Gotta Catch 'Em All: Teamwork, CAD, and Rapid Prototyping. Learning Graphical Communications Through an Introductory Hands-on Design-Build-Test Project
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Introduction

The maker movement combines creative makers and advanced technologies such as the Arduino microcontroller and 3D printing to drive innovation in manufacturing, engineering, industrial design, hardware technology and education ([1]-[3]). Design-build-test challenges not only provide opportunities for students to learn deeper through making, but also educate next generation engineers in practical concepts such as design reviews, technical communication, and teamwork ([4],[5],[8],[9],[13]). The inclusion of 3D printing and computer aided design (CAD) in these also allows students to experience the realities of the manufacturing and design processes [6] and promotes student engagement [7]. These projects not only "provide an alternative assessment method for students who may not excel on written quizzes and exams" [10], but also teach students technical communication skills [11].

While design-build-test projects are a common pedagogy technique in engineering education [16-19], the ongoing COVID-19 pandemic has also introduced challenges for hands-on engineering learning. As a result of moving hybrid or completely remote, students are lacking the in-person makerspace experience which has shown to improve confidence in engineering design by demonstrating the realities of prototyping and manufacturing ([14],[15]).

An 8-week design-build-test project called the Pokémon Challenge was implemented in a freshman Engineering Graphics course at the University of California, San Diego. This short paper introduces the design challenge and describes some of the implementation obstacles faced during the pandemic related to teamwork, motivation, and the ability to ensure all students were able to participate even if remote. This case study found that despite communication challenges and fluctuations with safe, in-person learning, a hybrid approach to design-build-test projects is still effective in meeting these practical student learning objectives.

Pokémon Challenge

The purpose of the Pokémon Challenge was to allow students to use the engineering design process while building prototyping and graphical communication skills through hand-sketching, CAD, and manufacturing techniques. The project theme tasked students to develop a "Pokémon catching" mechanism that would be creative, aesthetically pleasing, and fit within a budget.

A. *Competition Format & Requirements*

Teams of 3-4 engineers were tasked to move a mass (the Pokéball) from the Start Zone to one of the tiers in the End Zone. Each machine started from rest and was triggered by a pre-programmed Arduino and servo motor. Scoring was determined by a Performance Index which penalized cost and rewarded precision, accuracy, height, and distance from the End Zone. Fig. 1 shows the complete test set-up. A crocheted hacky sack with a mass of approximately 41 g and a diameter of 2" was used as the "Pokéball".

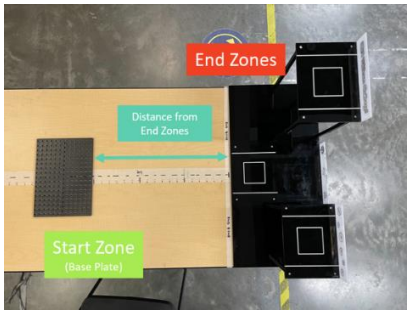

Fig. 1 Test Setup

Each machine was required to have at least one unique 3D printed part per team member, one unique laser cut acrylic part per team member, and one type of connection. Aside from these constraints, the project was left open-ended to promote creative engineering solutions and allow students to experience the engineering design process from start to finish.

B. *Deliverables*

The project consisted of weekly Team Design Reviews to pace the students throughout the quarter. Prior to each review, teams were required to submit an entry in their "Engineering Notebook". Teams started with individual hand-sketching, and initial project planning including designating roles and responsibilities. A draft CAD model, including all parts, fasteners, and the servo motor, was required by the fourth week of the project to begin manufacturing. Two rounds of testing were held during weeks 5 and 6, and the remaining two weeks were dedicated to improving their designs.

In addition to a physical prototype, students were required to submit a complete engineering drawing set using both

SolidWorks and AutoCAD (Fig. 2). Drawing sets included a Title Page, General Notes Sheet, Bill of Materials, Build Schematic, Exploded Views of assemblies, sub-assembly placements, custom part drawings, and experimental test setup views. Drawings were required to be detailed enough so that their parts could be replicated exactly.

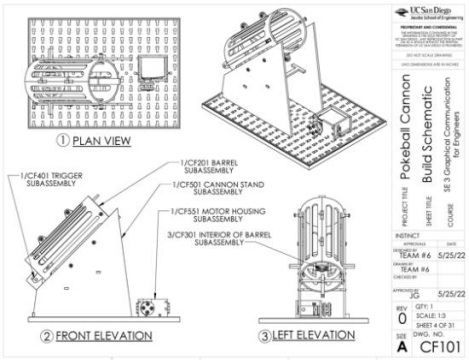

Fig. 2 Sample SolidWorks Construction Drawings

The term project culminated in a final competition and poster session where they showcased their final designs and highlighted key features, challenges and learning points.

Competition Results & Assessment

A. *Competition Results*

The top two teams both had an extendable scoping or scissor mechanism, used mostly custom-made parts, and obtained consistent scores throughout all three testing iterations (Fig. 3 left). Although both teams did not reach the higher tiers, the PI rewarded them for their precision and accuracy, a consequence of their complex design. Many teams were also successful using a launching mechanism (Fig. 3 right), which was easier to construct, but not as precise.

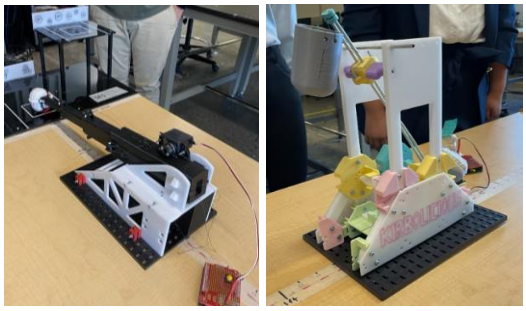

Fig. 3 (left) Extendable Scoping Mechanism, (right) Trebuchet

B. *Survey Results*

The teaching team conducted a survey at the end of the project to understand the students' perspective on their learning outcomes and experience. Out of the 156 students that completed the survey, 95% agreed that the term project was effective in teaching them rapid prototyping and 87% of students agreed that team problem solving resulted in effective solutions. Student comments included, "I liked the creativity aspect of being able to take unique approaches to solve the given problems" and "What I enjoyed most was making the prototypes and testing them because it gave us all a sense of how life as an engineer could possibly be".

Students also expressed concerns about the project. Only 61% of students felt that the amount of work for the project was reasonable, "I think it was too heavy on the work as it was taking over all of my other classes". Perceptions of increased workload in design projects vs. perceived learning value have been reported in the literature [20].

C. *COVID Accommodations*

During the 2021-2022 academic year, UC San Diego courses were permitted to be up to 50% remote with masks required in all in-person classroom environments. Students in this class were required to attend all labs and lectures in-person. However, accommodations were made for those who were ill or quarantined by allowing them to attend via zoom for Team Design Reviews and testing. Although these students were unable to participate in the makerspace, teams were still able to share updated CAD files through GrabCAD and update their Engineering Notebooks with their remote peers. This allowed students to work on flexible communication and collaboration, which is valued by employers, especially as industry becomes more globally connected.

From the student surveys, 80% agreed that the hybrid delivery of the term project (with some students sometimes on zoom) did NOT impact them in successfully getting work done. When asked about the remote portion of the class, 41% of students expressed that attending lab remotely was convenient, especially while completing software heavy assignments. Many students appreciated that the instruction team prioritized their safety with one commenting that "the benefit [of remote lab] was that if someone got COVID, they were still able to fully participate in lab. It was really kind that [the instructors] did this, and it helped many groups".

Conclusions

Implementing a maker hands-on project during a pandemic presents additional complications with supporting rapid prototyping, teamwork, and fostering engagement on top of the existing challenges with design-build-projects. Overall, students found the Pokémon Challenge to be a rewarding experience and recognized that student learning outcomes were met. They were grateful at the ability to join remotely if they had to quarantine or were sick, which allowed them to participate effectively in their team project. Future implementations of this project should improve on streamlining deliverables, establishing a clearer COVID-19 protocol with spontaneous, outbreak and quarantine related issues, and assisting students with time management, so they do not feel so overwhelmed with deadlines.

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