Coaches and Their Impact: One Model for Empowering Teaching Assistants in an Academic Makerspace

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ABSTRACT

This paper presents one possible staffing model for academic makerspaces, and hopes to spark ideas about how to empower student workers elsewhere. The Product Realization Lab, or PRL, is Stanford University's most heavily used makerspace and teaching lab. In the previous year, more than 1,000 students of all backgrounds used the PRL. At the heart of this academic makerspace is the team of 18-20 Teaching Assistants who help to operate and oversee open work sessions in the lab. In this paper, the unique role of Teaching Assistants as design "coaches" will be discussed. Benefits of the staffing model for both Teaching Assistants and their students will be presented. The paper includes a qualitative examination of reflections essays from students in an introductory design and manufacturing course, in order to determine the impact of the Product Realization Lab and Teaching Assistant "coaches" on the students' work. Ideas for improvement of this academic makerspace will be presented.

INTRODUCTION

The Product Realization Lab is an academic makerspace open to all students at Stanford University. The Lab facilities cover 9,000 square feet, and include 5 areas of focus – a woodworking lab, machining lab, foundry, welding/sheet metal room, and rapid prototyping lab. Of the more than 1,000 students who used the space in the previous year, about 30% came from departments other than Mechanical Engineering or Product Design. Each year, the PRL employs 18-20 graduate students as Teaching Assistants (TAs) to help manage the lab. A team of 5 dedicated academic and administrative staff teach courses, train Teaching Assistants, and direct outreach. In addition, a dedicated faculty member teaches several classes in the PRL, the most heavily subscribed of which is the ME 203: Design and Manufacturing course. Fig 1. shows a Venn Diagram which has been adapted from a recent review of academic makerspaces, and shows how the Product Realization Lab model compares to other universities [1].

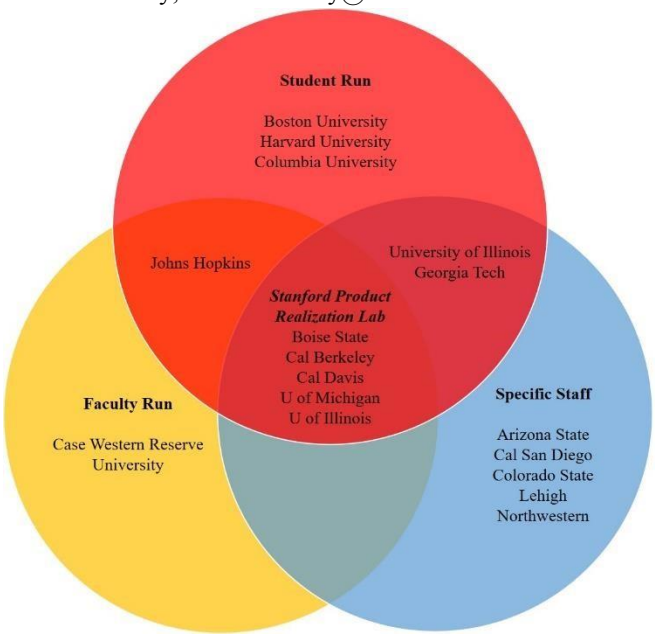

Fig. 1 Venn Diagram comparing different operational models for makerspaces, adapted from [1].

TEACHING ASSISTANT MODEL

One unique aspect of the Product Realization Lab model is the high level of responsibility and reward given to the Teaching Assistants. Each Teaching Assistant is provided a full tuition allowance from the university, as well as a stipend for living expenses. This effectively covers the cost of each Teaching Assistant's Master's Degree.

All PRL Teaching Assistants are graduate-level students; most – but not all – also received their undergraduate education at Stanford. Most TAs come from an undergraduate background in Mechanical Engineering or Product Design, but several other backgrounds are represented, including Business and Civil Engineering. One factor is common to the Teaching Assistants: they have all spent extensive time in the Product Realization Lab working on their own engineering and design projects.

As academic makerspaces at universities across the United States move toward various student staffing models, the graduate-level Teaching Assistant model at the Product Realization Lab warrants further exploration. Other models include the use of student volunteers and undergraduate hourly staff. At Stanford, undergraduate course loads and restrictions on hourly work limit an undergraduate's ability to staff the Lab, and it has long been the belief of the Lab's Director that all student workers doing the same work should be compensated at the same level.

The most significant "product" of the Product Realization Lab are the alumni Teaching Assistants, and there is significant energy and effort that goes into their training and cultivation of skills. Given their critical role as design coaches and mentors, it remains the position of the PRL Leadership Team that graduate student Teaching Assistants are the most appropriate staff for this makerspace.

A. RESPONSIBILITIES

Teaching Assistants in the Product Realization Lab are entrusted with a high level of responsibility. They sign a one-year contract to work with the PRL, and more than 90% return to the TA position for a second year. Their duties begin with two weeks of full-time training, before the academic year begins.

During this training period, the Teaching Assistants learn about safe operation of machines and machine maintenance. They practice teaching 4-hour "structured laboratories" which introduce students to the processes of milling, turning, welding, sandcasting, and finishing. They are trained in First Aid and CPR by the American Red Cross. During these two weeks, the Teaching Assistants form a community that will serve them throughout the school year, by learning how to work together and how to complement each other's diverse skills.

Once the academic year begins, PRL Teaching Assistants are expected to work 20 hours per week in the lab. As a team, they keep the lab open in 4-hour blocks from 8:30am – 11pm, 6 days each week. The Teaching Assistants' official priorities are to 1) supervise student safety, 2) protect the safety of lab equipment, and 3) help all students successfully complete their design projects. In addition, TAs are responsible for grading students' work, and are expected to spend 2 hours each week coaching a small group of novice design students.

There is a range of programming offered in the Product Realization Lab, and TAs are an integral element in each offering: demonstrations, workshops, structured labs, and courses. For example, in Spring 2015, Will Tucker (MSME '15), a Teaching Assistant in the Product Realization Lab, created a course entitled "Scan, Model, Print! Designing with 3D Technology" through the Stanford Student Initiated Courses program. Creating this course afforded Tucker the experience of teaching a group of students the new material that he created. Learning to work with a diverse student body is a skill that all of the Teaching Assistants in the PRL earn through their many hours of engaging with students.

With these responsibilities, the position of a Teaching Assistant in the Product Realization Lab is both physically and mentally demanding. The graduate students who hold Teaching Assistant positions in the PRL also take courses, but they generally do not participate in research lab work. The TAs are encouraged to consider their work with students in the PRL not as just a job, but rather as much a part of their education as a research thesis would be.

B. COACHING

There are twenty courses that are taught in, or supported by, the Product Realization Lab [2]. The most heavily subscribed of these courses is ME 203: Design and Manufacturing, in which more than 200 students are enrolled each year. For many of these students, the PRL is their first exposure to making.

As such, a primary goal of the Product Realization Lab is to teach students to learn resilience in the face of failure. The National Research Council has argued that in the 21st Century, a 'fluency' approach instead of a 'skills-based' approach is necessary in education. Teachers must "empower people to manipulate the medium to their advantage and to handle unintended and unexpected problems when they arise." [3] How does the Product Realization Lab accomplish this goal?

It starts on the first day of class. In ME 203: Design and Manufacturing, Professor David Beach asks all 80 students to stand up, raise their arms, and yell, "I failed!" After several repetitions, some students laugh and others cast nervous glances at their classmates. This exercise helps set the tone that failure is not only commonplace, but that learning from the challenges is something that is celebrated in ME 203.

Teaching Assistants model this behavior while they coach the students on design projects. Once per week during the 10-week course, each TA meets with a consistent group of 4-5 student coachees. Teaching Assistants instruct and grade a series of these students' assignments, beginning with brainstorming. Students are challenged to brainstorm 60 ideas, and to select a project based on a high level of the idea's 1) meaningfulness to them, 2) feasibility to create in the PRL, and 3) uniqueness of product after benchmarking.

Fig 2. Teaching Assistant Jamaal Montasser guides ME 203 students through a structured laboratory on the lathe.

Teaching Assistants coach students through each step of the design process, including:

- Project selection (using a decision matrix)
- Low-resolution prototyping (using materials like cardboard, clay)
- High-resolution prototyping (machining or otherwise transforming metal and plastic)
- CAD Design
- Creating a detailed Bill of Materials
- Product testing and assembly
- Product photography and documentation

Teaching Assistants are trained to "leave students with as much or more momentum as they had previously" after every interaction. TAs consistently use phrases like *what if, could be, maybe, perhaps, let's try it out,* when working with students; these are phrases whose frequent use have been found to encourage exploratory and playful learning in other makerspaces [4]. These interactions contribute to a highly-refined, student-designed project at the completion of the course. An example progression of student work is shown in Fig. 3.

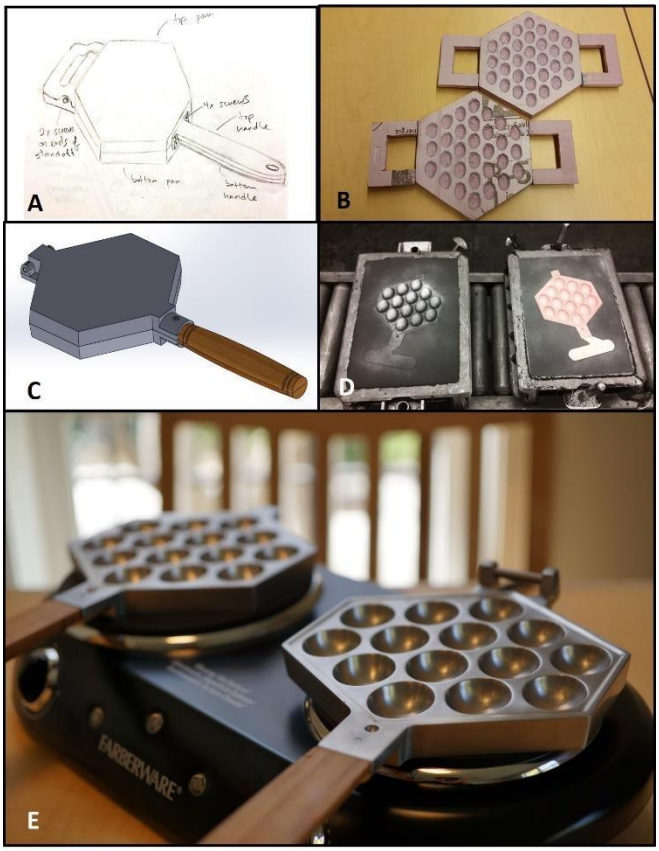

Fig. 3 Process photos of a student's work in ME 203. This "egg-puff iron" went through stages of (A) sketching, (B) prototyping, (C), CAD modeling, (D) sand casting, and (E) final presentation.

C. REWARDS

In addition to financial benefits, the Teaching Assistants receive ample rewards under this makerspace staffing model. TAs can use the lab after hours and during holidays, if accompanied by another person. They also have access to several professional development opportunities throughout the year, such as workshops to learn new skills (for example, a three-day blacksmithing workshop with a local professional smith), and "Meet the Makers" dinners with manufacturing professionals.

The Learning Factory at Penn State, an early experimentation with the campus makerspace, found that makerspaces can provide a kind of "home and social identity" for their students [5]. The Teaching Assistants at the PRL strongly benefit from this social community. They participate in weekly staff lunches, run a winter ski trip, and attend an annual TA Alumni networking event.

Finally, Teaching Assistants are empowered with additional responsibilities in their 2nd year. Veteran TAs chose an area of the lab in which they will become a "Specialist". They spend a majority of their time there, and have the freedom to build improvements for the space, suggest new equipment, and share their knowledge with other Teaching Assistants. Specialist TAs lead specific process workshops in areas such as sandcasting pattern making and silicone molding.

D. IMPACT & INSIGHTS FROM REFLECTIONS ESSAYS

What effect are the Teaching Assistants and the Product Realization Lab having on students? Students of the ME 203 class were asked to write an essay reflecting on their experience. The authors of this paper examined the essays to determine the qualitative impact of the Product Realization Lab. The authors adopted a similar research method which has been used previously by Burke to study makerspaces in libraries [6].

Students were given the following open-end prompt during the last week of the class:

"Write an essay describing what you have learned through the ME 203 adventure."

No other instructions were given. 70 students responded to the prompt in March of 2016. Their responses ranged in length from a short paragraph up to several pages in writing. Each essay was read, and the responses were coded into a set of categories which best matched the thoughts expressed. Then, the responses were tallied to determine the 11 most commonly shared thoughts. Results are shown Table 1 below.

Table 1: The 11 Most Common Reflections of Students in the ME 203: Design & Manufacturing Class.

Response ("I...")	# of Respondents	% of All Respondents
Learned a new manufacturing skill	35	50%
Am proud of my final product	28	40%
Learned resilience in the face of failure	22	31%
Am grateful for the TAs	21	30%
Gained creative confidence	18	26%
Learned the importance of creating a plan *before* coming to work in the PRL	18	26%
Learned time management skills	17	24%
Found prototyping to be valuable	14	20%
Had little prior experience	14	20%
Was challenged by selecting an appropriate project	11	16%
Gained a new appreciation for how things are made	10	14%

The students' responses to the open-ended prompt are informative. They suggest which lessons learned were more memorable – and which were potentially most important.

Students most frequently responded that they learned a new practical or technical skill, such as sheet metal forming, sandcasting, or machining. However, many of the top lessons learned were "soft" skills rather than technical skills.

A significant number of students reported being surprised by how long it takes to "make", and how important it is to learn time management skills. And, while many students felt it important to mention they had no prior experience, an even greater number gained creative confidence and learned resilience in the face of failure.

E. RECOGNITION OF TEACHING ASSISTANTS

A significant portion (30%) of students directly mentioned their gratitude for help received from Teaching Assistants in the PRL. The university has also recognized the effective work of the Teaching Assistants.

In 2015, Stanford awarded the Centennial Teaching Assistant Award to the entire team of PRL TAs, calling them "The Product Realization Lab Nineteen". This award 'recognizes outstanding teaching assistants for their tremendous service and dedication in providing excellent classroom instruction for Stanford students' [7]. It was the first time in Stanford's history that the award was given to an entire group of TAs.

F. IDEAS FOR FUTURE IMPROVEMENT IN THE PRL

In order to better understand the impact of the academic makerspace on students' learning, more directed survey questions are necessary. Current research is under way by Dr. Sheri Sheppard at Stanford University. Dr. Sheppard and colleagues shadowed coaching sessions throughout ME 203, and administered surveys which will help to measure students' motivation levels and to understand the importance of prototyping in students' learning.

How might makerspaces equip their staff to be effective design coaches? One idea is that while universities have makerspaces, they also have athletic programs. The Product Realization Lab Leadership team could offer a workshop for the Teaching Assistants led by one of Stanford's 140 athletic coaches. Coaches might share new ideas with the TAs regarding how to motivate, encourage, or provide timely feedback.

Additionally, many students (26%) responded that they learned an important lesson to create a plan *before* working in the Product Realization Lab. It is important to teach this lesson as early as possible in students' coursework. "Expert" Teaching Assistants might hold 'office hours' in their lab area of expertise. This could be a dedicated time when students receive coaching about topics like tooling, work-holding, and geometry changes to make parts more readily manufactured with the toolset of the lab.

Finally, there has not yet been a longitudinal study about the lasting impact of the makerspace on students after they have left the university. The authors propose a follow up survey with the students studied in this paper, one year after their completion of the ME 203 course. Currently, the Product Realization Lab is building an alumni email list which will include any student who has used the PRL for class or independent work. We hope that this list will spark ideas, create job connections, and cultivate a sense of Product Realization community after graduation.

G. CONCLUSION

A qualitative examination of student's essays demonstrates the impact of the academic makerspace. While students report learning new technical skills, they also frequently learned important "soft skills" such as resilience in the face of failure and time management. Perhaps most important are the newfound pride and creative confidence which students report.

A recent review of academic makerspaces found that the impact of makerspace correlates with the staff support which is provided [2]. The PRL staffing model gives both high responsibility and high reward to its Teaching Assistants. This is one possible staffing model which hopes to spark ideas in other academic makerspaces about how to empower student workers.

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