The Invention Studio: A Student-led Fabrication Space and Culture

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Creativity, invention, and innovation are values championed as central pillars of engineering education, particularly in Capstone Design courses. However, university environments that foster open-ended design-build projects are uncommon. In addition, fabrication and prototyping spaces at the university level are more like 'machine shops' where capstone students must contract out their actual building activities. The desire to make design and prototyping more integral to the capstone experience led to the creation of The Invention Studio, a free-to-use, 3000 ft^2 maker space and culture at the Georgia Institute of Technology. Though initially founded specifically for the Capstone Design course, the Invention Studio has taken on a life and culture of its own, far beyond just a capstone design prototyping lab. There, 500 student users per month hang out, create things (using $1M of capital equipment), meet, and mentor each other for at least 25 courses as well as independent projects. The Invention Studio is centrally managed and maintained by an undergraduate student group with support from the university staff and courses. Herein, the underlying motivation, organization, facilities, safety, funding, and intellectual property policies are described in an effort to guide others in the creation of such an environment. The Invention Studio's facilities, infrastructure, and cultural transformation are demonstrating the value and sustainability of hands-on, design-build education to stimulate innovation, creativity, and entrepreneurship in engineering undergraduates, in capstone design courses and beyond.

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Introduction

The Engineer of 2020 recognizes that creating, inventing, and innovating are essential skills for engineers[1]. It is the prospect of engaging and cultivating these skills that encourages many undergraduate students to consider studying engineering. However, in standard engineering curricula, students do not generally create or invent anything tangible until the culminating Capstone Design experience. This postponement can be credited to a shift in engineering education that occurred between 1935–1965[2]. Engineering curricula changed from hands-on, practice-based curricula to theory-based approaches with a heavier emphasis on mathematical modeling.

As counter-trends have emerged, some programs have now initiated freshman design experiences [3, 4]. The benefit of such experiences has been demonstrated at the University of Colorado Boulder, where students who participated in an early design experience were retained at a statistically significantly higher rate than similar groups of engineering students without such introductory experiences[5]. This finding speaks to the potential benefits of practicing creative activities early and often. The overarching goal of Georgia Tech's Invention Studio is to provide a place—a maker space—for students to apply classroom theory to, or simply experiment with, design-build projects, tools, materials, and mentoring within a community of their own management, independent of curricular requirements, classroom projects, or hierarchical structure of coursework. The space enhances the Capstone Design experience, while allowing students to experience design-build activities much earlier on in their studies, both in and out of the classroom. This paper provides an overview of the studio, its management structure, and some of the perceived impacts it has had on the capstone experience and on the student experience in general.

Overview of the Invention Studio

In 2009, the Georgia Institute of Technology (Georgia Tech) recruited its first student volunteers to manage a prototyping facility for capstone design students. Eventually, that space would become the Invention Studio: a continually expanding, "student-run design-build-play space" open to all students. As of 2013, the Georgia Tech Invention Studio is housed in the Mechanical Engineering department, and is a 3000 ft^2 state-of-the-art prototype fabrication facility used by 500 different students per month (See Fig. 1). Each semester, 25 classes, some ME, others outside of the discipline, utilize the facility, and students may also use the space for personal projects. The facility is managed and maintained by the Makers Club, which now boasts

Figure 1. (Top) Invention Studio at Georgia Tech, with 500 student users per month, (Middle) A team works on a robot for a sophomore-level ME Design class, (Bottom) A student creates and inlaid wooden guitar

over 70 undergraduate student members. Equipment worth almost $1M includes 3D printers, laser cutters, a waterjet cutter, injection molding, thermoforming, milling, and more, along with lounge, meeting, assembly, and testing space. Over 30 companies have donated resources to build and support the facility through the Invention Studio's connection to the Capstone Design Course. The studio is free-to-use and is accessible 24/7. It is a multidisciplinary endeavor, staffed and utilized by students from the colleges of engineering, sciences, and architecture. The Invention Studio seeks to (1) provide students with free access to hands-on, state-of-the-art prototyping technologies; (2) serve as a cultural hub and meeting ground; bolster design (3) within curricula and (4) as an extracurricular; (5) encourage collaboration between diverse teams of students from all years and majors, (6) welcome all types of projects, personal and professional; (7) excite students for careers involving creativity, design, innovation, and invention; (8) enable students to tackle open-ended, real world challenges; and to (9) serve as an exhibit and tour space to enhance the university's ability to recruit top students and to enable Georgia Tech.

The most unique aspects of the Invention Studio as compared to similar university and community maker spaces communities [6-8] are as follows:

- primarily student-run and "owned"
- accessible 24/7 for Makers Club, daytime hours for all users
- lacking restrictions on types of projects (e.g,. personal art projects are as welcome as course requirements)
- free-to-use
- state-of-the-art and well-equipped
- intimately linked to the design curriculum
- centrally located on campus

Management Structure

A student club called the Makers Club "owns" and runs the space. As of this writing, the club has approximately over 70 volunteer members, comprised of undergraduates from a diverse set of majors and years. Students in the Makers Club staff the Invention Studio for 4 hours/week in exchange for 24 hour keycard access. During this "shift," the Makers Club member on duty is called an Undergraduate Lab Instructor (ULI) and wears an identifiable arm band. During their 4-hour shifts, ULI's are responsible for leading other students in the use and maintenance of the lab and ensuring that resources remain available to those who wish to use them. These activities include machine training, repair, design and manufacturing advising, safety supervision, and cleaning.

Students generally enjoy this duty because they are able to help their peers, learn about a wide variety of design and manufacturing tools, build their resumes with skills, and gain leadership experience. Of course, 24 hour access is a real perk as well and leads to weekend long hacking sessions involving everything from pumpkin carving to Battlebot building.

The Makers Club has spending authority on social activities, tooling repair and maintenance, and expansion of the equipment and space layout. In

consultation with faculty and staff advisors, their needs are considered in proposals and plans.

Their ownership of the space has led to unexpected and wonderful cultural roots as well as spontaneous initiatives. For example, the ULI's and Makers Club members regularly run evening workshops on topics such as microcontroller programming, motorized scooter design, book binding, kitting, and others. The ULI's are supported in their mission by several paid university staff.

Impacts

Preliminary survey results of recent alumni who utilized the Invention Studio during their time at GT indicate that over 80% of users completed at least one class project (such as a capstone design project) within the facility. However, the Invention Studio is also frequently for personal projects, including Halloween costumes, Battlebots, and projects for student organizations, many of which have an engineering flavor. Many traditional university building spaces, such as machine shops, do not allow students to pursue non-academic projects. This may be a critical feature for the long-term engagement of students and community building, which will be studied in future research.

From the anonymous survey, a couple relevant quotes about the impacts of the studio are provided:

"*The studio has had a transformative effect on my education, job prospects, and career. During my years at Georgia Tech, engineering coursework was heavily weighted towards theory and abstraction…Time spent in the Invention Studio gave me an intuitive understanding of design principles and rekindled my enjoyment of engineering and fabrication. Furthermore, the skills I learned while at the studio were directly related to positive job prospects post-graduation.*"

"*I left [Georgia] Tech and immediately took a job as a small manufacturing startup's only engineer/designer. Experience with the Invention Studio … allowed me to design and manufacture effective parts from day one. The portfolio built from the Invention Studio … allowed me to skip ~5 years as a junior engineer and move straight into a leadership role*."

Safety

Ultimately, safety and responsibility must be maintained in a delicate balance with freedom, accessibility, and creativity in a space that encourages undergraduate students to use powerful machines. To promote and reward creativity, there are few strict rules in the Invention Studio—for example, clean up, do not hurt yourself or the machines, respect the people and culture, wear safety classes, keep hair short or pulled back, wear closed toed shoes. Penalties for disrespecting these few rules are severe and swift: one strike and violators are out. Approximately once per semester, a student who is disrespectful to the ULI's or the equipment is banned from the studio. It is important that students realize that studio use is a privilege and not a right.

In this way, the students are encouraged to be careful and aware of their surroundings in the Invention Studio, fostering a culture of safety through personal responsibility and ownership rather than through traditional 'top-down' rules. The culture of ownership, personal awareness, and responsibility is absolutely vital to the success of this endeavor. It should be noted that the liability in the Invention Studio is covered under the blanket university liability policies and insurance.

Intellectual Property

University intellectual property policies vary; fortunately, at Georgia Tech the policy is that students who are not employees of the Institute, not performing research under a sponsored program, or not using significant resources of the Institute, do not have an obligation to assign their intellectual property rights to Georgia Tech Research Corporation (GTRC). Therefore, undergraduates and specifically, capstone design students, working in the Invention Studio to create inventions keep all the rights to their own ideas. This is crucial for capstone teams who wish to patent their ideas and/or go on to start companies, which is encouraged. Students are welcome to use the Invention Studio all the way through the final prototypes of a product—they just may not sell anything made in the Invention Studio.

Funding and Expenses

Funding has been provided by a combination of university internal and external sources. Expenses for the current Invention Studio are approximately $100k of operations costs and $100k of equipment costs per semester. The largest fraction of the support, approximately 50%, has been obtained through the Invention Studio's connection to the Capstone Design course. The Capstone Design course staff solicits industry sponsors for team projects. The sponsoring companies receive reports and a prototype of the team's solution to the project, along with recruiting opportunities and branding. Since the student teams require a facility to design and fabricate their prototypes, the industry funds can support the maintenance and operation of the Invention Studio, in addition to other course expenses. Beyond the industry sponsors, about 30% of the Invention Studio support comes from the Georgia Tech "Technology Fee Fund." Through an internal competitive proposal solicitation, the Invention Studio receives funding for capital

equipment purchases. Approximately 15% of funding comes from cost reimbursement for support of university research, and. a small fraction of the funding comes from direct donations, either from industry or individuals.

Recommended Strategies for Replication

Visitors touring the Invention Studio often ask, "How can we start one at our university?" The simplest answer is to have a faculty champion to empower the students. The Invention Studio was created by giving keys to a small shop, equipped with merely a drill press, grinder, and hand tools, to 10 students out of 200 in a Capstone Design course. With financial assistance from a successful sophomore design course (ME 2110) [9], the first major piece of equipment, a waterjet cutter, was purchased. These 10 volunteers, selected based on past machine shop experience, needed to use the shop for their Capstone Design projects and gained a distinct advantage over the other teams from this 24 hour access. In exchange for the key, they were asked to volunteer three hours per week to help their peers in the class. Using this method, the Invention Studio opened for 30 hours per week. The link to the capstone design course was a crucial catalyst for the Invention Studio because it ensured that the founding ULI's *needed* to use the studio to be successful in their required projects and that the *industry funding* for the capstone course could support the studio. This link to capstone design for funding and facilities remains as vital infrastructure.

The emergence of a distinct club (i.e., Makers Club) that staffs the Invention Studio, independent of the Capstone Design course, occurred when the 10 volunteers included students not enrolled in the course, from other majors and years. This has the important benefits of ensuring that knowledge can be handed down through generations of students and that the Makers Club can grow to include a large and diverse student population. Through equipment donations and increased funding, the facility expanded, at a rate of approximately one room per year for the past five years. The Makers Club has grown proportionally at a rate of approximately twenty ULI's per year. The Georgia Tech community has been truly amazed by the initiative, independence, and resourcefulness of the Makers Club.

Conclusion

The Invention Studio is changing the culture of Georgia Tech by demonstrating the value and sustainability of hands-on, design-build education to stimulate innovation, creativity, and entrepreneurship in engineering undergraduates. The Invention Studio provides daily evidence that undergraduates can grow and maintain a high-end design-build facility. While this tremendous growth has created new challenges, the potential impacts at GT and beyond are unprecedented. For a two minute video, please visit: http://youtu.be/YTIjvVmTQLY

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