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First Year Engineering Student Success Enhancement Through the Support of Undergraduate Teaching Assistants

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Abstract

This informational paper describes an approach to utilizing undergraduate teaching assistants (UGTAs) in addressing challenges posed by using Computer Aided Design (CAD) and three-dimensional (3D) printing in a hands-on, first year engineering design class. At Wayne State University, we began using CAD and 3D printing tools to introduce design principles to first-year engineering students in the fall 2017 semester. This was prompted by the desire to involve students with CAD at an earlier stage of their academic careers. Assisting in instructing these principles, UGTAs provide hands-on support for students both during and outside of class and contribute significantly to the operation and maintenance of the 3D printing lab. Near the beginning of the semester, in-class support is focused on helping students during lectures. Near the middle of the semester, their in-class focus becomes more of a project management role as class activities transition to final project design and development. As project managers, each UGTA is responsible for two or three teams and provides guidance with navigating through engineering challenges that may arise. Outside of class, office hours are provided at least once per day by the UGTAs where students can receive help on assignments or other questions related to this course. In addition to providing direct support to students, UGTAs carry the bulk of the load in ensuring designed parts are 3D printed and provided to students with minimum latency. In addition to reviewing component suitability for printing and starting new print jobs, the performance of routine maintenance is primarily performed by the UGTAs. Lab support during the project assembly phase and training in-coming UGTAs are also tasks performed by the UGTAs. This paper will provide an overview of our approach to incorporating the efforts of undergraduate teaching assistants into a first-year engineering design class to assist other institutions with integrating that same practice.

Introduction

For several years at Wayne State University, engineering design principles were introduced to first-year engineering students using Lego® robotics systems. To create an environment that helps students learn through projects more resembling industrial trends, the transition from Lego® robotics to Computer Aided Design (CAD) and 3D printing began in the Fall semester of 2017. Our new class is required for mechanical engineering students but is open to all disciplines. This usually makes the class composition 75% mechanical engineers. Because this course is inclusive, included in the curriculum is an overview of all engineering disciplines, as well as a project on engineering ethics.

The benefits of this approach are generally two-fold. First, this course allows for an early introduction to CAD, and the manufacturing process allowing the students to learn transferable skills [1]. Additionally, this course provides an option to incorporate embedded controls, which can be a valuable resource for early engineering students [2]. By learning transferable skills, students are offered a greater opportunity for employment. Second, the CAD and 3D printing approach allows for a higher rate of student engagement because of the increased use of UGTAs [3]. This has proven to make students more likely to meet the learning objectives, while also creating an environment that cultivates real-world problem-solving skills [4-5]. While these benefits were substantial, new problems arose that needed to be addressed: there was a significant reduction in instruction time due to the latency of 3D printing later in the semester; and additional manpower was required to keep latency at bay between design submission and printed products.

At our institution, those problems were addressed largely through the employment of a team of undergraduate teaching assistants (UGTAs). UGTAs are students who have completed with excellence the first-year engineering design course, and in so doing, demonstrated strong communication and leadership skills. It has been found that employing UGTAs to assist with the learning experience for first-year engineering students has had a significant positive impact [5-6]. This employment gives UGTAs a chance to expand their mentoring, instructional, and project management skills.

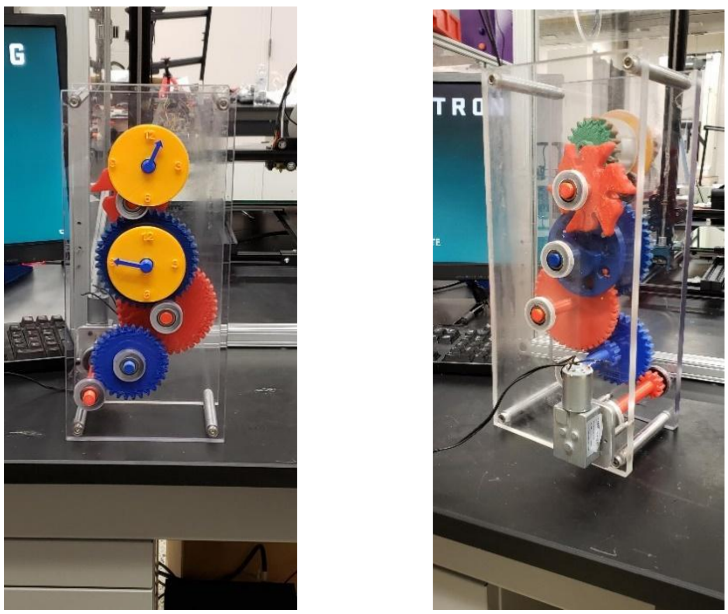
This paper presents an approach to the employment of UGTAs for successful implementation of a first-year engineering design course incorporating CAD and 3D printing by delineating their roles and responsibilities.

In-Class Support

The initial focus of the class is on the fundamentals of CAD. It is imperative that all students quickly adapt a rudimentary understanding of these skills since this expertise is the foundation for the rest of the semester. Step-by-step instruction is provided during the initial lectures, while UGTAs take on the responsibility of assisting any students that aren't on pace with the class as a whole. Utilizing one-on-one teaching, provided by UGTAs, during a larger lecture, allows for students who are advanced to continue -- reducing time waste and boredom – while keeping students who need help from falling behind. During this part of the semester, the UGTAs provide timely feedback by grading assignments within one week of submission, thus enabling students to learn from their mistakes, ask questions, and improve their performance prior to the ensuing assignment. By creating a strong classroom bond between students and UGTAs, our first-year engineering class is able to stay on track, while accommodating a wide diversity of students' learning styles and speeds.

As the semester progresses, the UGTAs take on a more significant role in the classroom through the responsibility of project management and help ensure that the classroom functions efficiently as a project-based, problem-solving environment. Each UGTA oversees two or three teams of four students each, as they work to create their final projects by coordinating project planning, encouraging an atmosphere of openness and acceptance, ensuring an even distribution of workload and coordinating the procurement of needed items that will not be 3D printed. By encouraging an atmosphere where students feel they can voice questions and ideas freely, UGTAs are able to help teams create projects that are tailored to their own specific interests. Typically, this involves selecting a generic mechanical project from a pre-approved list and giving it a unique twist through a mechanical enhancement and/or adding embedded controls. An example is shown below, figure

1, is a traditional clock that has been reimagined to show all the hands-on different clock faces. Another example of changing traditional objects is a wagon whose wheelbase functions as a scissor jack. As project development continues, UGTAs assist in identifying which outlying parts should not be self-modeled and manufactured (i.e. wheel bearings, extra bolts, embedded control components) and oversee cost-effective purchase of those materials. UGTAs also coordinate meetings between teams and the on-campus machine shop to create certain components that are not suited for 3D printing. An example of this is a clock that required a tough, transparent outer casing. This team was able to coordinate with the machine shop to create a plexiglass body (Figure 1).



Figures 1. Clock Made with Help from Machine Shop.

Additionally, UGTAs improve efficiency by helping teams avoid pitfalls through ongoing contact with their teams. Steps taken to make this happen range from helping with professional ways to work through group conflicts to helping students create alternative potential problem solutions for the purpose of improving their designs. The UGTAs also help to ensure that components are 3D printable with the resources available. This includes overall component size and project print time and that proper units (mm) are used for all 3D printed components.

Tutoring Outside of Class

Throughout the semester, the UGTA team provides ample opportunity for students to obtain help outside of the classroom. Much of this outside help is provided during office hours. The teaching assistants collaboratively create an efficient schedule for the semester that offers multiple hours of assistance every day, so that all students have access to this resource when needed. During office hours, UGTAs provide help with homework as well as engage in conversations with the students pertaining to ideas or alternative approaches to produce parts for their final projects. The goal of office hours is to create a place to ask questions and to cultivate engineering thought so that new and better ideas can be put into practice by the students. UGTAs create a log of students that attend office hours, as well as the student's reason for attending (Figure 3). In keeping this log, UGTAs become a critical part in tweaking the instruction of lectures -- being able to make changes that are tailored to student needs. This also allows the team of UGTAs and their lecturer to see which students are making an extra effort for success.

Date	Start Time	End Time	Student Name	[redacted]	Sec	Description of problem/resolution
1/14/2020	3:00pm	4:00pm	[redacted]		4	Homework assingment 1
1/14/2020	3:00pm	4:00pm	[redacted]		4	zip file
1/14/2020	3:00pm	4:00pm	[redacted]		4	Home work assignment 1 questions 1-4
1/21/2020	3:00pm	4:00pm	[redacted]		4	Home work assignment 2 question 1
1/21/2020	3:00pm	4:00pm	[redacted]		4	Homework assignemnt 2 drafting
1/21/2020	3:00pm	4:00pm	[redacted]		4	Homework assignment 2 revolving 8 degrees. and drafting
1/28/2020	3:00pm	4:00pm	[redacted]		4	Mirror feature on W and representing chamfer and minor diameter on HW 3 dradting
2/4/2020	3:00pm	4:00pm	[redacted]		4	HW 4 drafting exploded veiw and naming convention
2/4/2020	3:00pm	4:00pm	[redacted]		4	HW 4 aligning the shaft with thr u-support
2/4/2020	3:00pm	4:00pm	[redacted]		4	HW 3 creating the bracket, fillets and rounds
2/11/2020	3:00pm	4:00pm	[redacted]		4	HW 5 problem 1 creating circle with fillet

Figure 3. Example of UGTA Help Log.

Fabrication and Assembly

Laboratory operations, primarily executed by UGTAs, consist of 3D printing components, maintaining and repairing 3D printers, and overseeing student project assembly activities. Responsibilities related to 3D print components are as follows: preparing print jobs using the on-site CAM software (Cura™); execution of 3D printing jobs; tracking and organizing printed parts for each individual/team; maintaining the printers; and troubleshooting and correcting problems that arise. Cura provides a means to arrange models of parts on a virtual print bed; shows where support will be needed during the printing process; and provides estimates for material quantity and time needed for each print job. To help manage printer operation, printer configuration and utilization, track performance and print job status, and diagnose problems, a print log is maintained for each 3D printer. As each job is loaded onto a printer, the operator fills out an entry in the print log which provides the following: information for print setting optimization corresponding to print filament types; an indication of ownership; an estimated time that the printer will next be available; and a point of contact in the event of failure. An example of a print log entry form is shown in figure 4. The print logs allow comparison of material mass estimates provided by our CAM tool to the actual mass of the completed parts, resulting in more efficient use of print filament. Additionally, use of the print logs help in preventing problems with printing before they happen. Although the TAs are at different levels of printer knowledge, diligence in maintaining these logs and general team support enable newer, less experienced UGTAs to fix many of the problems that arise prior to the midpoint of the semester.

	Print Log For Printer:				Nozzle Size:					
	Operator	Start	Slicer	Applicatio	Description	Filament		Support	Act.	Job
	Name	Date	Time	Section	.gcode filename	Type	Brand	Type	Wgt	Status
	ID	Time	Wgt Est.	Name	slicer used	Diam.	T_{nozzle}	Density	(g)	
1										

Figure 4. Example of Print Log.

Prior to the onset of the semester, UGTAs collaborate to create an efficient process that works for them, the students, and the coordinating professor resulting in the ability to print almost continuously, thus minimizing the time between design and final product realization to the greatest extent possible. The drawback to this near-continuous use of printers is the increase in maintenance and troubleshooting effort required. UGTAs perform most of the maintenance and participate in the troubleshooting process. **Figure 5** shows examples of the monthly and quarterly maintenance logs.

Taz 6 Monthly Maintenance

Printer ID			
	Date	Printed Name	Notes
Clean Printer			
Check / Adjust Belt Tension			
Lubricate Threaded Rods			

Taz 6 Quarterly Maintenance

Printer ID			
	Date	Printed Name	Notes
Check / Tighten set screws on stepper motor pulleys			
Check / Tighten set screws on small gear on the extruder			
Examine Threaded Rod Couplers			
Verify that frame screws are tight			
Check for software updates			

Figure 5. Monthly and Quarterly Maintenance Logs.

During the last few weeks of the semester, focus shifts away from office hours to the printing of final parts. In addition, UGTAs start to oversee student teams assembling their projects. Assembly usually occurs in the lab because teams need quick fixes to problems that may occur; this works out in the form of fixing current parts with tools or having a need for an immediate reprint. UGTAs strive to keep the lab safe and efficient to ensure the completion of final projects during this last phase of the semester.

Conclusion

Support provided by UGTAs has surpassed all expectations. The original intent was that they would assist the instructor in class with students who fell behind, hold office hours to provide further help to students in need, and provide moderate assistance with 3D printing and project assembly. Because of the enthusiasm and initiative of the UGTAs to improve the efficacy of learning, they have taken over most of the responsibilities associated with the 3D printing lab, provided almost all assistance on assignments, and provided valuable insights and ideas which have served to improve the content and delivery of the course. Additionally, they have developed a system for intercommunication to ensure that consistent direction is being provided to students, while at the same time coordinating problem solutions with the instructor. Having been given goals and constraints, ownership in their areas of responsibility, receptiveness to hearing their points of view, and a voice in the decision-making process and in curriculum development, the UGTAs have provided outstanding contributions to the current implementation and future development of this course. In the future, it is expected that greater UGTA involvement will be incorporated into other sections of this course.

Acknowledgment

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