INTERDISCIPLINARY PROBLEM SOLVING

A CASE STUDY EXAMINING SKILL DEVELOPMENT IN AN UNDERGRADUATE INVENTION ACCELERATOR PROGRAM

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The Invent@SU invention accelerator teaches collaborative problem solving and necessary communication skills to students from multiple majors during an intensive six-week summer program. This iteration of the program blends both engineering and industrial design methodologies to enable students to define a problem, develop a novel solution, and pitch the journey to a panel of non-expert judges. The educational goal of the program is to enable students to exchange skills with their peers from other disciplines, learn about the complexities of inventing, and further develop key soft skills that enable success through their educational and professional pursuits beyond the program. Data collected through skills self-assessments and focus group studies begins to elucidate links between the structure of the program to perceived gains in visual and verbal communication ability. Limitations of the study and plans for future development are discussed which focus on not only the relationship between undergraduate design students and engineers, but also with other disciplines across campus.

Keywords: interdisciplinary; collaboration; invention; product development; communication.

1. INTRODUCTION

Student accelerator programs in universities are not new. There are plenty of examples on campuses across the United States (Cohen et al., 2019) and differ in their function to makerspace initiatives or business plan competitions. Campus makerspaces are designed to provide students with resources such as space and equipment and they serve as a space for experimentation with technology and ideas (Wilczynski, 2015). Unlike the ubiquitous campus business plan competition, an accelerator program requires that the invention works, or that the inventors can provide significant evidence of pending functionality. Campus accelerator programs typically give students seed money, education and mentoring, and the opportunity to pitch or showcase a working prototype for investment in further product development and customer discovery initiatives such as those supported by the National Science Foundation US I-Corps program (*US NSF - I-Corps - About*, n.d.).

Invention is a field that typically belongs to research and development teams, however this approach to new product development has become more popular in design challenges within the undergraduate curriculum. Industrial design is becoming recognized as key contributor to this kind of innovation (Yoshioka-Kobayashi & Watanabe, 2017), thus has become increasingly popular in ID classes, and in

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engineering capstone courses (Wrigley & Bucolo, 2011) (Qattawi et al., 2019) as a vehicle for project-based learning. These class-based design challenges typically have a problem statement or brief from an external client that students must collaborate on to find a novel and workable solution. Unless the course is designed to incorporate students from other disciplines, the teams are rarely interdisciplinary. Although it has been acknowledged that multidisciplinary project work can lead to better outcomes for students (Hotaling et al., 2012), setting up multidisciplinary student experiences can be challenging and are often one-off sponsored projects (Larsen et al., 2009) (Hosnedl et al., 2008) rather than sustained initiatives.

Within the context of project-based learning, the engineering and design disciplines seem like a natural inventing team, yet the team dynamic can be upset as conflict arises from differences in methodological approach. The common root of conflict documented in literature stem from designers focusing on the outside-in approach, and engineers seeking to design from the inside-out, or a user experience focus versus pure technology focus (Ulrich & Eppinginer, 2008). To mediate such conflict, skills development in verbal and visual communication needs to be mastered (Manfredi, 2019b) thus management of the design process can be undertaken more effectively (Gericke and Blessing, 2011).

This case study examines how the practice of invention was taught to an interdisciplinary student cohort over a six-week summer 2019 program. Whilst introducing them to the complexities of engineering and industrial design methodologies, multiple strategies were employed to build the verbal and visual skills necessary for teams to compete for seed funding. Self-assessment and focus group findings explored what the students learned during the program, and how they perceived their skill gain through practice and iterative critique.

2. PROGRAM OVERVIEW

HISTORY AND PROGRAM STRUCTURE

The Invent@SU program is the progeny of the Invention Factory program that began at The Cooper Union in 2013. The founders oversaw cohorts of twenty engineering students through a six-week process of ideating, prototyping, pitching, provisional patent application filing, and competing. Students accepted into the program received a stipend to participate in the intensive program which runs full days during the week. The program was introduced to Syracuse University on 2017 and has since evolved to develop a stronger focus on interdisciplinary collaboration amongst students from any discipline, led by faculty with equally diverse expertise. Since the program's introduction, students have gone on to win business plan competitions which were historically dominated by business students.

The program structure was as follows:

- Students self-formed into two-person teams and began brainstorming to find a problem area. At the end of the first week, students pitched a novel need-based design. The faculty and students voted on each invention and those receiving majority support began prototyping their invention. Those without enough votes repeated the process to develop a viable invention.
- During weeks two through five, students received a $1000 budget per team to prototype. As they iterated, they pitched weekly to an audience of alumni and faculty to receive suggestions for design and narrative improvements. The pitches are filmed and critiqued by the faculty and acting coach. Work on their provisional patent applications was also in progress.

- In week six, students filed provisional patent applications with the USPTO and pitched their invention to a judging panel comprising trustees and successful entrepreneurial alumni. The judging panel then awarded the $5000 first-place prize and a $3000 second-place prize.

PARTICIPANTS AND INSTRUCTORS FOR SUMMER 2019 PROGRAM DELIVERY

Undergraduates applied to the program through an online application process. Follow-up video interviews were conducted select the final twenty participants (14 males, 6 females) from various majors across campus (Table 1). Whilst interdisciplinary teaming was encouraged, some teams chose to rely on previous friendships, whilst others were formed on the first day of the program after introductions.

Major	***Associated College***	***Number***
Bioengineering	Engineering and Computer Science (ECS)	4
Chemical Engineering*	Engineering and Computer Science (ECS)	1
Computer Science*	Engineering and Computer Science (ECS)	3
Economics	Arts and Sciences (A&S)	2
Electrical Engineering	Engineering and Computer Science (ECS)	2
Industrial Design	Visual and Performing Arts (VPA)	4
Mechanical Engineering	Engineering and Computer Science (ECS)	3
Public Health	Sport and Human Dynamics (FALK)	1
Undeclared		1

*Table 1. Majors declared by the students in the cohort. *Dual major*

The program was facilitated by two professors: a Professor of Practice in the college of Engineering and Computer Science with a background in biomechanical engineering and an Assistant Professor of Industrial Design, with a background in product design, mechanical engineering, and human touch perception. A graduate student assisted with program administrative duties and helped students with pitching She had participated in the program and placed second the year prior. Support staff included:

- An Associate Professor of Acting worked with the students twice weekly during weeks 2-5 to improve posture and voice control whilst pitching their invention.
- A video communications specialist filmed prototype shorts for use in final pitches during week 6.
- Machining specialists for physical prototyping support.
- Guest evaluators and judges included alumni, current and retired faculty, and individuals who support entrepreneurial activity in New York state.

3. METHODS

COMMUNICATION BETWEEN STUDENTS AND THE INSTRUCTORS AND STAFF

Communication skills were developed for two delivery formats: formal lectures which carried information that every student needed to know, and one-to-one or small group format for skills that were specific to the design problem. Formal lectures included introduction to research methods, various design thinking tools, how to write a provisional patent, engineering drawing production, the basics of giving presentations and pitching, and weekly deadline briefings. One-to-one and small group teaching was reserved for project specific skills such as programming microcontrollers, basics in analog electrical engineering, modeling in CAD, 3D printing, sewing, and machining. These skills were deemed critical to student success in developing an invention. Success relied on their ability to synthesize the information as a team to explain their product through verbal, written, and visual communication.

In addition to teaching, a critique-based approach, common in design education and not in engineering, was adopted to give students feedback on the structure of their weekly presentations to guest evaluators. Feedback was given for patent writing skills such as how well they explained the relationship between the problem and proposed solution. Visual communication skills were routinely reviewed to address how understandable images were without additional explanation. Visuals were an important communication tool between the teams and the machining specialists in the early stages of prototype development.

PEER TO PEER COMMUNICATON
Students commonly had misconceptions about the role that other disciplines play in the inventing process. Communication skills such as sketching out flow diagrams, spider diagrams, lists of tasks, verbal descriptions, and low fidelity prototypes were taught to help the students work out strengths within their team. They learned when to delegate, and when to work together through the process.

STUDENTS COMMUNICATING WITH AN UNFAMILIAR AUDIENCE
During the weekly pitch sessions, students focused more on their visual and verbal communication skills, translating information that was technical to a narrative that succinctly explained the need-based solution. The expertise of the guest evaluators (up to 8 different people every week) was largely unknown to the students, thus the importance of an approachable narrative. Simple slide decks containing basic drawings of concepts, photos of prototyping in action, videos of working prototypes, and simple animations were utilized. Filmed presentations were extensively critiqued with professors the following day so that modifications could be made to address ambiguity in the narrative or made changes to the invention.

STUDENT COMMUNICATON WITH PEOPLE WHO HAVE KNOWLEDGE OF THE ART
The premise of invention is to create something unique that is patentable. Students needed to master basic engineering drawings (exploded, axonometric) and systems diagrams, paired with a specific writing style suited to patents. Although a provisional patent is rarely read, students needed to follow the format to attain a date stamp for the filing a full patent after the program. This output enabled them to think through the structure of their invention, and exhaustively communicate it in writing so that anyone with an understanding of the art could build their product.

DATA COLLECTION
Data was collected from the student perspective about their skill sets coming into the program and at its conclusion. An anonymous incoming survey was used to capture basic demographics, prior experience with inventing, and self-assessment of skills that are core to the invention process. At the end of the program, focus groups were conducted by an evaluator and another anonymous survey was distributed. The evaluator interacted with the students for research purposes only and was not a part of the delivery or supporting staff team.

4. RESULTS & DISCUSSION

Ten teams worked to produce novel products in various product markets. Inventions included a blood glucose sampling and analyzing smart watch, an eco-friendly chemical activated cooling vest, and a submerging robot designed to clean microplastics from fresh waterways. Each team demonstrated the application of skills to produce: a working prototype, provisional patent, a video explaining their invention, and a final presentation to a judging panel. The winner of the cohort, Paani, designed a low-tech sari water filter for women in the slums of India (Figure 1, left) and the second-place invention: a pen that combined art and music therapy for children with autism spectrum disorder (Figure 1, right).

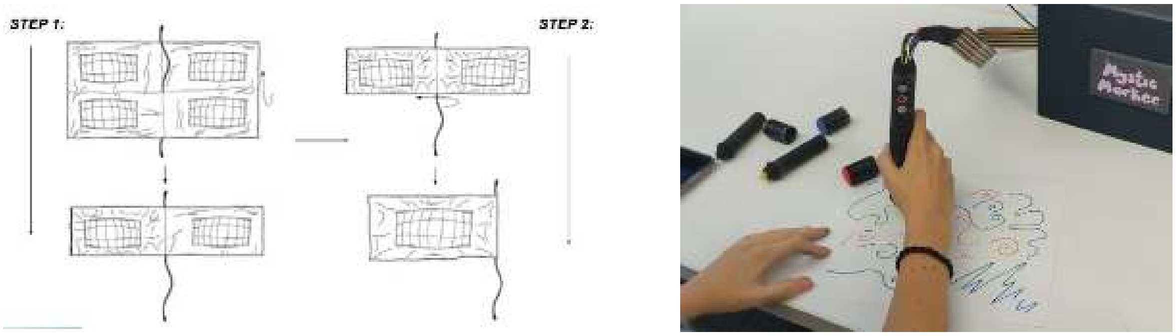

Figure 1. (left) Patent drawing of Paani, a four-layered water filtering system embedded in sari fabric for use in the slums of India and (right) prototype of Mystic Marker, a pen that plays musical instruments when the user draws.

INCOMING SKILL SELF-ASSESSMENT SURVEY

It is expected that an invention program would attract students who believe they have good problem-solving skills (Table 2). Over half of the cohort were studying disciplines such as engineering and design, where problem solving is core to the overall learning objectives. In assessing ‘making’, there were different scores for ‘Building Things’ versus ‘Prototyping’. A higher ability in building would suggest more comfort with following instructions where the outcome is clear, whereas prototyping suggests a more open-ended making process where the student needs to spend more time troubleshooting. Prototyping is an important part of the industrial design process, therefore the higher comfort level with this specific skill, could be attributed to the industrial design students.

To what extent do you believe you already have the abilities and skills in the following areas?

Ability/Skill	A great deal	Somewhat	Slight	Not at all
Ideal generation	6	9	4	1
Problem solving	11	8	1	0
Building things	6	7	7	0
Prototyping	3	6	5	6
Oral presentation	6	6	7	1
Written presentation	8	6	6	0

Table 2. Student self-assessment of core outcomes of the accelerator program. n=20

The wider spread in oral and written presentation self-reported ability was reflected in the performance of the cohort over the 6-weeks. Whilst a comfort with writing and presenting prior to the program existed, a steep learning curve was observed by the instructors as students were routinely critiqued on specific presentation and writing styles needed for pitching and patent writing, of which they has little prior experience.

SELF-ASSESSMENT OF SKILL DEVELOPMENT AT THE END OF THE PROGRAM

The skills self-assessment survey expanded on the incoming survey. Using Coplin's model for personal and professional success (Coplin, 2019) student reflected on eleven soft skills gains that were deemed important to the invention process (Table 3). Verbal communication through presentation is of importance to this study due to the amount of instruction that was executed to improve these soft skills (see Communication Methods). Their ability to verbally communicate effectively could be due to a combination of many of these skills listed. To pitch effectively as a team, students must have critically thought their way through problem solving exercises, questioned assumptions about the potential user, and developed empathy for the situation they were designing for. The students needed to persevere through the constant questioning of their work and build confidence in themselves and their teammate.

To what extent did you gain skills from the invent@SU program in each of the areas listed below?

Ability/Skill	A great deal	Somewhat	Slight	Not at all
Oral presentation	13	2	0	0
Written presentation	2	5	5	3
Teamwork	9	3	3	0
Conversation	11	2	1	1
Questioning	10	3	1	1
Problem solving	10	3	2	0
Perseverance	10	2	3	0
Confidence	11	4	0	0
Motivation	9	4	2	0
Critical thinking	11	2	2	0
Empathy	7	3	4	1

Table 3. Student self-assessment of expanded skill outcomes at the conclusion of the program. n=15

Writing is a key component of not just the provisional patent, but also in the planning of a pitch. Students were encouraged to write scripts for their videos and their weekly presentations to ensure a smooth delivery of their crafted narrative. Perhaps gains in writing were not perceived as important as the other soft skills and tangible skills learned in the program. Nevertheless, writing is a crucial skill in communicating an invention to the reader of a patent yet could have been viewed as a task that is outsourced to a professional in the event of a full patent application.

FOCUS GROUP: STUDENTS WITH THE INSTRUCTORS AND STAFF

The programming delivered by the instructors and supplemented by other staff was appreciated by the cohort (Figure 2). The interplay between the core skills of engineering design and industrial design was valued by the students as they worked through both approaches to product development to invent user-centered, need-based solutions.

How good [engineering prof], [design prof], and [graduate assistant] were at giving us feedback.
I was surprised at how effective the acting coach was. At first it felt silly, but she gave us very specific knowledge, and I made real progress.
The exercises the acting coach give us made a difference. It also relieved the stress of the rest of the work. It was fun.
I was surprised by how helpful the staff was. They helped me grow, provided best pointers. They would watch us and stop us when we went in the wrong direction.

It was a great team. They really complemented each other. Dr. [design prof.] helped us with software. [Engineering prof.] helped us with mechanics. It really helped that they came from different disciplines. And [the graduate assistant] was helpful in so many ways.

Figure 2. Focus group quoted from students when asked about their interactions with the facilitators and expert staff.

FOCUS GROUP: PEER TO PEER

Students acknowledged that teamwork could be difficult, that it took time to forge a good working relationship and that sometimes having known the person first was an advantage (Figure 3). 'Persevere' was often used to describe team working which reinforces the complexities of collaboration, especially when the team is interdisciplinary. When asked about their experience with collaboration outside of their own field of study, students responded with thoughts that mirrored the often-siloed approach to undergraduate education (Figure 4). Knowledge of what other disciplines do, and how they can contribute to the inventing process is crucial and was clearly missing from their college experiences thus far. The positive student experiences collected from this interdisciplinary approach is therefore pedagogically relevant and supports other experiences that have been curated in the industrial design studio (Manfredi, 2019a).

Keep an open mind. If you disagree and can't resolve it, get another option.
Communication was an important learning [outcome].
If you disagree, you need to persevere and learn to make concessions.
Our previous friendship made it easier.
We became friends through this process.
We didn't know each other before. We learned what ticked each other off.
It was hard at first. It took 3 days to learn how we could work together.

Figure 3. Student's thoughts on their partner, disagreements, and working together.

During the year I only get to work with others in engineering. In this project, I worked with designers. Our skills matched up perfectly.
I had no idea what design was. I learned what skills I don't have.
Invention is about all fields.
Got a chance to explore fields other than the usual.

Figure 4. Student's thoughts on working with people outside of their chosen major.

5. CONCLUSION AND FUTURE WORK

This pilot study looked at how students perceived their gain in various soft skills during a 6-week interdisciplinary invention accelerator program. Given the diverse fields of study and academic standing, student's pre-program skills self-assessment level ranged in physical making, oral, and written communication. Through various teaching techniques employed throughout the program, all student teams successfully worked through a hybrid engineering and industrial design process to produce a working prototype, file a provisional patent, and pitch their invention to a non-expert audience of judges. The skills developed during the program were evaluated through self-assessment and focus group studies and generally pointed to improvement in multiple areas associated with effective communication.

There are limitations to the reporting in this initial study. Firstly, the results could be specific to this group of students. Without identifiers that link self-assessment scores and focus group reflections with a discipline, it is impossible to assess whether students from a specific major benefitted more, or less, from the program objectives. Secondly, the self-assessment and reflections were conducted at the end of the program, therefore do no capture the challenges and breakthroughs as they happened. Thirdly, whilst it is shown that there are gains in perceived skills at the end of the program, it is currently unknown whether the skills gathered and the lessons learned through the program positively impact their continued academic experience in and beyond the lecture theater.

To address these limitations, a longer-term study is proposed that looks at multiple years of the program that does track data with discipline. To capture data throughout the six-week journey, the goal is to implement a midway self-assessment check-in and include more regular contact with individuals throughout the process either through interview or journaling. It is anticipated that a longitudinal study will be developed to track each student after invent@SU to examine how the skills gained during the program shape the rest of their undergraduate education and career choices post-graduation. Of additional interest is the professional identity of the students before and after the program. A study on professional identity is also proposed to see how this program shapes how one perceives that own discipline and how it intersects with others. Lastly, a larger program of research is proposed to investigate how educators can embed methods into their teaching to improve the working relationship between industrial designers, engineers, and other non-design centered disciplines into the curriculum.

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