AC 2009-2157: FACILITATING LIFELONG LEARNING SKILLS THROUGH A FIRST-YEAR ENGINEERING CURRICULUM

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The Facilitation of Lifelong Learning Skills through a Project-Based Freshman Engineering Curriculum

Abstract

Engineering accreditation criteria, as well as the Engineer of 2020 report, list lifelong learning as a critical attribute of future engineers. While exercises can be embedded in engineering curricula that promote independent learning, assessing the level at which lifelong learning has been achieved is difficult. The first year engineering curriculum at Louisiana Tech University provides activities that support development of lifelong learning skills. Examples include the requirement of student attendance at professional society meetings or service functions and independent research into global and societal issues that are likely to influence their careers. Our project-based curriculum requires skills beyond those imparted in the classroom. For example, students must learn with little or no classroom instruction to create parts and assemblies with a 3D modeling tool, to diagnose technical problems with their projects, and to learn to implement sensors as part of their design projects. By analyzing student questionnaires and curricular content, we measure the numbers of activities that promote lifelong learning as well as the extent to which these activities are completed independently. This paper will provide an overview of our first year engineering experience as well as the assessment results that help us measure the extent of lifelong learning.

Background and Introduction

Criterion 3H (Program Outcomes) of the 2008-2009 ABET EAC requires that engineering programs instill within their students "a recognition of the need for, and an ability to engage in life-long learning"[1]. Though all engineering programs recognize the need for providing their students with tools to continue to learn new tools and strategies throughout their professional career, many experience difficulty determining methods to measure how well their curricula instill lifelong learning attributes. The Engineer of 2020 discusses "the imperative for engineers to be lifelong learners," noting that technology changes rapidly and that engineers frequently change careers.[2]

Litzinger et al. noted that lifelong learning can occur in two modes: formal and informal. The formal mode includes university courses, and the informal mode refers to learning that takes place naturally as an individual learns to accomplish a task[3]. We believe that project-intensive educational experiences provide fertile ground for practicing both modes of lifelong learning.

Nelson[4] described a general education class targeted to engineering and technology students. The primary objectives of the class were to provide students with the opportunity to think reflectively on merits and drawbacks of technology in a personal as well as global and societal context and to promote lifelong learning and skills. Assignments and discussions that help students develop their own opinions and attitudes regarding the impact of engineering and technology on global and societal issues instill a passion for learning in some students. Most people naturally want to do something in their lifetime that benefits society, so discussing "the bigger picture" can be an important motivator for sustained lifelong learning.

Gustafson, McCaul, and Soboyejo conducted a survey of 280 alumni during the academic year 2000-2001. Asked how their undergraduate experiences could have better prepared them for their professional careers, their top four responses included[5]:

- Changes in the content of engineering courses, including the use of current technology and software, more industry interactions, and real-world context;
- More involvement in professional organizations;
- An increased use of trade/professional publications within the curriculum; and
- Increased focus on professional skills, including ethics, teamwork, and communication.

Several have reported the need to teach and encourage students to use library resources such as trade publications and journals as well as electronic databases to find information for help with projects or research papers[5,6]. In some cases, alumni have strongly encouraged their universities to incorporate the use of such resources, realizing that they themselves would have benefited from an earlier introduction to using these resources.

Several studies have evaluated the role of confidence as a facilitator of or inhibitor to learning. McElhoe, Kamberelis, and Peters[7] found that in teaching computer skills to non-traditional students, the confidence that the students gained in using computers was more important to the students than the actual skills that they learned. Norman and Hyland[8] examined the role of confidence in lifelong learning with a group of student teachers. They determined that a lack of confidence influenced the student teachers to be more self-critical of themselves and anxious, leading to an avoidance of some tasks. On the other hand, persons with increased levels of confidence were able to adapt to new situations more quickly, enjoy learning more, and interact with others more easily. The student teachers developed confidence in part through discovering and practicing new teaching methods, self-management, and interactions with others, particularly to gain help.

Our approach to encouraging the development of lifelong learning skills and attitudes is to couple practice in self-learning with an innovative classroom spirit. This paper describes a first year engineering curriculum that seeks to instill an attitude of lifelong learning in our students by

- Including project based educational experiences that provide formal and informal modes of lifelong learning;
- Coupling engineering and technology with discussions on global and societal issues to motivate lifelong learning;
- Requiring that students attend professional society meetings on campus to provide an avenue for self-learning as they enter their careers; and
- Incorporating current technology and open-ended design to promote self-learning and most importantly, confidence.

We first provide an overview of our freshman experience and then discuss our strategies for promoting and measuring lifelong learning.

The First year Engineering Curriculum: "*Living with the Lab*"

All engineering students at Louisiana Tech enroll in an integrated curriculum designed to incorporate many of the educational practices of the National Science Foundation Educational Coalitions[9]. Students complete three engineering courses (ENGR 120, 121 and 122) which are implemented as combined lecture / laboratory classes and which meet twice each week for ten weeks for 110 minutes per meeting, as shown in Table 1.Our freshman integrated curriculum includes differential and integral calculus courses, basic chemistry lecture and laboratory courses, and a calculus-based physics course; students also typically enroll in several non-technical courses during the first year. The first year integrated courses are taken in "blocks" so that classes of 40 students take the same sections of each mathematics, science and engineering course during each quarter. The topics presented in the mathematics and science courses are coordinated to some degree with the topics presented in the engineering courses to motivate student learning and to provide for content overlap.

Table 1. First-year technical courses.

Fall Quarter		Winter Quarter		Spring Quarter	
Course	*Credits*	*Course*	*Credits*	*Course*	*Credits*
ENGR 120	2	ENGR 121	2	ENGR 122	2
MATH 240	3	MATH 241	3	MATH 242	3
CHEM 100	2	CHEM 101/103	2/1	PHYSICS 201*	3

* Students in chemical engineering postpone physics and take an additional chemistry in this quarter.

Our first year experience boosts experiential learning through student ownership of a "laboratory" platform in a new curriculum that we call "*Living with the Lab*[10]." Approximately 800 first year students enrolled in the new curriculum between the fall of 2007 and the winter quarter of the 2008-09 academic year.

The *Living with the Lab* Concept. Our faculty members have found that when teaching traditional laboratory and shop classes, making certain that all necessary equipment and supplies are ready before class can be difficult. Sustaining this effort with large numbers of students over time may not be feasible. Assignment of projects to students or student groups who have purchased their own robotics kits makes it possible for the "laboratory" or "design platform" to travel with the students to the places where they spend their time – their dorm rooms or apartments, or even the local coffee shop. When students control and maintain their own hardware, significant increases in experiential learning is possible; students are *Living with the Lab*. The end result is more hands-on student activity without an excessive investment of faculty time.

The Hardware Platform. The major aim of the *Living with the Lab* curriculum is to create innovative students with a can-do spirit through a project based curriculum where students repeatedly apply technology and fundamentals to solve problems. The new curriculum boosts experiential learning by putting the ownership and maintenance of the "lab" into the hands of the students. Each student must purchase a robotics kit (~$110) with a programmable controller, sensors, servos, and software, along with a toolkit (~$70) that together provide the basis for a mobile laboratory and design platform. A basic tenet of the curriculum is that student-owned labs motivate student learning and broaden the spectrum of projects and design topics that can be addressed, thus facilitating innovation. We have adopted the Boe-Bot platform sold by Parallax[11], in part because the kit comes with an excellent tutorial and activities for increased self-directed learning.

University Facilities to Complement Student-Owned Labs. Two Freshman Projects Laboratories have been specifically designed to support the curriculum. One of the laboratories accommodates up to 40 students (Figure 1) while the other accommodates 24 students. The smaller classroom is primarily used for classes for honors students. The two classrooms together include the following equipment and furnishings:

- 16 tables that seat 4 students each;
- A tablet computer system at the front of each room for faculty use;
- An LCD projector with a projection screen in each room;
- 16 milling/drilling machines with associated tooling;
- 3 lathes; and
- Ample cabinet space for storage of course tooling and supplies.

Figure 2 shows one of the 16 milling/drilling stations. Parts kits are also provided to students as needed to facilitate project work.

Figure 1. Layout of the integrated freshman classroom / laboratory / shop area.

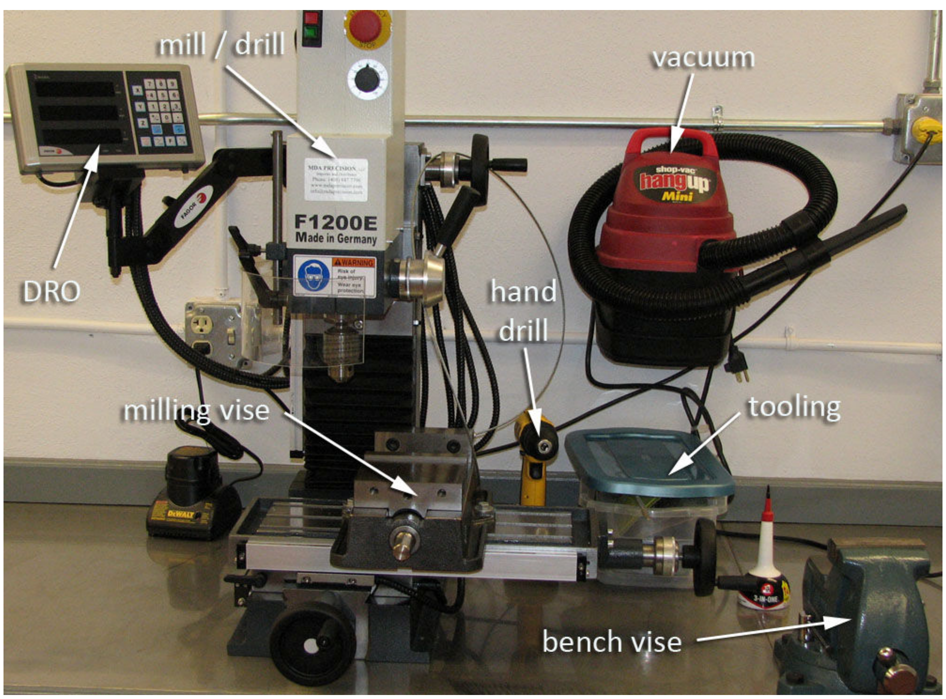

Figure 2. Students utilize a milling / drilling machine to assist with projects.

The First-Year Projects. Students taking ENGR 120 begin to utilize their robot kits as they learn about electrical circuits. They build simple circuits on the breadboard of their robot to verify Kirchoff's Voltage and Current Laws. However, the major project in ENGR 120 involves fabricating and testing of a centrifugal pump[12] as shown in Figure 3. Students fabricate the pumps through a series of drilling operations on the milling / drilling machines in Figure 2. The impellers are designed using SolidWorks, and each team's design is rendered on a rapid prototyping machine. Students test their pumps at different heads, quantifying the energy imparted to the fluid and the energy delivered to the electric motor to determine pump efficiency.

ENGR 121 students complete the fish tank project that involves controlling the temperature and salinity of a small volume of water, as shown in Figure 3. Students build almost the entire system from scratch, including the pump (from ENGR 120), the conductivity sensor, and a microfabricated resistance temperature detector (RTD)[13]. This project provides an outstanding opportunity for students to learn the fundamentals of salt water chemistry, conservation of mass, and conservation of energy on a just-in-time basis as they implement their projects. The students also gain repletion in linear regression, introduced in ENGR 120, as they calibrate their conductivity and temperature sensors.

ENGR 122 students design and fabricate a "smart product" of their own choosing and present their final prototype at the Design Expo held at the end of the first year. Students are more formally introduced to teamwork, brainstorming and creative design methods. Along the way, they learn engineering fundamentals (statics and engineering economics) and build on the skills introduced in earlier courses. Final projects are judged by teams of junior/senior engineering students and faculty members from the College of Engineering and Science and the College of Administration and Business. An example design project is shown in Figure 3; students work in teams ranging from two to four members for all ENGR 120, 121 and 122 projects.

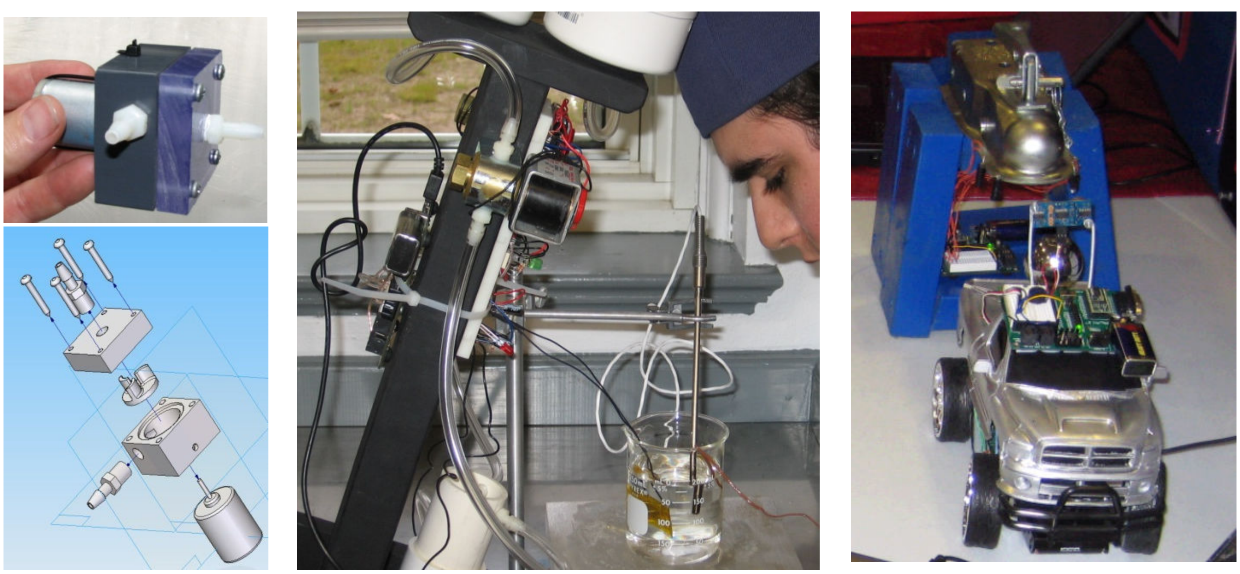

Figure 3 – Centrifugal pump (left), the fish tank (center), and a smart trailer hitch which provides an example of an innovative product (right).

In the spring of 2008, 33 groups successfully presented their final prototypes at the Design Expo. Although every project demonstrated use of course principles to a different application and required learning of new material without instructor assistance, several projects were recognized by the external reviewers as having significant technical merit and originality. Examples of these projects recognized included the following:

- SPOTBOT: A product offers automated spotting assistance as needed, allowing an individual to lift weights without another person in the room.
- Electronically Assisted Trailer Hitching: A product that lets a driver line up a truck's trailer hitch with a trailer without directions from another person.
- Eco-Friendly Lighting System: A product that automatically turns lights on/off based on the detection of the presence or absence of a person in the room; the product also adjusts lighting levels to compensate for changes in lighting levels based on the amount of light coming into a window.
- Smart Backpack: A product that determines whether the student user has loaded all books and supplies needed for classes for each day.

Objectives for the Freshman Engineering (*Living with the Lab*) Curriculum. We have sought to implement a college-wide freshman course sequence focusing on instilling "The Engineer of 2020[2]" attributes A1 through A6 and to a lesser degree on the remaining attributes (A7-A10), as shown in Table 2. The ten attributes provide a set of guideposts to help us evaluate whether or not our strategies are effectively preparing students for their engineering careers. The curriculum objectives are grouped into seven threads that span the freshman year[14], as shown in Figure 4. Linkages to the attributes of "The Engineer of 2020" (A1 through A10) are shown in parentheses after each objective. Each thread in the curriculum spans the entire freshman year. For example, every course has an engineering system that must be fabricated and tested, with the level of ambiguity and complexity increasing as the year progresses.

Table 2. Key attributes that the "Engineer of 2020" should possess[2]

No.	Attribute
A1.	Strong analytical skills
A2.	Practical ingenuity
A3.	Creativity
A4.	Good communication skills
A5.	Lifelong learners
A6.	Dynamic, agile, resilient and flexible characteristics
A7.	High ethical standards
A8.	Leadership skills
A9.	Professionalism
A10.	Business and management skills

SYSTEMS:

1. **fabricate, test and evaluate the efficiency** of an engineering system (A1,A2,A3,A6)
2. **fabricate and test** an engineering system where two physical parameters are controlled (A1,A2,A3,A6)
3. **conceive, design, and fabricate** a prototype utilizing a controller, sensors and actuators (A1,A2,A3,A6)

ELECTROMECHANICAL:

4. **utilize** a programmable controller that interfaces with selected sensors and actuators (A1,A2)
5. **implement** functional circuits on a solderless breadboard for sensing and control applications (A1,A2)
6. **utilize** multimeters to troubleshoot circuits and to determine the power usage of a device (A1,A2)
7. **describe** the specifications, operating procedures, and underlying physics for the hardware utilized (A1,A2)

FABRICATION AND ACQUISITION:

8. **fabricate** parts using a wide range of conventional manufacturing processes (A2)
9. **design and fabricate** an RTD sensor using microfabrication processes (A1,A2)
10. **locate** materials, supplies and components in stores and from online suppliers (A2)
11. **specify and purchase** materials, supplies or components for projects (A2)

SOFTWARE:

12. **utilize** Excel, Mathcad and SolidWorks to assist in engineering analysis and design (A1,A2)
13. **formulate and implement** sequential computer programs for sensing and control applications (A1,A2)

FUNDAMENTALS:

14. **apply** concepts of electricity and DC electric circuits (A1)
15. **apply** basic statistics to quantify and model experimental data (A1)
16. **apply** conservation of energy to engineering systems (A1)
17. **apply** basic chemistry and electrochemistry to salt water mixtures (A1)
18. **apply** conservation of mass to engineering systems (A1)
19. **apply** least squares fitting to calibrate sensors (A1)
20. **apply** concepts of statics to engineering systems (A1)
21. **apply** engineering economics to solve time value of money problems (A1)

COMMUNICATION:

22. **utilize** the specified engineering problem solving approach when completing assignments (A1,A4)
23. **properly** present technical information in tables and graphs (A4)
24. **communicate** the results of investigations and projects both orally and in writing (A4)
25. **assess** potential impacts of selected global and societal forces on our planet and its inhabitants (A5,A6,A7)
26. **regularly attend** professional society meetings and other student-led functions (A7,A8,A9)
27. **work individually and collaboratively** to complete course assignments (A4,A8)
28. **apply** creative problem solving techniques for product design (A3)
29. **manage** time and resources during the development of an innovative product (A10)

Figure 4. *Living with the Lab* curriculum objectives with linkages to ENGR 2020 attributes.

Strategies for Lifelong Learning in the *Living with the Lab* Curriculum

Some ways in which students develop lifelong learning skills in ENGR 120, 121 and 122 are:

- *Independent learning in computer programming and 3D modeling skills.* Homework exercises require students to develop elementary programming skills using PBASIC to program the microcontroller supplied with the Boe-Bot kit[11]. These skills are developed primarily through self-paced tutorials provided by Parallax. Students also learn elementary 3D modeling skills; we are currently using SolidWorks2008[15] from Dassault Systèmes SolidWorks Corp. Students develop 3D models and assemblies and learn to make simple 2D drawings. Again, the students learn develop virtually all their instruction through self-paced tutorials provided with the software.
- *Locating and specifying parts and components.* Students must locate and specify parts and components similar to those provided by the instructor in ENGR 120, 121 and 122 projects. Students learn that most prototypes are composed of off-the-shelf parts and components; they learn that they must "dig" to find the appropriate parts and components for their own projects. Getting into a habit of finding information by searching the Internet, browsing supply catalogs, or visiting local hardware stores is a form of self-learning that translates to lifelong learning if the habit takes hold.
- *Attendance at professional society meetings*. Many technical courses and conferences are sponsored by professional societies, and these events provide a major source of lifelong learning opportunities for technical professionals. To encourage student involvement with professional societies and local service organizations, students are required to attend at least five qualifying meetings each quarter; this counts as 5% of their grade. We anticipate that the students will learn the benefit of interacting with their peers and will continue to attend seminars targeted to their discipline even after graduation.
- *Development of troubleshooting skills*. Students gain practice in analyzing engineering systems many times during the ENGR 12X course sequence. Initially, students learn to use a multimeter to troubleshoot simple circuits with a single resistor and LED. As the electromechanical systems become more complex throughout the year, the students must develop higher levels of problem-solving to identify and eliminate problems in their systems. Repeatedly successfully overcoming difficulties through troubleshooting builds the confidence required to tackle tougher challenges. The type of person who is known for tackling tough technical challenges is often the same type of person who stays abreast of the latest developments in his/her field (David: Not sure we can make this case without an appropriate reference; may need to revise this sentence or drop altogether.). For this reason, we believe that project-based education builds the confidence and attitudes that foster lifelong learning.
- *Open-ended design.* Our first-year engineering curriculum includes design and prototyping of a smart product in ENGR 122. Successful completion of open-ended design projects necessitates that students learn on their own. Our design project utilizes the IDEO Design[16] approach that requires that students perform research to learn about the client, market, the technology and the constraints. This is an example of how self-learning is incorporated into the first year experience.

- *Consideration of global and societal issues*. Students must independently research two issues of global consequence in each of the three first year courses and must generate a short paper or presentation relating what they have learned. Examples of issues explored include global warming, ethical dilemmas in biotechnology, and the shortage of fossil fuels. In-class discussions of these issues typically draw responses even from students who may not contribute to any other in-class discussion during the quarter. The independent research skills required to explore these issues helps build the skills required for lifelong learning.

Assessment Results

During the winter quarter of 2008-2009, a survey was conducted of ENGR 120 students to determine their prior familiarity with the skills taught in the class, as well as how much instruction they received from their instructor. For example, questions 1 and 2 in the 26-question survey were posed as follows:

- *Prior to ENGR 120, how often had you used the Internet to locate sources for parts and supplies?* Note that for all questions dealing with experiences prior to the student taking the class, allowable responses ranged from 1 to 7, where 1 = "Many times", 4 = "A few times", and 7 = "Never".
- *While taking ENGR 120, how much instruction did you receive in class on how to use the Internet to locate parts and supplies?* Note that for all questions dealing with the level of instruction the student received in the class, allowable responses ranged from 1 to 7, where 1 = "My instructor carefully taught me how to perform this activity", 4 = "My instructor gave me a few tips on how to perform this activity", and 7 = "I completed the activity by learning how to do it myself."

Twenty-three of 52 students taking the ENGR 120 class in the Winter 2008-09 quarter responded to the survey. The results are summarized in Table 3.

Table 3. Students' self-reported experience prior to taking ENGR 120 and the level of instruction received during ENGR 120.

Activity	Prior Experience	Instruction Level
	1 = Many times *4 = A few times* *7 = Never*	*1 = My instructor carefully taught me how to perform this activity* *4 = My instructor gave me a few tips on how to perform this activity* *7 – I completed the activity by learning how to do it myself*
Use the Internet to locate sources for parts and supplies	3.65	4.17
Use the Internet to research price information	4.65	4.52
Use the Internet to research information for a presentation or research paper	5.83	4.30
Use presentation software	4.65	4.35
Use spreadsheet software to perform calculations on a set of data	3.74	1.70
Use spreadsheet software to graph a set of data points	5.26	1.96
Use a math analysis program (Mathcad) to perform calculations	2.65	2.04
Write computer programs	3.48	2.74
Breadboard circuits	3.61	2.87
Solder circuits	2.13	3.22
Use a drill or milling machine	4.09	3.13
Complete a technical or engineering project requiring fabrication	2.91	2.83
Use a 3D modeling tool to draw a part or assembly	2.00	3.61

As expected, the three lowest scores for instruction level were for the use of a spreadsheet for calculations, the use of a spreadsheet for plots, and the use of a math analysis package. In fact, our instructors do spend significant parts of several lecture periods making sure that students learn these skills. On the other hand, three of the highest scores for instruction level were for the use of the Internet for locating information about parts and supplies, prices, and other selected course topics (global and societal issues). Students also learned to use presentation software, usually PowerPoint, on their own, because no instruction is provided for this skill.

The students appear to have responded somewhat charitably to questions on the instruction levels for programming and for using a 3D modeling tool. Though we do discuss how to use specific commands in their programming projects and explain some programming concepts such as looping or calling subroutines, the students really learn these skills largely through self-study and practice. Regarding 3D modeling, instructors typically only demonstrate *at most* the design of one part, an impeller blade used for a centrifugal pump project later in the quarter. Almost all other instruction on the use of the 3D modeling tool comes from software tutorials provided with the software.

We require our students to attend at least five professional meetings each quarter. Each meeting that they attend counts as 1 point toward their final average. Such meetings can include meetings of student societies such as IEEE and IIE and seminars by guest speakers hosted by the College of Engineering and Science. A self-reported summary of the different types of meetings attended by students taking ENGR 120, 121 and 122 in the spring of 2008 is provided in Table 4. Students report that they are attending a significant number of meetings; in fact, far more than what they could receive credit for. Our hope is that their involvement in student-led societies will translate to professional society involvement after graduation and increased lifelong learning.

Table 4. Average number of professional society meetings, student functions and service activities attended by each student.

ASME (American Society of Mechanical Engineers)	1.55	1.78	1.57
ASCE (American Society of Civil Engineers)	0.93	0.80	0.89
SNES (Society of Nanosystems Engineers)	0.29	0.30	0.18
AIChE (American Institute of Chemical Engineers)	0.83	1.02	0.58
BMES (Biomedical Engineering Society)	0.38	0.58	0.47
IIE (Institute of Industrial Engineers)	0.67	0.66	0.44
SAE (Society of Automotive Engineers)	0.36	0.34	0.15
IEEE (Institute of Electrical and Electronics Engineers)	0.60	0.68	0.55
ACS (American Chemical Society)	0.21	0.24	0.15
SWE (Society of Women Engineers)	0.17	0.36	0.42
ESA (Engineering and Science Association)	0.21	0.78	0.71
NSBE (National Society of Black Engineers)	0.45	0.62	0.35
College of Engineering and Science Events	0.95	1.89	1.65
College of Engineering and Science project meetings/workdays	0.62	0.90	0.78
Seminars sponsored by the College of Engineering and Science	2.00	1.96	1.69
Other University meetings	1.33	2.62	2.58
Service projects through the University	0.81	1.33	1.17
Service projects/activities with groups outside the University	1.83	1.74	1.40
Meetings that do not fit into one of the categories above	3.10	3.93	3.26
Totals Extracurricular Events Attended Per Quarter:	**17.3**	**22.5**	**19.0**

There is significant evidence that students in the *Living with the Lab* curriculum perform more hands-on activity and have more confidence in their abilities than with the previous, largely lecture-based curriculum. Table 5 details the average number of hands-on activities for ENGR 12X courses, comparing the results for the previous integrated curriculum (OLD) with the results for the new curriculum (LWTL, for *Living with the Lab*). It is clear that the new curriculum has resulted in a large boost in the number of hands-on activities that the students experience. We believe that the increased confidence and entrepreneurial spirit fostered through project-based education promotes a spirit of lifelong learning.

Table 5. "Hands-On" application means for ENGR 12X courses.

	ENGR 120				ENGR 121			ENGR 122	
Item	OLD Spring 06-07	LWTL Fall 07-08	LWTL Winter 07-08	LWTL Spring 07-08	OLD Spring 06-07	LWTL Winter 07-08	LWTL Spring 07-08	OLD Spring 06-07	LWTL Spring 07-08
Soldering	0.14	1.25	1.35	1.31	0.05	3.39	4.96	2.17	4.99
Layout	1.35	1.61	1.63	2.69	0.38	7.28	8.15	2.24	11.53
Assembly	2.15	2.17	3.62	2.98	0.50	7.86	9.07	3.10	11.27
Bending	1.04	0.49	0.82	1.38	0.18	1.76	3.24	4.77	6.08
Sawing	1.52	0.12	0.42	0.76	0.15	0.75	3.20	2.05	5.92
Drilling	1.81	2.10	2.92	2.55	0.31	7.90	8.48	4.29	9.66
Milling	0.34	1.59	2.26	2.29	0.00	4.08	4.73	0.09	3.46
Using a scale	4.12	1.78	2.31	4.67	0.82	7.89	9.92	3.59	14.17
Using a lathe	0.24	0.24	0.38	1.33	0.02	1.74	3.19	0.06	1.22
Rapid Prototyping	0.21	0.58	0.89	0.76	0.00	0.80	2.66	0.71	1.92
Cutting internal or external threads	0.23	1.01	1.35	1.48	0.02	5.86	5.75	0.55	1.17
Using a dial caliper	0.07	4.55	2.95	3.31	0.02	5.31	4.81	0.17	4.79
Using a multimeter	0.26	6.77	6.25	8.02	0.33	6.39	7.67	2.28	5.28
Implement circuits on a breadboard	0.04	12.04	9.77	13.48	0.44	14.84	13.91	0.62	14.48
Writing PBASIC programs	0.00	16.20	14.92	16.40	0.05	12.52	14.31	0.02	11.79
Totals Hands-On:	**13.5**	**52.5**	**51.8**	**63.4**	**3.3**	**88.4**	**104.1**	**26.7**	**107.7**

A Student's *t*-test was performed to compare the application means of the old curriculum (Spring 2007) with those of the new curriculum (Spring 2008). The performance means for the ENGR 120 *Living with the Lab* curriculum were found to be significantly higher ($p = 0.021779$) than those for the old curriculum. However, the differences between performance means for the new vs. old curriculum for ENGR 121 and 122 were found to be highly significant (ENGR 121: $p = 0.000038$; ENGR 122: $p = 0.00012$).

Table 6 compares the confidence levels of students taking the old curriculum (Spring 2007) and new (LWTL) curriculum (Spring2008) for all common course outcomes in the ENGR 12X series. For measures of confidence, 1 represents "completely unconfident" while 6 represents "completely confident."

Table 6. Confidence level means for common course outcomes for ENGR 12X courses.

Item	ENGR 120		ENGR 121		ENGR 122	
	Spring 06-07 (OLD)	Spring 07-08 (LWTL)	Spring 06-07 (OLD)	Spring 07-08 (LWTL)	Spring 06-07 (OLD)	Spring 07-08 LWTL)
Utilize the prescribed solution format when solving problems.	5.00	4.88	5.14	4.86	5.53	5.50
Work collaboratively with one or more other students.	5.41	5.17	5.20	5.08	5.49	5.36
Present the results of assignments and projects using written communication.	4.85	4.95	4.88	4.90	4.94	5.18
Present the results of assignments and projects using oral communication.	4.39	4.79	4.50	4.80	4.95	5.02
Generate 3D models of engineering components and assemblies using SolidWorks.	2.55	4.07	4.54	4.70	4.55	4.94
Present technical data in tables and on graphs in a professional manner.	4.76	5.07	4.66	5.00	4.47	4.69
Locate specifications and prices for the supplies, parts and systems used in course projects from manufacturers and on-line retailers.	3.85	4.76	3.17	4.82	5.14	5.26
Use linear regression analysis as appropriate in class projects.	3.58	5.00	3.98	4.90	5.23	5.14
Utilize MathCAD to assist in solving engineering problems.	1.67	4.79	4.41	4.74	5.23	5.05
Utilize Excel to assist in solving engineering problems.	4.85	5.43	4.64	5.16	4.52	4.90
Use creative techniques to overcome at least one project difficulty.	4.61	4.67	4.45	4.56	5.03	5.05
When I set a goal, I keep going after it no matter what the obstacles.	4.97	4.93	5.05	5.10	5.30	5.24
I enjoy developing technical tools that improve the quality of life for people.	4.88	5.21	4.77	5.20	4.92	5.03
I intend to develop new products/processes during my career as an engineer.	4.82	5.24	4.57	5.00	5.15	5.20
I prefer improving products/processes that already exist instead of developing something new.	4.28	4.26	4.63	4.24	4.70	5.36
Given a current societal concern explain the trends and assess the implications in a broad engineering context.	3.25	4.57	3.51	4.59	5.14	5.23

A Student's *t*-test was performed to compare the confidence levels that students sustained after completing each class in the ENGR 120 sequence. The results showed that students felt a greater confidence in their ability to complete the course outcomes common to each class. For both ENGR 120 and ENGR 121, the results were highly significant (ENGR 120: $p = .005435$; ENGR 121: $p = 0.008737$). For ENGR 122, the results were significant ($p = .025867$). ENGR 122 in both curricula require the students to design and implement a prototype, most likely accounting for the smaller difference in the confidence means.

Table 7 shows the mean number of times the students reported using a variety of sensors in their ENGR 122 design projects. Because no instruction on these was provided in class, students had to locate, download, read, and understand specifications and sample programs for these sensors with little or no help from instructors. The students' ability to successfully integrate these sensors in their projects is further evidence of their increased levels of self-learning.

Table 7. Student utilization of sensors not discussed in the courses (self taught).

Item	122 Spring 07-08
Hall effect sensor	0.58
compass (interfaced with Boe-Bot)	0.32
force sensor	0.76
temperature and humidity sensor	0.47
RF communication module (Boe-Bot to Boe-Bot communication)	0.66
embedded blue transceiver appmod (adds bluetooth capabilities to the Boe-Bot)	0.30
color sensor (senses red, green, and blue color at a point)	0.26
CMUcam vision system	0.24
limited rotation servo	1.94
LCD display output	0.80
Total Times Sensors were Utilized During Academic Year:	**6.33**

Additional anecdotal evidence suggests that students are developing lifelong learning skills. In focus group meetings conducted in Spring 2008[13], students reported that "I like that they (the instructors) didn't always tell us what to do – we had to figure it out on our own." However, "there was always someone there to help – faculty and classmates."

Conclusions

Engineering accreditation criteria, as well as the Engineer of 2020 report, list lifelong learning as a critical attribute of future engineers. The six-semester hour, project-based engineering curriculum at Louisiana Tech seeks to build a spirit of creativity and innovation in our students while providing experiences that foster the attributes of the Engineer of 2020. Self-learning activities are purposely embedded in the curriculum to give students practice in learning on their own. This self-learning takes place in an environment that supports the students' efforts to "try things out" and encourages students to "go for it" as they design their own products. We believe that the research skills and confidence associated with a project-intensive experience coupled with student involvement in professional societies provide essential ingredients for successful lifelong learning.

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