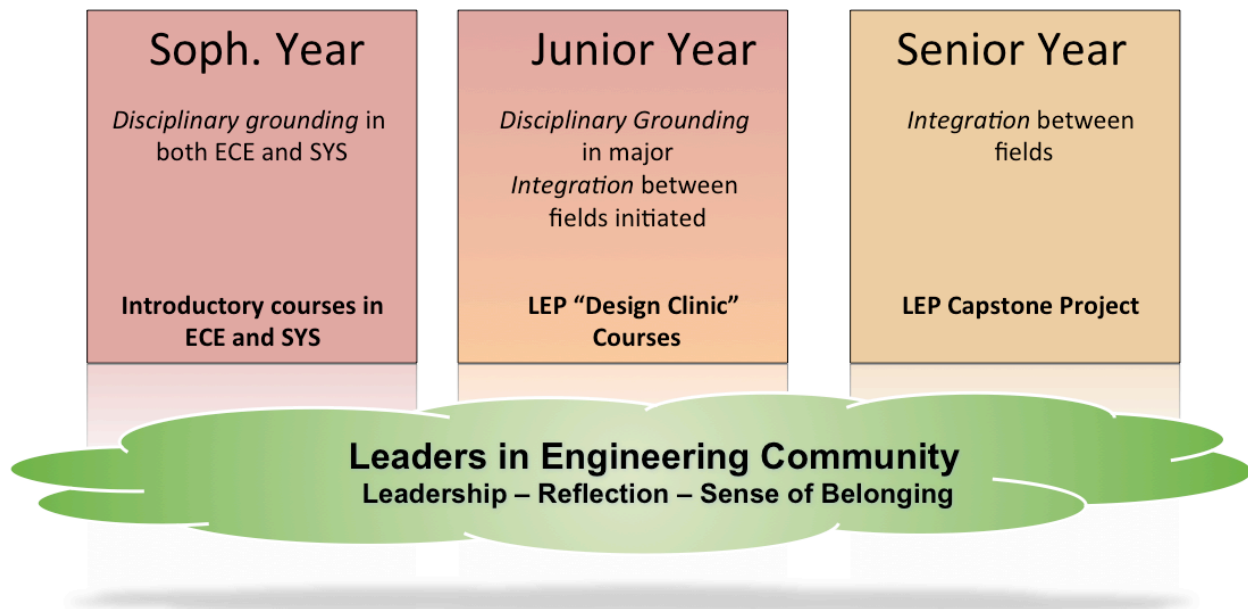
Students apply for the LEP at East Central State University at the end of their first year and, if accepted, are in the program from their sophomore through senior years. These students major in one of three majors: computer, electrical, or systems engineering. Because the electrical and computer engineering programs are intertwined, it is helpful to think of the LEP consisting of two main groups of students: systems (SYS) majors and electrical/computer (ECE) majors.

In the sophomore year, the main focus is on **disciplinary grounding**. Students take their normal introductory courses of their major and also take the introductory courses from the other major. For example, systems engineering students take two electrical engineering courses (circuits and digital logic design) and electrical and computer engineering students take two systems engineering courses (systems methodology and information systems) in addition to their required major courses. In the junior year, **disciplinary grounding** in a student's major continues while disciplinary grounding in the other major (ECE for SYS majors, SYS for ECE majors) tapers off.

The tapering is due to an increased focus on **integration** in the junior year. The focus of the junior year is two LEP classes (one each term) in which teams work to design and build actual systems. Finally, in the senior year, students continue to concentrate on **integration** while completing capstone projects designed specifically for LEP teams.

**Purpose/need** and **critical reflection** are incorporated into the LEP curricula through the LEP Learning Community. The LEP Learning Community meets every two weeks for one hour with goals of developing a sense of belonging among the students, educating students about the engineering field, strengthening leadership skills among students, and helping students learn skills for getting jobs and internships. All students in the program – sophomores through seniors – participate in the learning community together.

An overview of the LEP structure is shown in Figure 1. In addition to what is shown in Figure 1, LEP students must also complete an internship or research experience that is LEP-related prior to graduation.



**Figure 1 Overview of the Leaders in Engineering Program**

We first accepted students in Fall 2009 – the application process for this class is detailed in a prior paper<sup>2</sup>. Twelve students are part of this first LEP class that will graduate in May 2012. It is these twelve students that are the focus of the assessment plan presented in this paper.

The LEP curricular structure was designed to help students reach specific learning objectives. The high-level objective is as follows.

#### **High-level objective**

Electrical and computer engineering students in the LEP will be able to engage in doing and critiquing systems engineering work and vice versa.

The wording “engage in” is used to mean that an ECE LEP student may not be able to *lead* the SYS work on a project, but they can understand it, contribute to it, and give feedback to the systems engineers on the team (and vice versa).

Underneath this high-level objective are two sets of supporting objectives, one related to teamwork and one related to design.

#### **Supporting Objective: Teamwork**

Compared to their non-LEP peers, LEP graduates will be more skilled at:

- LEP students will be more able to work on interdisciplinary teams while their peers are more prepared to work on multidisciplinary teams, with the distinction between these two (as cited in the literature) being that multidisciplinary teams are composed of specialists who simply do “their” work while interdisciplinary teams are composed of specialists capable of working collaboratively across disciplines.
- LEP students will place greater value on the work of individuals from other disciplines.

### **Supporting Objective: Design**

Compared to their non-LEP peers, LEP graduates will be more skilled at:

- executing a design process,
- designing multicomponent systems including the ability to manage interfaces between subsystems, and
- applying practical design skills such as reading specifications sheets for electrical components or selecting parts from distributors for an integrated design.

The research question to be addressed by the research strategy described in this paper is as follows: *Are LEP graduates different than their non-LEP graduate peers with respect to their ability to perform interdisciplinary work as described in the LEP learning objectives?*

### **Literature Review**

To assess LEP students on the stated learning objectives, the research plan needs to address both teamwork and design-related areas. A brief literature review of prior work on assessing interdisciplinary teamwork skills and on assessing design skills is presented here.

#### *Prior Work on Assessing Interdisciplinary Teamwork*

An important component of many interdisciplinary engineering courses and programs is teamwork<sup>3,4</sup>. The Accreditation Board for Engineering and Technology (ABET) requires learning outcomes for undergraduate engineering students to include the ability to function on multidisciplinary teams<sup>5</sup>. At the graduate level, Integrative Graduate Education & Research Traineeships (IGERTs) were found to stress teamwork as an important learning outcome, along with disciplinary grounding, integration, communication, and critical awareness<sup>3</sup> (Borrego & Newswander 2010). Engineering education research reiterates the need for engineering students to develop teamwork skills as part of the undergraduate curriculum<sup>6-8</sup>.

Research on interdisciplinary teams has focused mostly on the barriers and bridges to interdisciplinary collaboration and teamwork, rather than specific assessment methods<sup>9-13</sup>. With undergraduate engineering students specifically, research has shown that these students are subject to, and acknowledge, the challenges of “disciplinary egocentrism,” which is defined as the “inability to think outside of one’s disciplinary perspective”<sup>11,14</sup>. As seen by Richter & Paretti’s examination of an interdisciplinary green engineering course, “disciplinary egocentrism” can limit the development of a student’s interdisciplinary understanding and his or her ability to function on an interdisciplinary team<sup>11</sup>. In considering various methods of assessment for interdisciplinary teamwork, it is necessary to be aware of these different barriers to interdisciplinary collaboration.

In the humanities and social sciences, researchers have developed assessments of interdisciplinary understanding, but these assessments have focused on one individual and his or her ability to execute interdisciplinary work by themselves<sup>15,16</sup>. In the formative and summative assessments of IGERT programs, specific methods for examining programmatic components can be found in the literature, but there exists a mismatch between the stated student learning outcomes (e.g. teamwork) and the evidence that students achieved those outcomes for these programs<sup>3,17,18</sup>. For the undergraduate level, research on interdisciplinary engineering programs

and courses is particularly limited<sup>11, 17</sup>. To assess students' understanding of integration as a component of the interdisciplinary process, one study examined the use of concept maps as a potential method<sup>19</sup>. In a similar study, researchers developed a questionnaire and utilized focus groups and interviews to evaluate the development of the students' interdisciplinary understanding over the semester<sup>12</sup>. While the instruments were able to provide some evidence of an increase in the students' interdisciplinary understanding and awareness of the interdisciplinary process, none of them resulted in a clear evaluation of the development of interdisciplinary teamwork skills<sup>12</sup>.

Researchers agree teamwork is a complex learning outcome<sup>3</sup>. While studied in other domains<sup>20, 21</sup>, there is no current standard of practice for teamwork assessment methods in an interdisciplinary engineering setting<sup>17, 22</sup>. Faculty looking to assess interdisciplinary teamwork may consider utilizing surveys, questionnaires, scenario-based assessments, assessments of student artifacts or criterion referenced assessments<sup>17, 23</sup>. Authors Wiggins and McTighe<sup>24</sup>, as one example, recommend a “backward design” framework for designing assessment methods and learning experiences based on the desired learning outcomes. For interdisciplinary teamwork, in this case, sub-outcomes could be utilized. One IGERT proposal, for instance, subdivided the teamwork and professionalism learning outcome into “(a) an understanding of group dynamics associated with leadership, membership, and peer to peer interactions, (b) the ability to listen, give, and receive feedback, (c) ability to set appropriate goals, milestones, and division of labor”<sup>3</sup>. By considering these learning objectives during the course design phase, faculty can avoid utilizing methods that do not provide a clear assessment of the development of team skills<sup>22</sup>. Other approaches include comparing teams based on the level of disciplinary integration within their research. Morse, et al.<sup>10</sup> developed a spectrum of disciplinary integration on a team, which compares level of interaction, problem definition, and vocabulary utilized for the cases of disciplinary, multidisciplinary, and interdisciplinary research. Interviews or observations may also serve as another form of assessment, as Richter, et al.<sup>12</sup> recommended after finding that peer assessments did not serve to properly evaluate the students' team skills at the end of an interdisciplinary engineering course.

### *Prior Work on Assessing Engineering Design Skills*

Due to their central importance to engineering and their inherent complexity, engineering design skills have been the focus of many assessment efforts. The approaches reviewed here are focused on assessing *process skills* and on answering the question “What would a student do given an open-ended design problem?” The focus is not on how to assess the quality of a design artifact itself. Furthermore, the assessment approaches reviewed here largely focus on if and when a student performs a certain process (e.g., problem definition), not on how well they perform it. In spite of having so many commonalities, the design process assessment approaches in the engineering education literature still show considerable variety.

All of the approaches reviewed are in contrast to using student design reports and presentations as measures of design knowledge. While using such materials for grading in a design class may be appropriate, they are not viewed as being reliable instruments through which to learn what a student knows about design and will do when they encounter a design problem that is not in a class. Students feel pressure to do “what the instructor is looking for” and frequently instructors require design teams to use certain design tools or complete certain design activities as part of

their project. Just because a student has performed a certain design activity (e.g., interacting with a client, writing requirements, generating alternative solutions, etc.) during a class project, does not mean that the student will ever do these things again in an authentic situation<sup>25, 26</sup>. The design knowledge assessment approaches reviewed here attempt to go beyond performance in a class project to uncover what a student would do on a real project.

The review starts with the approach that gathers the richest data and is the most time intensive to execute and generally moves towards less time intensive approaches that gather less data. These two dimensions, 1) the “richness” or “depth” of data and 2) the amount of time required to execute an approach, represent a central trade-off that researchers make when choosing which approach to use to assess design knowledge for their study.

### Ethnography

While ethnography has been used by many to study design<sup>27</sup>, a strong example of this is a study performed by Newstetter at the Georgia Institute of Technology<sup>26</sup>. In an ethnographic study, the researcher “embeds” themselves on a design project with the subjects and has both a participant and observer role. In the case of Newstetter, this meant working on an undergraduate design team for an entire term while taking copious notes and observations about her experiences and those of her student teammates. In addition to her participant observations, Newstetter conducted interviews with students in the class at various points during and after the term. The data is extremely rich – in Newstetter’s case highlighting that even though students were turning in design reports with certain elements such as decision analysis tools, the students saw the reports and associated design tools used as busywork and had no intentions of ever using them after the class. This is a prime example of why design reports and presentations alone are not good indicators of a student’s design knowledge. Clearly, the rich data came at a cost – the time required to perform such a study is unparalleled.

### Verbal Protocol Analysis

The typical way that Verbal Protocol Analysis (VPA) has been used to study design as follows: subjects perform a design activity (requiring several hours in most cases) while “thinking aloud” and then this data is transcribed, coded, and analyzed. Many researchers have used this approach; for example, one entire book contains dozens of analyses by different researchers of the exact same transcriptions from a design task<sup>28</sup>. Atman and others at the Center for Engineering Teaching and Learning have published numerous studies on design knowledge using VPA<sup>29, 30</sup>. The core VPA activity is time intensive – mainly in the transcribing and coding of data – but the time spent is in effort to capture a rich representation of a subject’s knowledge from the video and audio data. Several researchers have worked to make VPA less time intensive (shorter activities, “live” coding of data, etc.). One noteworthy example shows multiple design timelines from three-hour VPA activities to students as a way to provoke student reflection on their own design processes<sup>31</sup>.

### TIDEE and IDEALS Assessment

Davis and others have developed a suite of tools to be used in design classes to provide both formative feedback and summative outcome assessment<sup>32, 33</sup>. Their tools include assessments of design, communication, and teamwork skills and were developed as part of both the Transferable Integrated Design Engineering Education (TIDEE) and Integrated Design Engineering Assessment and Learning System (IDEALS). The tools are much less time intensive than VPA



or ethnography as the intent is to use their tools for all of a students in a class. The assessments are intended to be used both formatively as feedback and summatively to evaluate program outcomes. The deliberate dual-purposing of these assessment tools (to help students learn and to assess their learning) and their tie to accreditation outcome assessment distinguishes this set of tools from others reviewed here.

#### Human-Centered Design Task

Developed by Oakes, Cardella and others<sup>31</sup>, the Human-Centered Design Task has participants “complete a table of information needed and a timeline for a proposed process for completing a design task”<sup>31</sup>. The task requires only thirty minutes for participants to complete. Furthermore, the participants’ responses are entered into a one-page table, which increases the speed with which researchers can analyze the responses.

#### Design Process Knowledge Critique

Students completing the Design Process Knowledge Critique are presented with a proposed design process to complete a specific project<sup>25,34</sup>. This proposed process, frequently presented as a Gantt chart, has many good and many bad parts embedded in it. Students are given ten minutes to write a response to two questions “What is good about the proposed process and why?” and “What should be changed about the proposed process and why?”. A scoring rubric is used to rate student responses on seven design traits. For instance, researchers have looked to see if students notice that a proposed process jumps right into developing solutions without first defining the problem or talking with any stakeholders; if students do note this deficiency, then they get points on the rubric. A fully-trained rater can score a response in roughly one minute, thereby creating a design assessment tool that is time efficient while gathering less (but more focused) data than some of the other approaches reviewed here.

#### Design Ranking Task

The design ranking task has students select the six most important and the six least important design activities from a list given to the students. Students can complete this task in less than five minutes and scoring could be fully automated. Several authors have used this task or slight variations of it<sup>25,35</sup>.

Most of these approaches reviewed in this section are presented in more depth by Cardella, et al.<sup>31</sup>.

The main takeaway concerning design process assessment is that many diverse approaches exist, some of which are presented here, and that these approaches balance the trade-off between richness of data and time intensiveness differently. Most are broadly focused on engineering design process. None of the tools reviewed here are focused on explicit skills such as interface management or practical design skills like reading specification sheets, two learning objectives of the LEP. That said, many of the approaches – ethnography, VPA, critiquing a process, design ranking – could be altered in a way to highlight such specific skills.

### **Prior Assessment of LEP Students**

Due to the critical role of students’ preconceptions in the learning process, prior assessments focused on characterizing engineering students’ perceptions of the interdisciplinary process and interdisciplinary teams in the first year of their major coursework. These assessments included a

sample of both LEP and non-LEP students over the course of their sophomore year. The first, a four-phase mixed methods study, included an open-ended questionnaire aimed at exploring students' definitions of interdisciplinary projects and the relevant challenges<sup>36</sup>. The second phase of that study included a performance task and follow-up focus group, which examined a smaller sample of students' thought processes and perceptions as they interacted with an interdisciplinary engineering problem<sup>37</sup>. In the third phase, a survey was used to solicit quantitative data from a larger sample of students, focusing specifically on students' understanding of disciplinary grounding, integration, and the interdisciplinary process as a whole. Finally, grounded theory was used to interpret the results of the first three phases and develop a semi-structured interview protocol for the final phase<sup>38</sup>. The purpose of the interviews was to clarify the perceptions of the students and the conditions that gave rise to those perceptions<sup>14</sup>, by speaking with a small sample about their responses and experiences in the previous phases.

Results of this study indicated that the engineering students' preconceptions of interdisciplinary engineering projects emphasize a team of disciplinary specialists working together to find a solution. In particular, students identified the challenges faced by the team as more strongly rooted in the interdisciplinary project team dynamics than in the interdisciplinary process itself, which was viewed to have many benefits. Additionally, these perceptions were found to be directly influenced by students' previous team experiences, which in most cases were not interdisciplinary team experiences.

A second study focused on students' perceptions of their own leadership skills as well as the necessary leadership skills of a member of an interdisciplinary engineering team<sup>39,40</sup>. In this study a mixed methods approach integrated results from Bolman and Deal's Leadership Orientation Survey<sup>41</sup>, performance task-based focus groups, and individual interviews. Results demonstrated a difference in perceptions of how students define "leadership" based on gender. For interdisciplinary project team leaders, male students emphasized a leadership style based on directing work, running meetings, and overseeing project execution. The female students, however, recognized interdisciplinary leadership as facilitating collaboration among the team, being responsible, and contributing to the project's overall progress.

## **LEP Assessment Plan**

The purpose of the assessment is to see if and how the LEP has affected its participants. This plan seeks to meaningfully evaluate the progress of students on the LEP learning objectives by gaining access to the thought process of LEP students in relation to interdisciplinary thinking, capturing in real time the interactions of the LEP students with their peers and identifying noticeable differences in how the LEP students implement engineering design. The focus is not on student *perceptions* of what they know, but instead is primarily on how they actually apply their skills in authentic situations. This plan is written in such a way to be implementable over the course of one academic year and easily repeatable for future years.

The assessment plan consists of a three-phase strategy. During Phase 1, statistics will be collected that are baseline, easy to measure and repeatable in future years. Phase 2 will consist of interviews with faculty who advise LEP capstone projects (and therefore work for two semesters with LEP students on real world projects). These interviews are aimed at indirectly (via their capstone advisor) accessing students' design and interdisciplinary team skills in authentic

systems integration situations. This phase is designed to also be repeatable in future years. Phase 3 will consist of a performance activity for both LEP and non-LEP students. In Phase 3, researchers will directly observe students performing short design activities. This phase is not repeatable each year due to the time intensiveness of this phase.

Certain methods of data collection will not be used in this assessment plan because they do not match well with the objectives of this study or the small sample size (the LEP has between 12-20 students graduating each year). Those types of data collection methods include:

- Test-like closed-ended question:  
Because of their narrow focus, closed-ended (i.e., right/wrong) questions are challenged to capture information on complex skills like interdisciplinary teamwork or design. In addition, the sample size will be small and closed-ended questions are typically most useful in generating larger amounts of data that can be analyzed statistically.
- Surveys:  
The plan aims to access more than a student's own *perceptions* of what they would do in situations. In addition, the sample size is small and surveys are typically most useful in generating larger amounts of data that can be statistically analyzed.
- Interviews with students:  
As with surveys, interviews primarily gain access to a student's perceptions of their knowledge, not their ability to apply their knowledge in authentic situations.
- Ethnography  
Ethnography is too time intensive for inclusion in a plan with a goal of repeating the assessment each year.
- The design process critique (as discussed in the literature review):  
The design process critique works better with larger sample sizes and is not designed to assess the learning objectives of LEP in particular.

### Phase 1: Baseline Statistics

Phase 1 will consist of collecting baseline statistics on all LEP graduates to develop a profile of LEP graduates. These baseline statistics will be used as a method for understanding the success of LEP students prior to and after graduation and assess the distinct individuality (if it exists) of the LEP student in comparison to non-LEP students.

The statistics that will be collected include:

- A description of summer activities of each LEP graduate in the two prior summers
- Job or career plans upon graduation
- The number of post graduation offers (i.e. jobs, graduate programs, military, etc.)
- Final Grade Point Average and change in grade point average since joining the LEP
- The number of students receiving dean's list honors or academic probation
- The number and type of leadership positions held while at the university

### Phase 2: Interviews with Capstone Advisors

The Capstone is a two-semester real world project conducted during each engineering student's senior year, whether LEP or non-LEP. The objective of this phase is to gain access to LEP

students' performance on an authentic systems integration project. This access is available through the capstone advisor who meets regularly with the team, which may be composed of all LEP members or a mix of LEP and non-LEP members. By interviewing the capstone advisors, the researchers will have the opportunity to investigate noticeable differences in the LEP students' performance within their capstone groups. The idea is understand how LEP students interact on teams in relation to their peers and how this difference in interaction adds value to the overall effectiveness of the team and capstone experience.

An interview will be conducted with the capstone advisor at the end of the academic year. Types of questions to be asked include:

- Are there any notable differences between students on your team?
- How do LEP students function differently in their groups as opposed to other students not in the LEP?
- In terms of willingness to engage in doing and providing feedback to work not aligned with their own discipline/major, do you notice any differences between students on your team?
- Which students on your team are best at valuing and appreciating work done by team members not from their own discipline?
- Which students on your team are better at doing the specific detailed work associated with creating, analyzing, and implementing a solution? For example, for a project involving the creation of an information system, which students are the best at actually implementing a user interface for that system or creating the actual database?
- Which students on your team are better at determining recommendations/solutions for the capstone project (i.e., determining what to do, not actually implementing said solution)? For example, for a project involving the creation of an information system, which students are best at determining what the user interface will do and how this functionality will connect with other parts of the overall information system?

The questions asked will remain open ended enough not to lead to one specific answer while ultimately helping to assess the students' progress in relation to the established LEP objectives and identify differences between the LEP students and their peers.

### Phase 3: Performance Activity

The goal of the Phase 3 is to gain rich data from direct observations of students in an authentic systems integration and design activity. The activity draws from the perspective of Verbal Protocol Analysis in that student teams will be encouraged to talk aloud as they work through a design project; the students will be expected to actually make a physical prototype of their system in a three hour design session.

### Activity

The activity the students will participate in is an ECE/SYS integration focused mini-project where students will be asked to build a prototype within the three-hour timeframe. The scope of the project will include multiple options for hardware and software made available to the students for use. Each team will have to decide which hardware and software they will use to complete the task, as some components will be more appropriate or easier to use than others. For example, the students might be given multiple types of sensors, prototyping processor boards

(e.g., Arduino, phidgets), or software options (e.g., Labview, java) to implement into their designs. Multiple design problems are being considered for this performance activity, including:

- Newspaper Distribution Box Counting Systems: A daily student newspaper wants a device that they can attach to a distribution location and track when and how many papers are taken. The device needs to record in a database when newspapers are taken from a newspaper distribution box and to display the results in a useful way for the newspaper staff.
- Door Alarm: A dormitory needs to have an alarm put on a room that contains high voltage power equipment. The door is locked, but the danger in the room is so high that the administration has decided that an alarm would enhance safety. The device needs to sound an audible alarm as well as send an email or text message to key university personnel telling them when the door was opened.
- Piano Stairs: In an effort to get more people to use the stairs at a subway stop (and fewer to use the escalator), a design team was tasked with creating a system that played music when patrons progressed up the stairs (e.g., when you stepped onto the next step, a new note played).

Sample

The sample for this activity will include a set of 24 students divided into six teams. There will be two teams comprised of LEP students and two teams with non-LEP students. In addition, two teams will have two students from the LEP and two not from the LEP. Each team will be made up of two SYS students and two ECE students, randomly assigned. The overall research design is shown in Table 2.

**Table 2 Experimental Design for Sample of Twenty-Four Students**

<i>Team</i>	<b>LEP students</b>		<b>Non-LEP students</b>	
	<b>SE major</b>	<b>ECE major</b>	<b>SE major</b>	<b>ECE major</b>
<i>1</i>	2	2		
<i>2</i>	2	2		
<i>3</i>			2	2
<i>4</i>			2	2
<i>5</i>	2			2
<i>6</i>		2	2	

Data Collection

The activity will last no longer than 3 hours with a one-hour follow-up focus group to de-brief with the students. Students will be encouraged throughout to speak aloud to explain what they are doing and why. The entire session will also be video and audio recorded for future reference and analysis of data. Questions of interest to be asked to the focus group will include:

- If given the opportunity to redo this activity, would you do anything differently?
- How did your team go about dividing the work needed to be done for this activity?

- What was your team’s overall strategy for approaching this activity? Describe the process of how your team went about finding a solution.
- Do you feel like you were successful given the time and material constraints of the activity? How do you know?
- Who contributed the most to the project? Least? (asked individually and not as part of the focus group)

### Coding and analysis

Two researchers will independently watch the video data from the performance activity. Areas of interest will be identified for further analysis. The areas of interest will be transcribed and coded using open coding. While we will need to wait for the data to see which themes emerge, the two researchers will be guided by the following attention-focusing questions:

- What do the teams spend time on (identifying the problem, formulating the problem/getting information, developing ideas Prototyping and testing)?
- How do the students organize their team?
- How much do the students only do work within their own discipline?
- How do the students handle interfaces between subsystems?
- Do the students value the work of others from other disciplines?

The focus group recordings will be transcribed and coded using open coding. Grounded theory will be used to identify emergent themes from the focus groups and the video data.

### **Closure**

The LEP was designed to help bridge the gap between engineers working at the system level, envisioning new products or functions and engineers working at the component level, developing innovative components with desired attributes (reduced power consumption or fast switching time for example). All too often the two groups of engineers cannot achieve a full collaborative innovation without substantial prior experience. At the system level, the scope of the capabilities and limitations of the specific components is invisible. At the component level, innovations and optimizations may be misaligned with product needs. At the component level, engineers “push” technological advances; at the system level, engineers attempt to “pull” components to fill anticipated needs. This balance between “push” and “pull” is a delicate balance that is facilitated by extensive engineering experience. The LEP attempts to “jump start” this push/pull balance by encouraging students to analyze and design at multiple levels and in more than one discipline.

Gauging the success of the LEP towards this goal is a difficult process for several reasons: small numbers of participants, potential self-selection bias, and the difficulty in attributing observed desirable (and undesirable) outcomes to the educational experience. In this paper we described a proposed assessment process from which we expect to gain useful information that can help evaluate the success of the pilot LEP as well as provide suggestions for improvement.

## References

- [1] V. Boix Mansilla, E. D. Duraisingh, C. R. Wolfe, and C. Haynes, "Targeted Assessment Rubric: An Empirically Grounded Rubric for Interdisciplinary Writing," *Journal of Higher Education*, vol. 80, pp. 334-353, 2009.
- [2] R. Bailey, H. T. Rowan-Kenyon, A. Swan, M. Shoffner, and A. E. Coso, "Implementing an interdisciplinary engineering program – recruiting students, building courses, developing a community," in *American Society for Engineering Education Annual Conference*, Louisville, KY, 2010.
- [3] M. Borrego and L. K. Newswander, "Definitions of Interdisciplinary Research: Toward Graduate-Level Interdisciplinary Learning Outcomes," *The Review of Higher Education*, vol. 34, pp. 61-84, 2010.
- [4] C. Haynes and J. B. Leonard, "From Surprise Parties to Mapmaking: Undergraduate Journeys toward Interdisciplinary Understanding," *The Journal of Higher Education*, vol. 82, pp. 203-211, 2010.
- [5] Accreditation Board for Engineering and Technology, "Criteria for Accrediting Engineering Programs: 2009 - 2010," ed: ABET, Inc., 2008.
- [6] L. Bellamy, D. Evans, D. Linder, B. McNeill, and G. Raupp, "Teams in engineering education," *Report to the National Science Foundation on Grant Number USE9156176*, 1994.
- [7] C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering design thinking, teaching, and learning," *Journal of Engineering Education*, vol. 94, pp. 103-120, 2005.
- [8] D. L. Evans, G. C. Beakley, P. E. Crouch, and G. T. Yamaguchi, "Attributes of engineering graduates and their impact on curriculum design," *Journal of Engineering Education*, vol. 82, pp. 203-211, 1993.
- [9] J. T. Klein, "Interdisciplinary Teamwork: The Dynamics of Collaboration and Integration," in *Interdisciplinary Collaboration: An Emerging Cognitive Science*, S. J. Derry, M. A. Gernsbacher, and C. D. Schunn, Eds., ed: Mahwah: Lawrence Erlbaum Associates, Inc., 2005, pp. 23-50.
- [10] W. C. Morse, M. Nielsen-Pincus, J. E. Force, and J. D. Wulfhorst, "Bridges and Barriers to Developing and Conducting Interdisciplinary Graduate-Student Team Research," *Ecology and Society*, vol. 12, 2007.
- [11] D. Richter and M. C. Parette, "Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom," *European Journal of Engineering Education*, vol. 34, pp. 29-45, 2009.
- [12] D. Richter, M. C. Parette, L. D. McNair, and M. Borrego, "Assessing Student Perspectives of Interdisciplinary Collaboration," presented at the American Society for Engineering Education Annual Conference, Austin, TX, 2009.
- [13] J. Younglove-Webb, B. Gray, C. W. Abdalla, and A. P. Thurow, "The dynamics of multidisciplinary research teams in academia," *Review of Higher Education*, vol. 22, pp. 425-440, 1999.
- [14] A. E. Coso and R. Bailey, "The effect of previous team experiences on students' perceptions of interdisciplinary engineering problems," in *American Society for Engineering Education Annual Conference*, Vancouver, BC, 2011.

- [15] V. Boix-Mansilla and E. D. Duraisingh, "Targeted assessment of students' interdisciplinary work: An empirically grounded framework proposed," *The Journal of Higher Education*, vol. 78, pp. 215-237, 2007.
- [16] V. Boix-Mansilla, E. D. Duraisingh, C. R. Wolfe, and C. Haynes, "Targeted Assessment Rubric: An empirically grounded rubric for interdisciplinary writing," *The Journal of Higher Education*, vol. 80, pp. 334-353, 2009.
- [17] M. Borrego and S. Cutler, "Constructive alignment of interdisciplinary graduate curriculum in engineering and science: an analysis of successful igert proposals," *Journal of Engineering Education*, vol. 99, pp. 355-369, 2010.
- [18] R. Richards-Kortum, M. Dailey, and C. Harris, "Educational brief: Formative and summative assessment of the IGERT program in optical molecular bio-engineering at UT Austin," *Journal of Engineering Education*, vol. 92, pp. 345-350, 2003.
- [19] M. Borrego, C. B. Newswander, L. D. McNair, S. McGinnis, and M. C. Paretti, "Using concept maps to assess interdisciplinary integration of green engineering knowledge," *Advances in Engineering Education*, vol. 2, pp. 1-26, 2009.
- [20] F. Dochy, M. Segers, and D. Sluijsmans, "The use of self-, peer, and co-assessment in higher education: A review," *Studies in Higher Education*, vol. 24, 1999.
- [21] P. C. Powell, "Assessment of team-based projects in project-led education," *European Journal of Engineering Education*, vol. 29, 2004.
- [22] D. Richter, S. McGinnis, and M. Borrego, "Assessing and Improving a Multidisciplinary Environmental Life Cycle Analysis Course," presented at the American Society for Engineering Education Annual Conference, 2007.
- [23] B. M. Olds, B. M. Moskal, and R. L. Miller, "Assessment in Engineering Education: Evolution, Approaches, and Future Collaborations," *Journal of Engineering Education*, vol. 94, pp. 13-25, 2005.
- [24] G. Wiggins and J. McTighe, *Understanding by Design* 2nd ed. Alexandria, VA: Understanding by Design 2005.
- [25] R. Bailey, "A comparative study on undergraduate and practicing engineer knowledge of the roles of problem definition and idea generation in design," *International Journal of Engineering Education*, vol. 24, pp. 226-233, 2008.
- [26] W. C. Newstetter, "Of green monkeys and failed affordances: A case study of a mechanical engineering design course," *Research in Engineering Design*, vol. 10, pp. 118-128, 1998.
- [27] D. Vinck, *Everyday Engineering: An Ethnography of Design and Innovation*: MIT Press, 2009.
- [28] N. Cross, H. Christiaans, and K. Dorst, *Analysing design activity*. Chichester ; New York: Wiley, 1996.
- [29] C. J. Atman, J. R. Chimka, K. M. Bursic, and H. L. Nachtmann, "A comparison of freshman and senior engineering design processes " *Design Studies*, vol. 20, pp. 131-152, 1999.
- [30] C. J. Atman, R. S. Adams, M. E. Cardella, J. Turns, S. Mosborg, and J. J. Salemm, "Engineering Design Processes: A Comparison of Students and Expert Practitioners," *Journal of Engineering Education*, vol. 96, pp. 321-334, 2007.
- [31] M. Cardella, W. C. Oakes, C. Zoltowski, R. Adams, S. Purzer, C. J. Atman, J. Borgford-Parnell, R. Bailey, and D. Davis, "Special Session - Assessing student learning of engineering design " in *Frontiers in Education*, Rapid City, South Dakota, 2011.



- [32] D. Davis, S. Beyerlein, P. Thompson, J. McCormack, O. Harrison, and M. Treviasn, "Assessing Design and Reflective Practice in Capstone Engineering Design Courses," presented at the American Society for Engineering Education Annual Conference, Austin, TX, 2009.
- [33] D. C. Davis, K. L. Gentili, M. Treviasn, and D. E. Calkins, "Engineering Design Assessment Processes and Scoring Scales for Program Improvement and Accountability," *Journal of Engineering Education*, vol. 91, pp. 211-222, 2002.
- [34] R. Bailey and Z. Szabo, "Assessing engineering design process knowledge," *International Journal of Engineering Education*, vol. 22, pp. 508-518, 2006.
- [35] S. Mosborg, R. Adams, R. Kim, C. J. Atman, J. Turns, and M. Cardella, "Conceptions of the engineering design process: an expert study of advance practicing professionals," in *American Society for Engineering Education Annual Conference*, Portland, Oregon, 2005.
- [36] A. E. Coso and R. Bailey, "Examining students' perceptions of interdisciplinarity based on gender and disciplinary affiliation," in *American Society for Engineering Education Annual Conference*, Louisville, KY, 2010.
- [37] A. E. Coso, R. Bailey, and E. Minzenmayer, "How to approach an interdisciplinary engineering problem: characterizing undergraduate engineering students' perceptions," in *Frontiers In Education*, Washington, D.C., 2010.
- [38] A. L. Strauss and J. M. Corbin, *Basics of qualitative research : grounded theory procedures and techniques*. Newbury\*Phrk, Calif.: Sage Publications, 1990.
- [39] H. T. Rowan-Kenyon, A. E. Coso, A. K. Swan, R. Bailey, and M. Shoffner, "Students' Perceptions of Leadership on Interdisciplinary Engineering Teams," in *Association for the Study of Higher Education Annual Conference*, Indianapolis, IN, 2010.
- [40] H. Rowan-Kenyon, A. Coso, A. Swan, and R. Bailey, "The role of gender in student perceptions of leadership on interdisciplinary engineering teams," *Journal of Women and Minorities in Science and Engineering*, in press.
- [41] L. G. Bolman and T. E. Deal, "Leadership orientation instrument," ed. San Francisco: Jossey-Bass, 1990.