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Campus-wide Course Modification Program to Implement Active & Collaborative Learning and Problem-based Learning to Address the Entrepreneurial Mindset

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Abstract

While active and collaborative learning (ACL) and problem-based learning (PBL) have been effectively implemented at the college-level for many years, their widespread use in engineering education is a more recent development. Research has shown that ACL and PBL allow for higher critical thinking, reasoning, achievement, and retention in students. In addition, because ACL and PBL typically require teamwork, communication, and tolerance for ambiguity among other aspects, they are also an ideal vehicle for instilling the attributes of the entrepreneurial mindset in students.

Lawrence Technological University implemented a six year process to modify 75% of the courses in the engineering curriculum to include ACL and PBL. Besides traditional engineering courses, such as statics and design, the modified courses include those in our general education core curriculum, such as calculus, history, literature, communication, and the sciences. As such, this course modification process involves more than 50 faculty members from multiple departments and colleges. The process entails intensive week-long workshops, report-back accountability sessions, closing-the-loop sessions, support teams of faculty from related content areas, coordinators, peer-reviewers, and a leadership team of university administrators, faculty and staff.

This paper will explain the reason and objectives for the course modifications and will detail the process to modify many diverse courses including faculty evaluation of the program. The paper will discuss the impact that the course modifications have had on the university as a whole. Finally, the paper will present assessment results of pre- and post-course surveys of student perceptions of the use of ACL and PBL to apply attributes of the entrepreneurial mindset. The surveys demonstrate a positive shift in perceptions.

1. Introduction

Lawrence Technological University has offered engineering students entrepreneurial education programs for many years. Recognizing that graduates entering industry will require business and entrepreneurial skills, the College of Engineering developed an entrepreneurial certificate program and founded the Lear Entrepreneurial Center. The entrepreneurial certificate program develops student skills in communication and business components in the engineering profession and includes a multi-disciplinary capstone design experience for which teams are eligible for student venture grants administered by the institution. Several multi-year grants have strengthened the program through workshops, keynote speakers, faculty curriculum awards, student venture grants, and faculty incentives to work with industry sponsored student teams. Specifically, the College of Engineering received an invitation to participate as part of a larger initiative to develop the Kern Entrepreneurship Education Network (KEEN). The invitation also provided funding to develop and integrate entrepreneurial education across the curriculum. The network is limited to private institutions with ABET accredited engineering programs and is by invitation only.

The goal of KEEN is to make entrepreneurship education opportunities widely available at institutions of higher learning, and to instill an action-oriented entrepreneurial mindset in engineering, science, and technical undergraduates. The skills associated with the entrepreneurial mindset are communication, teamwork, leadership, ethics and ethical decision-making, opportunity recognition, persistence, creativity, innovation, tolerance for ambiguity, risk analysis, creative problem solving, critical thinking, and business skills (including marketing, financial analysis, and strategic planning).[1, 2, 3, 4, 5] KEEN has specifically outlined seven student outcomes pertaining to the entrepreneurial mindset.[6] A student should be able to:

1. Effectively collaborate in a team setting (teamwork)
2. Apply critical and creative thinking to ambiguous problems (problem solving)
3. Construct and effectively communicate a customer-appropriate value proposition (customer awareness)
4. Persist through and learn from failure to learn what is needed to succeed (persistence)
5. Effectively manage projects and apply the commercialization process within respective disciplines (project management)
6. Demonstrate voluntary social responsibility (social responsibility)
7. Relate personal liberties and free enterprise to entrepreneurship (free enterprise)

As of March 2013, KEEN includes nineteen institutions across the U.S. The KEEN program provides access to vital resources for building quality entrepreneurship education programs that engage engineering and technical students including grants, faculty fellowships, capacity building workshops, networking opportunities, and resources. More specifically, KEEN provides financial and developmental resources to grantee institutions for the development of entrepreneurship curricula, modules, and extracurricular activities like business plan competitions, speaker series, student entrepreneurship clubs, and seminars.

2. ACL, PBL, and the Entrepreneurial Mindset

Active learning has been defined as any instructional activity that engages students. Collaborative learning is a pedagogical technique where students work in small groups to reach a common goal.[7, 8] Cooperative learning is similar to collaborative learning, but the student groups are more structured in the former (among other subtle differences).[9] For the course modification program at Lawrence Tech, faculty are implementing both formal (cooperative) and informal (collaborative) techniques into their courses. For implementation at Lawrence Tech, these pedagogical techniques are collectively referred to as Active and Collaborative Learning (ACL). The literature suggests that ACL is highly effective at improving student learning outcomes if properly implemented.[8, 9, 10, 11] In an analysis of over 300 experimental studies over a 75 year span, ACL was found to have multiple beneficial outcomes.[12] These include higher achievement and retention of material, critical thinking and higher-level reasoning, differentiated views of others, accurate understanding of others' perspectives, liking for classmates and teachers, liking for subject areas, and teamwork skills. These outcomes are highly general and have been shown to apply to postsecondary STEM education where the main effect of small group (predominantly cooperative) learning on achievement, persistence, and attitudes was significant and positive.[13]

While it is clear that some of the attributes of the entrepreneurial mindset are present in the outcomes of ACL (e.g., teamwork, critical thinking), the outcomes can also be mapped to three of the seven KEEN student outcomes as shown in Table 1.

Table 1. Mapping ACL Outcomes to the Entrepreneurial Mindset (i.e., KEEN Student Outcomes).

ACL Outcome	KEEN Outcome
Critical thinking and higher-level reasoning	Apply critical and creative thinking to ambiguous problems
Differentiated views of others	Social responsibility
Accurate understanding of others' perspectives	Social responsibility
Teamwork skills	Effectively collaborate in a team setting

ACL includes many various techniques some of which will be listed and categorized in the following section. Problem-based learning (PBL) is considered one of those ACL techniques, although highly-formalized and often extensive in scope and scale. "The principal idea behind PBL is that the starting point for learning should be a problem, a query, or a puzzle that the learner wishes to solve."[14] PBL often uses less-formal/shorter ACL techniques as part of the overall process and typically have the following common features:

- Learning is initiated by a problem.
- Problems are based on complex, real-world situations (and usually open-ended).
- All information needed to solve problem is not given initially (i.e., ill-defined).
- Students identify, find, and use appropriate resources. (Therefore along with the previous point, it is common that the elements of the problem are "scaffolded," "staged," or "progressively disclosed.")
- Students work in permanent groups.
- Learning is active, integrated, cumulative, and connected.
- Students report solutions.[15]

In PBL, the problem is the organizing focus and stimulus for learning. Since new information is acquired through self-directed learning, the teacher acts as a facilitator or guide. The common features of PBL can be mapped to the attributes of the entrepreneurial mindset as shown in Table 2.

Table 2. Mapping PBL Features to the Entrepreneurial Mindset.

PBL Feature	Entrepreneurial Mindset Attribute(s)
Open-ended, real world problem	tolerance for ambiguity
Ill-defined	tolerance for ambiguity
Students identify, find, and use appropriate resources	opportunity recognition persistence creativity innovation creative problem solving critical thinking

Students work in groups	teamwork
Learning is active, integrated, cumulative, and connected	teamwork
Students report solutions	communication

3. The Course Modification Process

Because of the need to instill the entrepreneurial mindset in engineering students, Lawrence Tech began a comprehensive transformation of the engineering curriculum in 2009. Based on the evidence presented in the previous section, ACL and PBL were chosen as the primary pedagogical techniques used for course modification. As an additional pedagogical technique, faculty are also trained on group/team dynamics, team formation and composition, and other elements of effective teamwork, but are not required to uniformly adopt a specified team size, etc. This allowed for flexibility for individual course needs and instructor desires. Over a six year period faculty will modify at least 75% of the courses in the engineering curriculum. Of course the engineering curriculum does not consist of purely engineering courses; the curriculum also includes general education core curriculum courses such as those in history, literature, communication, the natural sciences, and mathematics. As such, this course modification process involves more than 50 faculty members from multiple departments and colleges.

The course modification process is directed by the Course Modification Team which consists of the Provost, the Deans of the College of Engineering, the Deans of the College of Arts and Sciences, the Director of the Center for Teaching and Learning, the (former) Director of Assessment, the Entrepreneurship Programs Coordinator, and a faculty member to serve as team chair.

Each year, the Course Modification Team identifies key courses (i.e., typically required courses well suited for the entrepreneurial mindset) within the engineering curricula and then the deans invite instructors of those courses to participate. During the first year of course modification, most of the courses selected were within the first year of the engineering curricula. (Lawrence Tech's College of Engineering offers undergraduate degrees in Architectural, Biomedical, Civil, Computer, Electrical, Industrial Operations, Mechanical, and Robotics Engineering as well as Construction Management and Engineering Technology.) By the second year, sophomore courses emerged on the list of courses for modification. With the many various discipline-specific courses that are required during the junior and senior years, four additional years of course modification are necessary.

Faculty members in the course modification program are designated as Kern Innovative Teaching (KIT) faculty and represent a horizontal dense network (or cohort) of collaborating faculty. Each academic year, approximately 15 faculty members are invited to join the KIT faculty, and each faculty member is assigned one course to modify. A small stipend and course release time is offered over a two-year period as an incentive for faculty to join the program and to provide them resources necessary to make the proper modifications to their courses. The first four cohorts (KIT 1 through 4) are shown in Table 3. KIT 5 is currently being formed. Also noted on the table are content groupings. Faculty members were grouped together by course content, and these groupings serve as a mechanism for intellectual and emotional support.

Because course modification of this type requires a change in instructional techniques as well as development of new content, these content groups are considered critical to the success of the program. Not only do the faculty in each of these groups work together during workshops (brainstorming and bouncing ideas off each other), they also meet regularly throughout the semesters to refine course content and share successes.

Table 3. Course modification list by content grouping as of January 2013.

Content Grouping	Faculty member	course(s)	KIT
First Year Engineering	Don Carpenter	ECE 1012 Civil Engineering Perspectives	1
	Andy Gerhart	EGE 1012 Introduction to Engineering	1
	Laura Lisiecki	EGE 1023 Engineering Materials	4
	Jerry Cuper	TME 1023 Technical Graphics	4
	Eric Meyer	BME 1002 Intro to BioMed Eng	3
	Filza Walters	EAE 1081 Intro to Arch Eng	3
Chemistry	Bill Madden	CHM 1213 Unversity Chemistry 1	1
	Nicole Villeneuve	CHM 1213 Unversity Chemistry 1	1
Physics	Scott Schneider	PHY 2413/2423 University Physics 1 and 2	1
	Changgong Zhou	PHY 2413/2423 University Physics 1 and 2	1
Biology	Jeff Morrissette	BME 2203 Anatomy and Physiology	2
	Julie Zweisler-Vollick	BIO 1213 Biology	2
Early Calculus	Chris Cartwright	MCS 1414/1424 Calculus 1 and 2	1
	Guang-Chong Zhu	MCS 1414/1424 Calculus 1 and 2	1
Later Calculus	Mike Merscher	MCS 2414/2423 Calculus 3 and Differential Equations	2
	Glen Bauer	MCS 2414/2423 Calculus 3 and Differential Equations	2
	David Bindschadler	MCS 2414/2423 Calculus 3 and Differential Equations	2
	Sonia Henckel	MCS 2414/2423 Calculus 3 and Differential Equations	2
Economics	Richard Dengate	SSC 2303 Principles of Economics	1
	Karen Evans	Economics support and management courses	2
	Kingman Yee	EGE 3012 Engineering Cost Analysis	4
Humanities, Communications, Management	Rachel Azima	LLT 1213/1223 World Masterpieces 1 and 2	2
	Melinda Phillips	LLT 1213/1223 World Masterpieces 1 and 2	2
	Margaret Hadley	LLT 1213/1223 World Masterpieces 1 and 2	2
	Holly Helterhoff	COM 2103 Tech and Prof. Comm.	4
	Jason Barrett	new Ethics course and/or SSC 2423 Dev. of Am. Exp.	4
	John Tocco	ECE 4243 CE Management Practices (helping with Ethics)	3
Solid Mechanics	Patricia Shamamy	EGE 2013 Statics	2
	Chris Riedel	EGE 2013 Statics (Also Materials)	2
	Giscard Kfoury	EME 3013 Mechanics of Material (also Statics)	2
	Heidi Morano	EME 3013 Mechanics of Material	2
	Keith Kowalkowski	ECE 3723 Theory of Structures	3
Electrical	Nick Zorka	Electronics and Computer Applications	2
	Lisa Anneberg	EEE 3223 Advanced Digital Electronics	4
	Umasankar Kandaswamy	EEE 3314 Electronics	4
	Kun Hua	EEE 4423 Communication Systems	3
	James O'Connor	TEE 3103 DC/AC Circuits	4
Thermo-Fluids	Robert Fletcher	EGE 3903 Alt. Energy Fundamentals	4

Thermo-Fluids (continued)	Lew Frasch	EGE 3003 Thermodynamics	3
	Selin Arslan	EGE 3003 Thermodynamics	3
	Yawen Li	BME 3703 Biotransport	4
	Edmund Yuen	ECE 3523 Hydromechanics	4
	Liping Liu	EME 3123 Fluid Mechanics	3
Manufacturing and Numerical Methods	Sabah Abro	TME 3333 Six Sigma 1	4
	Ahad Ali	EME 3023 Manufacturing Processes	3
	Vernon Fernandez	EME 3033 Engr. Numerical Methods	3

The KIT training process requires a two-year commitment involving week-long workshops, ACL/PBL implementation, report-back accountability sessions, and closing-the-loop sessions. Because of the commitment, almost all of the faculty members in the KIT program are full-time, although a few trusted adjunct instructors have also been selected to participate. Currently 56 faculty members have been trained in PBL and ACL techniques representing approximately 46 courses. (Table 3 reflects a lower number of KIT faculty; some faculty are no longer with the university while other faculty were invited guests from other KEEN institutions.)

Faculty members learn strategies for course improvement through two types of workshops: a one-day entrepreneurial mindset workshop followed by a one-week theme workshop. The theme workshop alternates each year between problem-based learning and active and collaborative learning techniques. As noted earlier, PBL reinforces the critical thinking/problem solving component of the entrepreneurial mindset, and ACL reinforces teamwork, communication, and further critical thinking skills. Both techniques are frequently coupled with other elements of the entrepreneurial mindset including customer awareness, social responsibility, project management, and business topics.

A new KIT cohort is selected each Spring semester. A contract is created for each invited KIT faculty member which notes the responsibilities as well as the compensation (stipend and course release time). Each May, the KIT group begins training at the one-day entrepreneurial mindset workshop as indicated in Table 4. This workshop involves an overview of the objectives and outcomes of entrepreneurial mindset education as well as invited speakers from various institutions and corporations. The workshop is interactive, and typically faculty members create small-scale learning modules to incorporate into class sessions. A week later, the KIT faculty begin an intensive theme workshop. Because only one of the two major techniques is taught each year (ACL or PBL), there are always two KIT cohorts overlapping (e.g., KIT 3 and 4 were trained together last year, KIT 4 and 5 will train together this year). The theme workshops do not only teach the faculty members about PBL or ACL; the workshops are a "deep dive" into PBL and ACL. The research and literature is reviewed, past successes are explained and examined, and development time is allotted with real-time feedback and critiques. By the end of the week, each faculty member will create a couple of ACLs or PBLs, and present them to their peers and workshop facilitators. After receiving feedback, the faculty member will have time over the summer to refine their ACL/PBL modules and create more for the upcoming academic year.

There is naturally some faculty resistance to incorporating these techniques to their full potential, especially from those faculty that have spent their entire careers using a traditional lecture style. For this reason, it is critical that the workshop allots time to discuss and solve the potential difficulties (for students and faculty alike) of incorporating a new pedagogical technique. It is important to remind the faculty that there is still a place for lecture; a wholesale course modification is not necessary or practical. Another crucial element of the theme workshops is for the participants to experience a variety of PBLs and ACLs (wherein the KIT faculty are playing the part of a student). Through these experiences, reluctant faculty members are often convinced of the impact for student learning as well as sparking ideas for ACL/PBLs of their own.

For the first PBL workshop and then the following year for the first ACL workshop, Lawrence Tech brought in experts to facilitate the workshops. Mark Serva and Richard Donham from the University of Delaware facilitated the PBL workshop, while Karl Smith from the University of Minnesota and Purdue facilitated the ACL workshop. The advantage of the incremental KIT training program is that it produces trained faculty for subsequent cohorts. By the third year, Lawrence Tech faculty began facilitating the workshops (with such success that they are now being invited to facilitate PBL and ACL workshops at other institutions).

At the end of August, just before the start of the academic year, the KIT faculty gather for a follow-up meeting. Each faculty member presents the ACL/PBLs to be deployed. This follow-up meeting serves three major purposes. First any PBL/ACL refined since the May workshop can be presented. Second, any newly developed ACL/PBL can be critiqued. Finally, the meeting ensures accountability. The best plan is to prepare for the course during the quieter summer, than to try to develop classroom content "on-the-fly" during the hectic Fall/Spring semester.

In late April, just as the Spring semester is drawing to a close, the KIT faculty meet again for a close-the-loop session. Two artifacts are required at this meeting. The first is the "deployment" documents. This includes a completed standardized form that details each ACL/PBL as well as any support documents (e.g., classroom hand-outs, grading rubrics). Any instructor familiar with ACL/PBL should be able to use this documentation for deployment without any verbal instruction. The second artifact required is a "plus/delta" presentation, which allows for personal reflection for improvement as well as formal program evaluation.[16] In the plus/delta format, course instructors discuss the "plus" or positive aspects they experienced as part of the course modification process and the "deltas" or items they would recommend improving. Improvements could be suggestions for the course modification program or specific to their course.

By May, the process repeats with a new entrepreneurial mindset workshop and the alternate theme workshop (e.g., a PBL workshop if ACL was the previous year's focus). If the faculty member is at the end of his/her two year cycle, he/she is then officially done with the formal training, although it is hoped he/she will continue to use and/or develop more ACL/PBL classroom material. Often the veteran KIT faculty are called upon to help with training or to present at conferences. As such, an additional benefit to the KIT program is the ability to contribute to the scholarship of teaching and learning within that faculty member's specific discipline (whether in journals or at conferences). Samples of the types of PBL problems (some integrated with ACL techniques) are provided in Table 5.

Table 4. Course Modification Process Timeline. (KIT 5 and the timeline following 2013 are not shown.)

Year	Term	KIT 1	KIT 2	KIT 3	KIT 4
2009	May	E-Mindset Workshop PBL Workshop Modify course			
	Aug	Follow-up Meeting			
	Fall	Teach			
2010	Spring	Teach			
	April	Close-the-loop meeting			
	May	E-Mindset Workshop ACL workshop Modify course	E-Mindset Workshop ACL Workshop Modify course		
	Aug	Follow-up Meeting	Follow-up Meeting		
	Fall	Teach	Teach		
2011	Spring	Teach	Teach		
	April	Close-the-loop meeting	Close-the-loop meeting		
	May	Select KIT 1 Faculty will facilitate PBL Workshop	E-Mindset Workshop PBL workshop Modify course	E-Mindset Workshop PBL Workshop Modify course	
	Aug		Follow-up Meeting	Follow-up Meeting	
	Fall		Teach	Teach	
2012	Spring		Teach	Teach	
	April		Close-the-loop meeting	Close-the-loop meeting	
	May		Select KIT 1 and 2 Faculty will facilitate ACL Workshop	E-Mindset Workshop ACL workshop Modify course	E-Mindset Workshop ACL workshop Modify courses
	Aug			Follow-up Meeting	Follow-up Meeting
	Fall			Teach	Teach
2013	Spring			Teach	Teach
	April			Close-the-loop meeting	Close-the-loop meeting
	May			Select KIT 1, 2, and 3 Faculty will facilitate PBL Workshop	E-Mindset Workshop PBL workshop Modify courses
	Aug				Follow-up Meeting
	Fall				Teach
Etc.					Continued

Table 5: Sample of PBL problems introduced into modified courses.

Course	Level	PBL Title	Description
Courses in the College of Engineering			
EGE 1012 Intro to Engineering	Freshman	Egghead to the Czars	Students design, build, and test a travel package for Faberge eggs to meet the logistical needs of a client.
ECE 1012 Civil Engineering Perspectives	Freshman	Materials Storage	Students complete a simulated Request for Proposals (RFP) process as they design a materials storage facility based on the needs of a municipal client.
ECE 1012 Civil Engineering Perspectives; EGE 1012 Intro to Engineering	Freshman	Solar Oven	Students develop a solution to address world poverty and health through the design/build/test of a solar oven and apply for implementation funding.
ECE 3213 Soil Mechanics	Junior	Levee Leakage	Students investigate the issue of seepage problems of levees using the concept of hydraulic conductivity.
Courses in the College of Arts & Sciences			
SSC 2203 Economics	Sophomore	Smoking Incentives	Students investigate the effectiveness of the cigarette tax as a disincentive to consume tobacco.
SSC 2203 Economics	Sophomore	North Korea Resource Allocation	Students learn how to reduce nuclear capabilities and increase domestic production of food.
CHM 2123	Sophomore	Dying for a Breath of Fresh Air	Students learn stoichiometry as they design a cartridge that will serve as a safety breathing apparatus.
PHY 2413 Physics 1	Sophomore	Movie Magic - Possible or Impossible	Students evaluate if a collision in a film is possible or impossible using the fundamental laws of physics
PHY 2423 Physics2	Sophomore	Cell Phone Testing Lab	Students test how accurately the cell phone can deliver sound in different acceleration conditions based on customer needs.

As previously mentioned, ACL includes many techniques. For the purposes of the ACL workshop and KIT faculty training, only the more popular techniques are included. These techniques are divided by scale/scope and level of impact. Table 6 indicates the ACL techniques and their subdivision.

Table 6: Active and Collaborative Learning techniques and their associated "level" at Lawrence Tech

Level 1 – easiest, substantial-impact, low-effort
Think Pair Share
Think Pair Write Share
Muddiest Point
Random Calling
Formulate – Share – Listen – Create
Minute Paper
Level 2 – more prep time, medium effort

IF*AT (immediate feedback readiness test)
IRAT/GRAT (individual/group readiness assessment test)
Quick Thinks
Level 3 – even more prep, restructuring of class time, can be deep impact
Jigsaw
Cooperative Base Pairs
Gallery Walk
Constructive Subject-related Debate/Controversy
Peer composition/editing

4. Assessment

A variety of assessments are in progress concerning the course modification program, and they pertain to both student learning and program evaluation. Student learning is being assessed using a combination of indirect and direct assessment techniques. Indirect assessment consists of pre-and post-tests completed by students enrolled in a modified course. Direct assessment consists of the application of a rubric implemented by faculty. Direct assessment results will not be reported in this paper as select details are available in reference 4. The program is being evaluated using the aforementioned annual close-the-loop (plus/delta) sessions and faculty surveys.

4.1. Indirect Assessment Methodology and Demographics

Three different versions of a survey were developed to assess students' perceptions of course modifications depending on which course students were enrolled. The PBL survey contains 16 questions to gauge students' adeptness with approaching entrepreneurial problems, including their ability to recognize problems, obtain information from a variety of sources, and likelihood of collaborating with others. The PBL version was administered during the 2009-2010 academic year in KIT 1 courses, and the 2011-2012 academic year in KIT 3 courses. The second version of the survey, including only ACL questions, was administered in 2010-2011 academic year in KIT 2 courses and the 2012-2013 academic year in KIT 4 courses. The ACL instrument contains 10 questions that attempt to gauge students' interest in and propensity to engage others in collaboration, understand others, and seek information from a variety of sources. The third version contains 18 questions common to the other two versions and was administered each semester since Fall 2010 in courses that included both ACL and PBL concepts (2^{nd} year of implementation for KIT 1, KIT 2 and currently KIT 3 courses). Much of the data is still being collected and analyzed, so only preliminary results will be reported here.

In all three versions of the survey, questions were written in the form of statements and students were asked their level of agreement on a five point Likert-type scale between 1 (strongly disagree) and 5 (strongly agree). Statements were written based on program objectives and include questions from other validated and implemented assessment tools used on campus including the Teamwork Evaluation Survey[17] and the Leadership Self-Perception Assessment Instrument[3]. Table 7 lists all 18 questions and their relationship to elements of the entrepreneurial mindset. A majority of statements are related to teamwork and problem solving.

While other elements of the entrepreneurial mindset are included in course modifications, the survey was developed to be uniformly administered in all courses and therefore focused more on common elements.

Table 7: Relationship of pre- and post-test statements with entrepreneurial mindset.

	Statement	Entrepreneurial Mindset Element
1	I am able to recognize problems that exist.	Problem Solving, Ambiguity
2	When confronting a new problem, I am good at devising many possible solutions.	Problem Solving
3	When solving a problem, I tend to try just one solution.	Problem Solving, Persistence
4	I get discouraged when my solution fails.	Persistence
5	I am able to identify information relevant to the problem.	Problem Solving, Ambiguity
6	I ask relevant questions to clarify situations and gain new knowledge.	Problem Solving
7	I am able to independently gain new information from various sources.	Problem Solving
8	I produce quality work in terms of thoroughness, neatness and accuracy.	All
9	I accept responsibility for my actions and the work I produce.	Teamwork
10	I am a creative person.	Problem Solving
11	I understand and identify with the feelings, experiences, and motives of others.	Teamwork
12	I can list attributes associated with the entrepreneurial mindset.	All
13	I see how problem identification and solving builds entrepreneurial skills.	Problem Solving
14	I collaborate well with others to develop appropriate solutions to problems.	Teamwork, Problem Solving, Customer Awareness
15	I develop and maintain good interpersonal relationships with team members.	Teamwork
16	I contribute an equal share in team based activities.	Teamwork
17	It is clear to me that working on teams is critical to my education.	Teamwork
18	It is clear to me that teamwork skills are crucial in my future profession.	Teamwork

Each survey is administered online through Blackboard™ course management software and takes a few minutes to complete. Faculty have the option of setting aside class time for students to electronically access and complete the survey or instructing students to complete the survey out-of-class. The survey is administered once at the beginning of the semester (pre-test) and again at the end of the semester (post-test) to gauge improvement in the entrepreneurial mindset. In the past, some class-level attrition had occurred in a few cases and the post-test was not uniformly administered as a couple of faculty opted out of the program.

Paired and unpaired t-tests were conducted on statements to determine statistical significance of difference in means. Results were analyzed for each individual course with some courses indicating a larger effect on student responses than others. While a detailed analysis of this data is beyond the scope of this paper, a brief discussion of results is included to show that the survey is being successfully implemented.

To date, the investigation consists of fourteen administrations of a survey from the fall semester of 2009 to the spring semester of 2013 as shown in Table 8. (Note that much data is still being processed.)

Table 8: Survey Administration Summary

Administration	Survey	Semester	Student Responses (Pre)	Student Responses (Post)
1	PBL (v.1)	Fall 2009	241	144
2	PBL (v.1)	Spring 2010	154	130
3	ACL (v.2)	Fall 2010	178	148
4	ACL + PBL (v.3)	Fall 2010	309	223
5	ACL (v.2)	Spring 2011	271	141
6	ACL + PBL (v.3)	Spring 2011	147	106
7	PBL (v.1)	Fall 2011	N/A	N/A
8	ACL + PBL (v.3)	Fall 2011	N/A	N/A
9	PBL (v.1)	Spring 2012	N/A	N/A
10	ACL + PBL (v.3)	Spring 2012	N/A	N/A
11	ACL (v.2)	Fall 2012	N/A	N/A
12	ACL + PBL (v.3)	Fall 2012	N/A	N/A
13	ACL (v.2)	Spring 2013	N/A	N/A
14	ACL + PBL (v.3)	Spring 2013	N/A	N/A

Many students were enrolled in more than one modified course indicating that more surveys were completed than the number of unique students. Within the first two years of program, some students experienced as many as 8 or 9 different modified courses! Of course, as the students continue into their junior and senior years, they will experience even more (currently up to 12). Table 9 lists the number of unique students participating in at least one modified course. Figure 1 shows the aggregate modified course experiences. In accordance with the phased-in approach, a majority of students involved in modified courses have been either freshmen or sophomores (Figure 2). As the program matures, a higher number of junior and senior courses will be included in the course modification process.

Table 9: Number of students who have experienced a modified course.

Semester	Unique Student Count
Fall 2009	228
Spring 2010	116
Fall 2010	405
Spring 2011	419
Fall 2011	469
Spring 2012	386

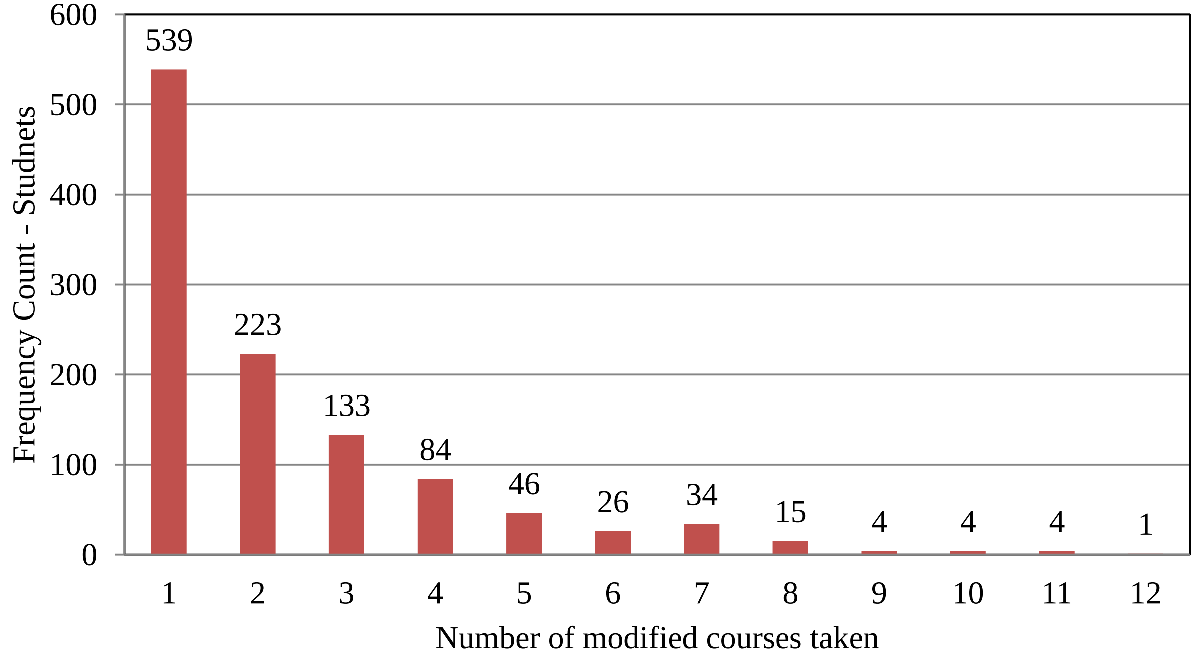

Figure 1. Aggregate modified course experiences from Fall 2009 through Spring 2012. (n = 1113 unique students)

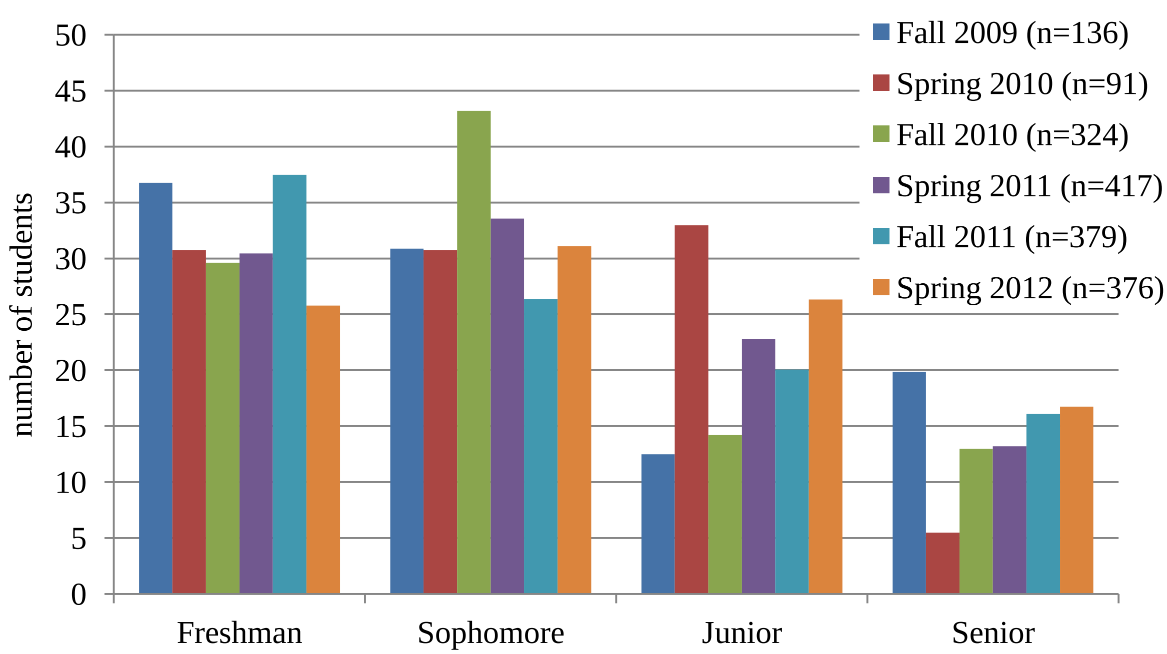

Figure 2. Number of student participants by grade level classification from Fall 2009 through Spring 2012.

Figure 3 shows that 61% of the students that have completed at least one modified course majored in engineering with the remaining students majoring in one of the other three colleges at Lawrence Tech (Arts & Sciences, Architecture, and Management). Of the 61% in engineering, there was an expected distribution of majors (Figure 4) when considering enrollment within each program with mechanical engineering being the largest engineering program on campus and the highest represented in student participants. Note that 79% of the survey respondents were male, which is not uncharacteristic considering the college's gender ratio.

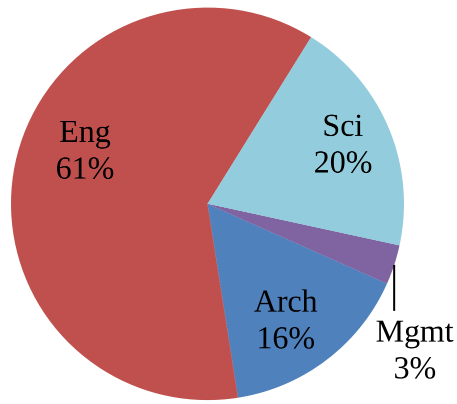

Figure 3. Student participation percentage by college from Fall 2009 through Spring 2012

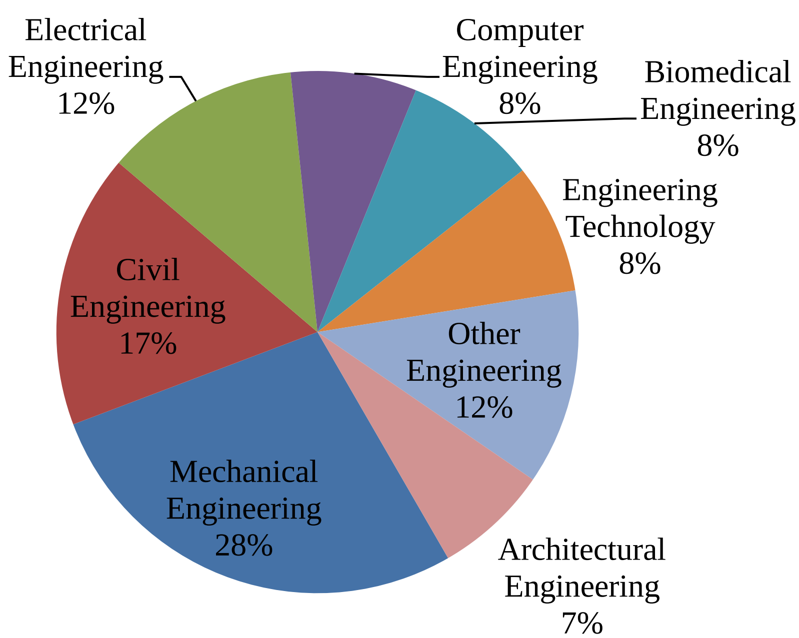

Figure 4. Student participation percentage by engineering major from Fall 2009 through Spring 2012

4.2. Indirect Assessment Analysis

To assess change in student perceptions, paired and unpaired t-tests were performed to compare mean responses at pre- and post-test. Unpaired t-test results were included because of the large number of unpaired responses (only 666 unique pairs out of 1526 total responses). With one exception, only the paired t-test results are presented here. To date, only data from the first two academic years has been processed. Results are presented by survey version with each version having two administrations (one per academic semester). Detailed results are available in reference 7, so only a summary will be presented here.

4.2.1. Problem-Based Learning (PBL) Survey: Fall 2009 and Spring 2010

Highly significant ($p < .01$), positive differences were found in paired t-tests of the following statements in the fall 2009 administration:

- 2 When confronting a new problem, I am good at devising many possible solutions. (paired spring 2010, unpaired fall 2009)
- 5 I am able to identify information relevant to the problem. (fall 2009)
- 7 I am able to independently gain new information from various sources. (fall 2009)
- 10 I am a creative person. (fall 2009)
- 12 I can list attributes associated with the entrepreneurial mindset. (fall 2009)
- 13 I see how problem identification and solving builds entrepreneurial skills. (fall 2009)

In general, students participating in PBL courses perceived higher confidence for identifying and gathering information related to a problem as well as devising multiple solutions. They were also capable of relating PBL to the entrepreneurial mindset. The spring semester saw fewer highly significant gains than the fall semester, but fewer courses and student responses likely played a role at the data exhibiting significance at the $p < 0.05$ level instead of higher levels.

4.2.2. Active and Collaborative Learning (ACL) Survey: Fall 2010 and Spring 2011

Highly significant ($p < .01$) positive differences were found in paired t-tests of responses to the following questions in the fall 2010 and spring 2011 administrations:

- 3 I am a creative person. (fall 2010)
- 5 I can list attributes associated with the entrepreneurial mindset. (spring 2011)
- 6 I collaborate well with others to develop appropriate solutions to problems. (fall 2010)
- 7 I develop and maintain good interpersonal relationships with team members. (fall 2010)
- 9 It is clear to me that working on teams is critical to my education. (fall 2010)

Student responses indicate that they felt improvement in their ability to collaborate with others to develop appropriate solutions to problems. They also reported better ability to maintain good relationships and understood that working on a team is appropriate when developing solutions. This is likely because of the formal and informal types of ACL exercises introduced into the course and the emphasis faculty place on team process and progress and not just final team deliverables. As with the analysis in section 4.2.1, fewer gains were seen in the spring administration.

4.2.3. ACL + PBL Survey: Fall 2010 and Spring 2011

Highly significant ($p < .01$) positive differences were found in paired t-tests of responses to the following questions in the fall 2010 and spring 2011 administrations:

1 I am able to recognize problems that exist. (fall 2010)
2 When confronting a new problem, I am good at devising many possible solutions. (fall 2010)
5 I am able to identify information relevant to the problem. (fall 2010)
6 I ask relevant questions to clarify situations and gain new knowledge. (spring 2011)
7 I am able to independently gain new information from various sources. (fall 2010)
8 I produce quality work in terms of thoroughness, neatness and accuracy. (fall 2010)
10 I am a creative person. (fall 2010)
11 I understand and identify with the feelings, experiences, and motives of others. (fall 2010)
12 I can list attributes associated with the entrepreneurial mindset. (fall 2010 and spring 2011)
13 I see how problem identification and solving builds entrepreneurial skills. (fall 2010)
14 I collaborate well with others to develop appropriate solutions to problems. (fall 2010)
15 I develop and maintain good interpersonal relationships with team members. (fall 2010)

The combination of ACL and PBL exercises saw the greatest expansion in the students' perception of their entrepreneurial mindset, with a majority of questions seeing significant student gains. There are two factors that likely contribute to these gains. The first is the inclusion of both ACL and PBL exercises which would reinforce student outcomes. The second is the maturation of the faculty teaching the courses since this administration represents the second year for the KIT 1 faculty who would improve on their techniques from year one. These results document the improvement of the faculty to deliver the program as well as student improvement.

4.3. Program evaluation

Formal program evaluation is being conducted by analyzing mandatory peer reporting (close-the-loop) sessions that uses the "plus/delta" format and through an online survey of KIT 1 faculty regarding their impression of the process upon completion of their two year commitment. As of January 2013, three close-the-loop sessions have been completed with hundreds of pluses and deltas presented. The majority of the pluses have been specific to student learning, while the deltas have been a mix of suggestions for the program and for course implementation. Overall the pluses have outnumbered the deltas – a positive indicator. Many comments have multiple repeats among faculty members.

Overall, faculty identified teamwork, improved student motivation, communication, and student design as the primary positives aspects associated with the ACL/PBL process. One student particularly enjoyed PBL in his calculus course when he asked the professor. "This is a math class; why are you talking about reality?" The most repeated response was "students like this" referring to PBL and ACL. During the 2009-2011 ACL/PBL roll-out, the areas that needed improvement were split between programmatic suggestions (need better protocols and reporting forms) and classroom improvements (faculty feel they need to create more PBLs and improve the ones they use). Given that faculty had only been involved for two years, these are reasonable and expected suggestions for improvement. During the 2011-2012 PBL roll-out, nine faculty members noted that team dynamics monitoring was the area most in need of change (although one faculty member made a plus from this delta during the course). The faculty reported that often a single team member dominated the PBL or that the team members' responsibilities were not equally divided. Another common area suggested for improvement centered on the need to better stage/disclose the PBL or to include more progress checks during a long-term PBL (i.e., a PBL that takes more than one week to complete). Finally a major concern was classroom time; the faculty are discovering which course material is crucial to be in lecture format and which material caters best to PBL. With time and experience, most of the deltas will automatically be fixed. Effectively implementing new pedagogy requires practice.

The second instrument for program evaluation was a faculty survey regarding their impression of the process. Ten KIT 1 faculty completed the optional survey and their responses are detailed in reference 7. Overall, a vast majority (90% - 9 out of 10) agreed that their inclusion in the process was personally and/or professionally satisfying and will continue to use ACL/PBL in their courses. Most faculty (70% - 7 out of 10) believed their students have a better understanding of course material and are better problem-solvers because of course modifications. 80% believed their students were better team members because of the course modifications. Only 50% of faculty agreed with the statement "my students have a better understanding of the entrepreneurial mindset because I integrated PBL/ACL in my courses," while 80% of the faculty feel they gained a better understanding of the entrepreneurial mindset after integrating PBL/ACL into their course. Therefore, faculty should make a better connection to the entrepreneurial mindset with their course improvements and how PBL and ACL are supposed to reinforce mindset elements. Nonetheless, students did report seeing a connection between PBLs and the entrepreneurial mindset in their pre-/post-tests.

4.4. Impact on the University

It is not uncommon at a university that faculty in each college or department operate very independently of the others. Faculty rarely interact between colleges, and rarely between departments within the same college. Because engineers of various disciplines, architects, artists, business managers, scientists, mathematicians, etc. must all work together in industry, it is unfortunate for students preparing for their careers that universities operate in such a manner. At Lawrence Tech, the inclusion of faculty from three colleges (10 departments) in the course modification program has begun breaking down these barriers. The result tends to be higher/better collegiality as well as more streamlined processes for initiatives throughout campus (e.g., new course approvals, assessment committee work, etc.).

Adjunct professors have also been impacted. The students are demanding more problem-based learning, a more active classroom, and a more engaging experience. (They want to learn!) Similar demands are being asked of full-time faculty that have not participated in the KIT course modification program. (In some cases, seasoned professors with historically high ratings from students' course evaluations have experienced a drop in their ratings.) In addition, the College of Architecture, which has not been included in the course modification program, is now interested in involvement. Therefore, the Center for Teaching and Learning has begun an abbreviated course modification training for all non-KIT faculty (adjuncts included). The training takes place in a series of short one hour workshops, and each workshop is tailored to specific departments. (For example, mathematics professors attend a separate workshop from natural sciences professors.) These workshops only explain the pedagogical techniques and present examples that can be used in the classroom. They are not intended to fully train an instructor on developing their own PBL or ACL. With time and experience, development will probably happen naturally.

With the continuing success of the course modification program and the positive response from students and faculty, the university administration and board of trustees have made ACL and PBL methodologies a priority in the 2012 Strategic Plan. From Fall 2012 through Fall 2015, the university is striving for a 10 % increase per year in the number of courses using PBL and ACL.

5. Conclusions and Future Research

Lawrence Tech has implemented a six-year process to significantly transform its engineering undergraduate curricula. By the end of the six-year process, over 60 faculty members from engineering, humanities, social sciences, business, natural sciences, and mathematics will have been trained to develop and facilitate ACL and PBL classroom modules which aid in instilling the entrepreneurial mindset. Participating faculty members and their respective courses are selected by a team of university faculty, staff, and administrators. Each faculty member participates in a two-year training program that includes multiple workshops, peer reviewing, and assessment. A support structure of faculty grouped by content has helped to create significant and worthwhile classroom modifications to better equip students for a successful career. A self-sustaining, tiered training program has been structured so that experienced faculty can serve as trainers. In addition, the course modification process continues to expand beyond the formalized KIT program.

Assessment results indicate that students are perceiving gains in various attributes of the entrepreneurial mindset, most significantly in problem-solving and teamwork. The greatest self-reported student gains occur when both ACL and PBL techniques were used together in the course. Faculty responses to the implementation of ACL and PBL have been very positive with increased student motivation being one of the most common "pluses." The suggested changes centered around improving teamwork and the typical "growing pains" of implementing new, fresh classroom techniques. Most of the "deltas" can be automatically fixed with more classroom experience.

The analysis of assessment data will continue through the end of the six-year course modification training process. This growing dataset allows for future research that could include richer comparisons among students from different demographic backgrounds and class years, tracking students longitudinally over time, and a factor analysis showing different components of the entrepreneurial mindset.

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