Project Lab: A Structured Extracurricular Design and Innovation Experience for Engineering Students

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Abstract

Engineering students desire opportunities to practice and improve their engineering design and product development skills in an authentic environment that augments engineering skills developed in curricular courses. In response, Project Lab was developed to offer students directed product design and development experiences. Students in Project Lab work on an interdisciplinary team to design, fabricate, validate and deliver a functional engineered device or application that meets client or user needs using the Stanford Design Thinking framework. The team works directly with the client to identify needs, iterate a solution and deliver a working device that meets client specifications. Students in Project Lab also develop team building, client management, communication, and presentation skills that improve their confidence and career-readiness. Successful students emerge from Project Lab with translatable professional and interpersonal skills that benefit them when applying for scholarships, internships, graduate school, co-ops and permanent positions.

Keywords

Engineering Design, Innovation, Career Development, Design Thinking, Cocurricular Experiences Professionalism, Teamwork, Career Management

Introduction

Often, students request project-based work to acquire skills not available in a classroom setting; opportunities to be trained and supported in meaningful ways that connect experiential experiences to classroom theory based learning. Project Lab is a unique collaboration between a faculty member who teaches engineering design and innovation and an engineering career services specialist who provides students with career and professional development training. Project Lab provides a platform which creates awareness and exposure to cocurricular opportunities through client interaction, product design and development, and enhancement of workplace skills applicable to their career. In addition, authentic immersive hands on training provides opportunities for the students to integrate classroom and extracurricular learning.[1,2] An objective of engineering career services is to create an understanding and build awareness of what skills various industries seek through career events, workshops and hands on participation in programs like Project Lab that train students on workplace skills and social factors.

The University of Alabama at Birmingham (UAB) School of Engineering has approximately 900 undergraduates across in Bachelor of Science programs: Biomedical; Civil, Construction and Environmental; Electrical and Computer Materials; and Mechanical. The engineering curricula

are similar to each other and those at other engineering schools. While critical to development of competent engineering graduates, the standard engineering curriculum provides students with little opportunity for 'hands on' product development and team-based projects until the senior capstone design course. Project Lab provides an outlet for students at all levels to practice engineering design and project development skills. To remain inclusive, we purposefully target all students, to bring together those from a diverse background (major, classification, gender, ethnicity, etc.) and diverse ways of thinking; which forces stronger collaborations and better ideation leading to successful project development.

Student recruiting into Project Lab begins with an interview to assess the student's critical thinking, design, problem solving, communication and teamwork skills. In the interview, the students learn about Project Lab clients, projects that have been delivered and the projects available the next term. The opportunities for hands on engineering design/build activities are emphasized. Students are made aware of the significance of participating in Project Lab and particularly how skills developed in Project Lab translate into better competitiveness for subsequent scholarships, internships, co-ops, graduate school and employment opportunities.

Project Lab is structured such that the student team manages all aspects of project management, including interactions with their client. Weekly collaborative sessions provide training and support, all within an environment which fosters communication and collaboration across teams, learning of effective strategies for product design and development, exchanging of ideas and brainstorming of solutions. Time management is also encouraged and developed to ensure they remain active working as a team.

In our experience, students entering Project Lab lack the communication, product ideation and engineering design skills needed to effectively interact with their client to develop an understanding of the problem and develop an effective solution. To provide these tools, students are required to review Design Thinking: A PROCESS GUIDE[3]. At the first weekly collaborative meeting, the instructors review the operation of Project Lab and relevant safety training and policies. The Stanford Design Thinking process is reviewed and students are led through exercises that demonstrate the steps of the design thinking process. The students practice interviewing each other to gain proficiency in empathizing, a cornerstone of design thinking. Then, the instructors lead the group though brainstorming activities on a project or problem that has been presented to Project Lab by a potential client. This practice provides invaluable understanding of the Design Thinking process that allows the teams to begin effective communications with their client early in the term.

Within the first week of the term, students are required to attend the initial client meetings, which were scheduled in advance by the instructors, to gain an understanding of the clients' responsibilities and learn about the projects the client has available. A key element of these visits is that the students learn about the client *in their environment*. Students and clients are made aware that the project budget is $50. This budget constraint forces students to think creatively about possible solutions. For projects with components that cost more than $50, the client is asked to procure necessary components (examples include Raspberry Pi, gyroscope, electronic tablet, computer monitor, etc.).

All of the clients and the available projects are presented and reviewed by the group during the next collaborative session. At this time, students form into teams of three to four students around one project that the team will work on for the semester. Within the next week (the third week of the term), each team is required to research the project and generate a list of questions to for the client. The team must schedule a meeting with the client to discuss the project they selected. Thus, by the end of the third week, each team has a client, a project and a plan (based on the Design Thinking approach) to develop and validate a prototype or series of prototypes that meet the client's or user's needs. For the rest of the term, the team develops, builds and validates prototypes as they approach an acceptable solution to the client's problem. The team is required to provide a two-page progress report to the client and the instructors every two weeks. We have found that this frequency of interaction with the client ensures that the team remains focused on the project without significant lapses in progress.

The weekly collaborative sessions provide opportunities to develop effective strategies for product design and development in a supportive environment. We regularly engage the entire group to discuss each project. This cross-fertilization of projects is critical to the success of Project Lab; often when a team is stuck on a particular aspect of their design, the knowledge to advance the project forward exists within the larger group. The collaborative sessions also provide the teams an opportunity to solicit feedback from the instructors on their project, effective client management and other topics as necessary. The instructors facilitate access to fabrication, prototyping or other resources needed to complete the project.

Students have access to a variety of prototyping and fabrication facilities in the Maker Space, Engineering Design Lab, Materials Processing and Applications Development Center, Engineering and Innovative Technology Development and other facilities on campus and in the community. Engineering faculty members assist as needed for specific project expertise (design, fabrication, electronics, coding, etc.). The instructors serve as a resource to the students as they identify specific skills or equipment they need to progress on the project.

To ensure team success, it is important to establish a comfortable working relationship within the team. To facilitate team cohesion, team building activities are incorporated into the first few collaborative sessions. These have included paper airplane building competition[4], Marshmallow Tower[5] and Lego design challenge[6]. These are timed competitions with a specific goal. For example: the goal of paper airplane building competition is to make a profit 'selling' quality paper airplanes to the instructors. Each team must design a single airplane and develop a list of quality criteria (e.g. flies straight, flies for a long distance, has a long flight time, etc.) before the production phase. Each team must pay for materials (paper), their labor and fixed costs. The instructors will 'buy' as many quality airplanes as the team can produce in the allotted production time (15 minutes). Profit is the difference between net sales and expenses. While these challenges are fun for the students, the timed aspect of the challenge forces the team to develop strategies 'on the fly' to maximize the team's success. Team dynamics are discussed in a debrief following each exercise using Tuckman's stages of group development[7] as a frame work. Even in these short duration team exercises, the four development stages (forming, storming, norming, performing) can be clearly identified. Students discuss challenges and

success during the team exercise; identifying setbacks and achievements in the context of the group formation dynamics.

At the beginning of the term, each team must develop or revise (for returning teams) Team Performance Plan (TPP) (Table 1). The TPP is a structured document that helps the team think critically about their term goals and the overall approach to the project. The important elements of the TPP are the team mission statement, recognition of team dynamics and their influence on team performance, an agreement on project roles and assignments, and how the team will communicate with each other, the client and the instructors. TPPs are updated each term to reflect changes in project scope, prior progress (or lack thereof), as well as addition of new team members, roles and responsibilities.

Table 1: Team Performance Plan

The Team Performance Plan assists students to critically think about the roles of team members in successful definition and execution of the team project.

Use the outline below to complete a Team Performance Plan.

1) What is the topic for the team project? (A few words are sufficient.)
2) List important assignments and due dates? (include assignments and dates):
3) Write a mission for your project in four to five sentences.
4) List three to four team dynamic factors that may influence the outcome of your project. Consider personality traits, skills of team members, knowledge of project, timelines, etc. Be as specific as possible.
5) List Team Members and their roles on the project.
6) What arrangements have the team made for operationalizing interactions on the project?
   a) Communication among group members (how, when?)
   b) Communication with client and instructors (how, when, why?)
   c) Team Meeting Schedule (where, when?)
   e) Other _____
7) How will project meetings be documented? Will a team leader be selected?
8) How will the team evaluate effectiveness measures such as quality, completion, timeliness and meeting specifications?
9) How will the team address any challenges or changes to the project not covered in the above (e.g. inadequate skill/expertise, team scheduling conflicts, workload, etc.)? How will problems that arise with an individual team member or between team members be addressed and resolved? Include plans to mitigate these to improve team success. What are the circumstances that could lead to a group member being expelled from the group?
10) Are there any outstanding concerns the team has regarding their ability to submit a quality project?

Table 1: Essential Elements of the Team Performance Plan.

In addition to the client meetings and client reports, each team must give a five to seven minute progress report to the Project Lab group during the mid-term collaborative session, a final written project report (engineering design file) and a final presentation open to Project Lab participants, clients and faculty or staff who aided a team during the semester.

Clients and Project Descriptions

Project lab clients include clinical and service departments at UAB as well as not-for-profit organizations in Birmingham. Since its inception in 2015, more than 80 students have participated in Project Lab, some for as many as four semesters. Project Lab has worked on more than 20

Client	Project
Alabama Department of Rehabilitation Services	**CCTV Device for Visually Impaired**
	Dragon Software Sound Amplification System
Children's Hospital Simulation Center	**Seizure Simulator**
	Hydroencephaly Trainer
	Capillary Refill Trainer
	Go-Pro Live-Feed and Attachment System for Simulation Training
	Device to Demonstrate Enlarged Liver in a Simulation Manikin Trainer
Lakeshore Fundation	**Footplate for Increased Stability on Exercise Machines**
	Performance Gloves for Rugby Wheelchair Athletes
	Aiming Device to Assist Blind Archers
	Tool Rack for Wheelchair Athletes
UAB Department of Transportation	Parking Location Availibility App
	Real-Time Shuttle Rider Counter and Reporter
Deep South Center for Occupational Therapy	**Mannequin and app for Hearing Loss Prevention Education**
UAB Highlands Hospital Occupational Therapy	Sit-to-Stand Walker
	2-in-1 Bedside Commode
	Wheeled Walker/Rollator for Improved Mobility & Stability
UAB School of Medicine Office of Interprofessional Simulation	Cental Venous Line Trainer
	UltrasoundableDevice for Venous Line Insertaion Training
UAB Clinical Innovation Center	Female Urinal

Table 2: Project Lab Clients and Projects. The table lists some of the clients and projects in Project Lab. Projects in bold have been delivered and are used by the client. Plain text projects are still under development.

projects for approximately 7 clients and have delivered over 8 projects to the clients (Table 2). Two sample projects are described below.

Hearing Loss Prevention Demonstration Mannequin: In summer 2015, Project Lab collaborated with the UAB Department of Art and Art History to upgrade a mannequin used by the university's Public Health department to educate children and young adults about potential hearing loss when listening to loud music via personal stereo systems/earbuds. The device works by placing a user's earbuds on the mannequin's head where an embedded microphone measures sound pressure level which is then displayed on a digital sound level meter in decibels (dB) (Figure 1). A Public Health staff person talks to the participant about whether the level is safe to listen to, or potentially damaging to their hearing. While functional, the mannequin brought to Project Lab and the digital dB display were not appealing or very informative (Figure 1A). Over two semesters the Project Lab Team transformed the mannequin to a more realistic human model with more pleasing facial expression (Figure 1B). Additionally, the team developed software to display the sound level in dB on a color-coded scale on a tablet screen that is more intuitive and understandable to the target user audience (Figure 1C). This device is used by public health staff in education and outreach programs, health fairs, recruiting fairs, middle school and high schools.

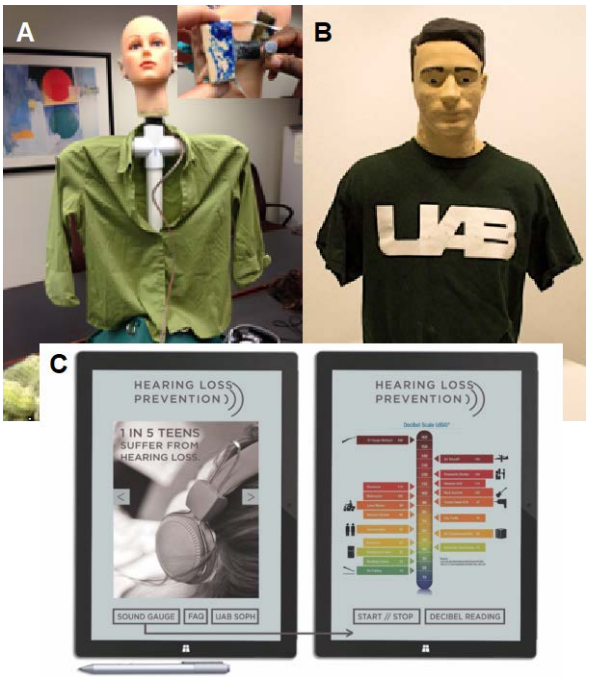

Figure 1: Hearing Loss Prevention Trainer. (A) Original mannequin showing exploded view of sound level meter in ear and digital decibel display on table. (B) Redesigned mannequin with more realistic torso and human face. (C) Sample tablet display screens showing color-coded sound output display relative to different environmental sounds (right) and educational materials (right).

Hydrocephaly Trainer: This project was requested by the Children's Hospital Pediatric Simulation Center for training parents and healthcare providers how to identify potential life-threatening intracranial pressure that occurs when fluid builds up in the skull and causes the brain to swell. This swelling can be readily detected by feeling the fontanel, the soft membranous gap between cranial bones in an infant's skull. The client wanted a device that

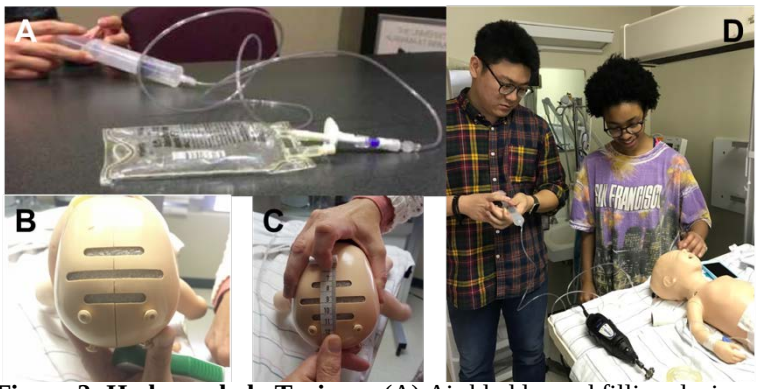

Figure 2: Hydrocephaly Trainer. (A) Air bladder and filling device to change pressure. (B) Top of infant mannikin skull with simulated skin removed. (C) Ruler indicates position of 'skull' material that must be removed to insert air bladder. (D) Testing device with air bladder in place and simulated skin reattached to mannikin.

could integrate into an infant simulation manikin used for a variety of training and education situations. This project was taken on by a pair of students new to Project Lab. The team exhibited a sound approach by first engaging the client to understand the problem from the perspective of a health care provider and a parent. Their major constraint is the size of the infant manikin's head – with limited room in the cranial cavity to deploy a device. Their solution was an 'air bladder' that fits under the scalp of an infant medical simulation manikin (Figure 2A). When inflated, the pouch provides a life-like feel of a bulging fontanelle that might indicate hydrocephaly or a brain tumor. The students validated the model in a 3D printed model skull covered in a skin-like rubber material before cutting away the manikin skull and installing the air bladder under the infant's scalp (Figure 2 D). This device is used routinely by the hospital staff to teach parents how to safely palpate an infant's fontanelle and to feel for potential increased intracranial pressure that would require immediate medical attention.

Discussion and Conclusions

The goal of Project Lab is to provide students with realistic hands-on opportunities to improve engineering design and build capabilities in a structured environment. Students are challenged to "train like an engineer". Project Lab activities including team building exercises, development of a Team Performance Plan, regular client updates, formal presentations, and the engineering design file that provide the students with a framework to approach problem solving, work in teams and develop an innovator's mindset. While each team controls their client interactions and project direction, the instructors provide regular feedback and encouragement to foster skills development and confidence in the students. Additionally, they serve as a resource to connect teams with expertise and resources across campus and in the community (3D printing, metal and wood fabrication, circuit building, programming, etc.) to design, build and validate prototypes. Through these activities, integration of career readiness planning is active as students intuitively self-assess their interests, skills, values, and personality. A foundation of the students' capabilities is developed and creates an ongoing exploration of the direct link between the different majors and associated career paths. The Project Lab partnership that blends training of engineering design, team building, and professional development skills provides complementary preparation that is responsive to employers' needs. For example, surveys such as the NACE Job Outlook 2018 Survey identified, 'problem solving skills' (82.9%)'ability to work in a team' (82.9%), and written communication skills (80.3%) as desirable attributes employers sought out on a candidate's résumé[3]. Skills and abilities gained while in Project Lab create a level of engagement which impacts lifelong development such as academic choices (modification of their degree program) and career management (pursuit of top graduate schools, competitive experiential opportunities and full-time employment). The overall awareness gained by student participation encourages a level of confidence gained through many levels of exposure to failure and success within Project Lab. Created are characteristics that lead to recognition by employers that our students possess 'well-roundedness'. A confidence is established in students and employers which indicates sufficiency in skills and knowledge for the workforce. Notably, critical 'soft skills' training is reduced for Project Lab students who have already gained these traits while working in an environment that cultivates learning and development through team and client interactions. As we continue to provide training that integrates career education through partnerships, it allows us to strengthen the support students receive and to create awareness on a larger scale that student success does not happen through one area of engagement or in a silo.

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