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Transforming the Hands-on Learning Experience in a First-year Engineering Design Class to a Remote-learning Environment

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Transforming the Hands-on Learning Experience in a First-year Engineering Design Class to a Remote Learning Environment

1. Introduction and Background

This evidence-based practice paper describes the transformation of the hands-on learning experience for MAE 3 Introduction to Engineering Graphics and Design at University of California San Diego (UCSD) for remote instruction. As a first year engineering design course, it plays an important role in establishing the foundation for students' principal area of study, teaching basic design methods, and helping the students gain a better understanding of their chosen major, which is essential for their intellectual development and engineering identity formation. As the first design course in the curriculum, the course aims to achieve critical cognitive learning objectives - such as fundamental design principles, basic engineering analysis, basic machine design, and design for manufacturing methods, as well as affective learning outcomes - such as project management and teamwork skills, engineer identity formation, etc. To achieve the desired learning outcomes through a student-centered pedagogical approach, the course integrates traditional lectures and assignments, with Project-based hands-on learning experiences in the lab.

Project-based learning (PBL) is rooted in the science of how people learn through experience[1][2][3], also grounded in social constructivist learning theory [4]. As an instructional method under the umbrella of experiential learning, PBL provides learners with project-based learning opportunities that allow them to apply what they learn to a real-world problem or challenge. Common features of PBL include driving questions, a focus on learning goals, self-directed and collaborative learning activities, scaffolded instruction that allows students to build on concepts, and the creation of a product or artifact[5][6]. When well-designed, PBL can foster creativity and encourage students to apply formal knowledge with experience, make informed judgments, and solve problems in real life contexts[7] – outcomes that align well with engineering design courses. Guo et al.[8] also highlights the potential for PBL to meet both cognitive and affective course outcomes. When integrated into engineering courses, early studies on the effectiveness of PBL in engineering indicate positive effects on student motivation, teamwork, and communication skills[9]. PBL has also shown positive results in sustained student motivation and retention in engineering[10][11][12], sense of self-efficacy[13], and in performance in subsequent engineering courses[14][15].

The remote instruction format forced by the COVID-19 pandemic raised a number of challenges to the course, especially for the PBL perspective. The course includes both lecture and labs, and historically has relied on face-to-face meetings, which allows students coming together to physically work on their team projects in the Design Studio, a lab space where students have access to computers, project workstations, laser cutters, 3D printers, and other machine shop

tools. The online delivery of lectures and tutor-led lab sections provides a great challenge for the instructional team to student engagement, as well as peer-to-peer interactions.

The course's PBL pedagogy is centered around two hands-on projects, both of which involve extensive fabrication and assembly. With the limitations of remote-teaching and social distancing during COVID-19, student access to the Design Studio and equipment was simply not possible, making hands-on work and project-based learning far more difficult as a result.The fact that students have various levels of access to resources created a huge obstacle for them to work on the hands-on project by utilizing materials available from the household. When the course was first taught online in spring 2020, the course survey showed that some students have access to high quality fabrication tools, such as 3D printers and even CNC machine, while others may not even have access to household tools, such as screwdrivers or even a good pair of scissors.

2. Course Transformation

All the challenges described above call for a transformation of the course to adapt to the remote instruction format. The transformation aims to achieve the original course objectives to the maximum extent. The detailed learning objectives for this course are as follows:

Cognitive Learning Objectives (CLO)

- CLO 1: Use the basic principles of engineering graphics and CAD tools
- CLO 2: Identify design problems and design a system to meet desired needs
- CLO 3: Perform effective graphical, written, and oral communication
- CLO 4: Apply the engineering design process
- CLO 5: Design basic machines

Affective Learning Objectives (ALO)

- ALO1: Display effective teamwork for group activities
- ALO2: Build a sense of belonging to the learning community
    - Feel included and welcome in class
    - Build connections to the instructors, peers, and the subject matter
- ALO3: Form an engineering identity
    - Demonstrate interest in engineering
    - Demonstrate confidence in their ability to perform engineering work

Table 1 summarizes the mapping between learning objectives and the corresponding course elements designed to teach and measure each of them.

	Lecture	Lab	Weekly assignments	Individual clock Project	Team robot Project	Interaction with instructional team and peers
CLO 1		+++	++	+++	+++	+++
CLO 2	++		+	++	+++	+++
CLO 3	+	+++	+++	++	+++	++
CLO 4	+			+++	+++	+++
CLO 5	+		+	+	+++	+++
ALO 1	+				+++	+
ALO 2	+	+	+	+	++	+++
ALO 3	+		++	++	++	+++

Table 1. Course objective and course elements mapping for in-person learning

+Taught in lecture or lab, introductory level of mastery
++exercised in regular assignments, medium level of mastery
+++ applied in open-ended hands-on projects, high level of mastery

In the rest of this section, each course element and the transformation will be described in detail. When the course was first offered online during Spring 2020, the instructional team made their best efforts to adapt the course to remote teaching. Reflection on and analysis of instructor and student experiences informed a systematic transformation of the course during summer 2020, with the goal of maintaining all learning objectives from the original in-person course. When the course was then offered again through remote instruction during Fall 2020, the transformation was implemented as follows:

Lectures: Lectures are designed to create the foundation of the course and the PBL course teaching approach, as they introduce a wide range of topics on the fundamental principles of the engineering design process, sketching and engineering graphics, design of machines, engineering design analysis, project management, etc. Lectures during remote instruction are taught synchronously via Zoom, with recorded lecture videos posted to the students right after each class. The instructors modified some of the lecture content and examples, to create more interaction opportunities. The instructor constantly reminded students to annotate on the screen

in order to answer either multiple choice questions or to draw design ideas and solutions. The instructor also encouraged students to use the chatbox to convey their understanding or confusion. A Teaching Assistant (TA) was delegated to assist the instructor with answering questions in the chat box and with reminding the instructor to answer any remaining questions.

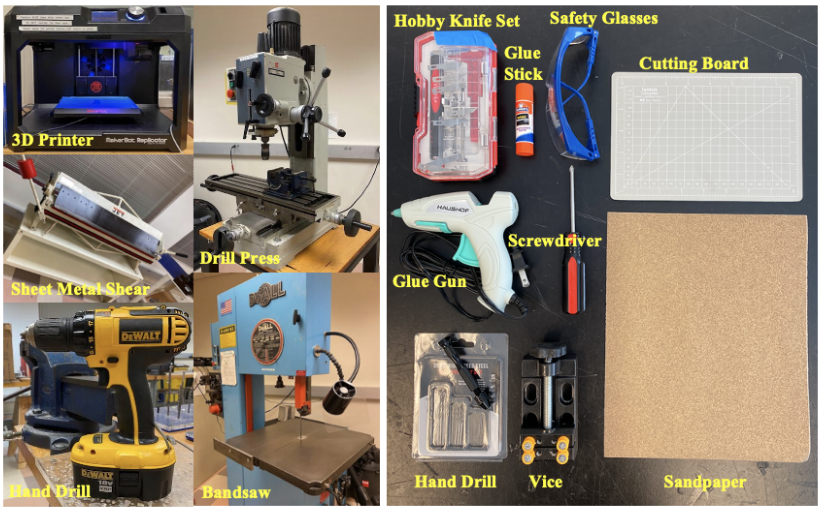
There are also several low-frequency hands-on experimental devices which students usually use once a quarter when they learn particular key machine design concepts (for example, moment visualization, basic machine components such as gears, belt drive, timing belt drive, friction drive, etc.) during in-person learning. Those devices were instead demonstrated to students during lecture either by instructor operation or through videos. The use of the videos and devices in front of the camera are intended to improve student engagement during lecture.

Labs: Labs are designed to be an extension of the lectures, and are critical elements for the PBL course structure. The labs enhance all the learning objectives through a range of hands-on learning activities, such as tutorial-style CAD modeling and basic manufacturing tool training, where students get the chance to apply the knowledge learned from lecture. Labs are also an opportunity for students to design and fabricate their hardware for the course projects.

The lab format and content was redesigned to accommodate the remote learning environment. As soon as the course moved to remote learning in Spring 2020, the design software was transitioned to Fusion 360 because of its cross-platform usability and its cloud-based file sharing capability. To facilitate hands-on learning during the lab and project activities, in Fall 2020, a hardware kit was shipped to the students prior to the start of the quarter. The hardware kit included tools that were designed to serve in place of the function of the design studio (Figure 1). The overall set of tools had to be economic and take into consideration the limited space that many students had to use the tools at home. The hardware kit also contained structural components and stock materials for customized components (Figure 2), energy sources and electrical and mechanical hardware (Figure 3). Figures 1 - 3 demonstrate the comparison between tools and materials students use from Design Studio during in-person instruction and from the hardware kits during remote instruction. More details of the hardware kit information is described in another paper by the same authors that emphasize on the development of hardware kit [16]. Students had to complete their assignments and projects using only the tools and materials from the hardware kits. Both the CAD tutorials and hands-on measurement experiments were rewritten based on the new CAD software and hardware kit.

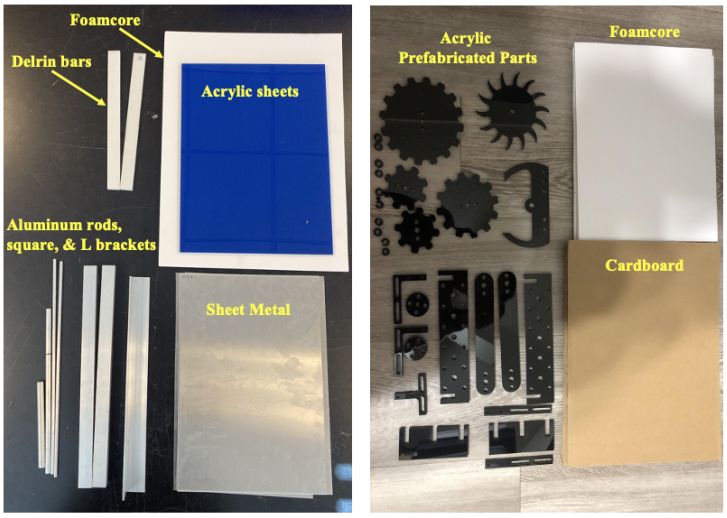
The role of the Instructional Assistants (IA) did not dramatically change once the course was moved to a remote format, but was adapted to the nature and struggles that a remote learning environment presented. In general, students in the in-person and remote versions of the course asked similar types of questions to the IAs during lab sections, although the remote students had more queries about CAD and hardware troubleshooting. Later in the quarter when teams were

working on their projects, the IA would put the teams into breakout rooms and the IA would check in and be available to assist with any questions. Instead of having only one lab section tutor leading the lab, since teaching remotely for the first time in Spring 2020, the section tutors paired up to help facilitate another lab section. Having two tutors is extremely helpful for running the team-based breakout room activities and answering individual student questions.



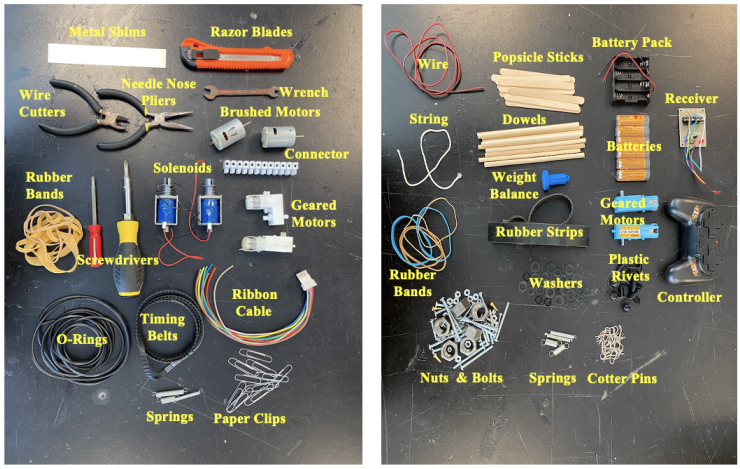
(a) (b)

Figure 1. Selected tools in the Design Studio (a), Tools in the hardware kit (b)



(a) (b)

Figure 2. Stock materials used in Design Studio (a), stock materials and structural component used in the hardware kit (b)



(a) (b)

Figure 3. Energy sources and other components for in-person instruction (a), Energy sources and other components for remote instruction (b)

Weekly Assignments: The weekly assignments are assigned immediately after lectures and labs, usually consisting of close-ended questions. These assignments are designed to help students deepen their understanding of the concepts and skills covered in lectures and labs. The lectures and labs were transformed significantly to maintain the learning objectives, thus the course was able to use the weekly assignments without major changes. Some of the engineering analysis assignments encouraged students to perform a hands-on experiment before doing the analysis, and this had to be done by providing videos to the students instead.

Project 1 - Clock Project: The escapement mechanism pendulum clock project is completed by each individual student during the first 3 weeks of the quarter, and is designed to introduce students to engineering analysis, CAD, manufacturing tools (laser cutter, drills, tappers, reamers, arbor press), design for manufacturing principles, and error analysis techniques they will need to use during the course.

The clock project was redesigned based on the tools, materials and fabrication techniques that could be performed by students in their own homes using the in-home hardware kit. The goal of the redesign was to provide the students the same opportunity to pick up the skills and techniques they need for the robot project, through designing the customized pendulum, fabricating and assembling the entire clock, conducting timing analysis, performing theoretical and experimental comparison. The original acrylic clock stand was replaced with a boxed cardboard stand and base that students need to fabricate by themselves. Insteading of using laser cutters to fabricate the acrylic, students use hobby knife sets and a hot glue gun to craft cardboard components. The fabrication process also enables students to realize the importance of manufacturing tolerance. Some pre-cut acrylic escapement mechanism components (the wheel and pallet) were provided to the students, as the shape of these components requires high precision to ensure accurate operation and timing. Since pendulum design affected the timing of the clock, students were still

required to design and fabricate their own pendulum for timing function and as an aesthetic feature.

Project 2 - Robot Project: Upon the completion of the clock project, throughout the rest of the quarter, students work in teams (3 or 4 students) on an open-ended robot design project. The project theme varies from quarter to quarter, with different tasks that the robot must achieve, but the open-ended nature of the project remains the same in order to give students a large design space to come up with creative designs. Through the robot project, students apply all the knowledge they learned to design, analyze, create, and test. The project also allows them to improve their problem solving, project management, and teamwork skills, as well as develop stronger connections with the instructional team and their peers.

Similar to in-person instruction, the remote robot project was still an open-ended project, promoting students' creativity and problem solving skills. Several aspects of the project and assignments were redesigned to accommodate the remote instruction environment and the new hardware kit, with the goal to maximally achieve the original learning objectives. First, each student needs to fabricate their own robot contest field, so they can use it for the design process for testing, as well as the final competition. A comparison between the in-person contest field example and the remote contest field from Fall 2020 is shown in Figure 4. Detailed instructions were given to the students to complete the fabrication process. Students were also encouraged to add decorative features to the contest fielding without changing the functional structure. For Fall 2020, the project theme was a popular video game, Animal Crossing. The robots need to pick up “fruits” (nuts wrapped by origami card paper with fruit shape) either sitting on or hanging on a “Tree” (tree shape stands made from corrugated cardboard) branches at various heights, then deliver them to the “basket” (a repurposed corrugated cardboard packaging from the hardware kit). This theme was selected from several candidate topics and was chosen in order to create a cheerful spirit among the students during the pandemic. Secondly, different from the in-person instruction when students design and build a single robot, during the remote instruction, the team had to work together to design the robot and validate the design decisions, but each student built their own robot hardware. The teamwork design process ensures the students have the opportunity to work in a team and exercise teamwork skills, the individual hardware allows all the students to have the hands-on learning experience, and all members are engaged with the project throughout the process. With each student building their own robot, the students were able to try slightly different fabrication techniques using the hardware kit, share with each other, and optimize the quality of the robot hardware. Thirdly, the contest tasks were redesigned to align with the hardware kit, potential workload change, and other constraints. During the in-person instruction final contest, the robot was operated by two team members on the contest table, and each team had 4 motors to use in their robot. But during remote instruction, each student built their own robot and operated the robot individually, thus 2 motors were given to each student in the hardware kit. The project task was designed accordingly, such that the robot does not have to travel in 2 degrees of freedom within the plane of the playing field to complete

the tasks. The average workload on the design and analysis for each individual student was about the same, as the team size for in-person was 3 to 4 students, and was reduced to 2 or 3 for remote robot projects. Each student will still be responsible for a motor powered mechanism design or non-motor powered passive mechanism design (such as a trigger mechanism using geometric features). Finally, the final contest, which used to be held in the university stadium, has to be moved online. The final robot contest was held online via Zoom for participating teams, and streamed on Youtube for anyone else to watch. The Youtube streaming helped to allow faculty and staff from the department and students' friends and family to attend the event with less effort, and also kept the online competition safe without worrying about "Zoom Bombing".

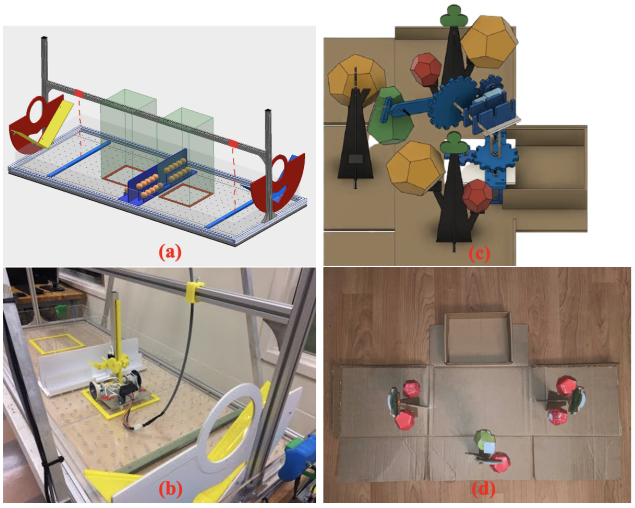


Figure 4. CAD of example contest table for in-person instruction (a), Picture of example contest table for in-person instruction (b), CAD of the contest table for remote instruction (c), Picture of the contest table for in-person instruction (d)

Intensive student interactions with the instructional team and peers: In addition to using the course elements described above to strengthen students' connection with the course content, the class also promotes student interaction with their peers and the instructional team in order to build a sense of belonging through the natural interaction during lectures, labs and office hours. During remote instruction, the instructors and lab section tutors kept closer track of students' lecture and lab attendance. This was helpful to identify students who were experiencing challenges and provide early intervention and additional support. In addition to the instructional team being able to provide additional support to the students, students were encouraged to support their peers as well. The course utilized Canvas (the online learning management system used by the course) discussion boards and Discord (a popular online communication tool). Monitoring the communications on both platforms, students had demonstrated a strong desire to help each other. This also made it easy for the instructional team to step in and clarify any information that students or other teaching staff were discussing. Instructors, tutors and IA take turns to answer students' questions. This discussion board information was automatically saved

and cataloged so that future students and instructional staff may benefit from their content. Students also used Discord to hold their group meetings. During the lectures and labs, the instructors also assign students from different robot teams to breakout rooms. The students found it helpful by having suggestions from people outside their robot team, sharing their experience and providing suggestions to each other. The systematic implementation of these tools definitely helped the class to keep a high level of interaction.

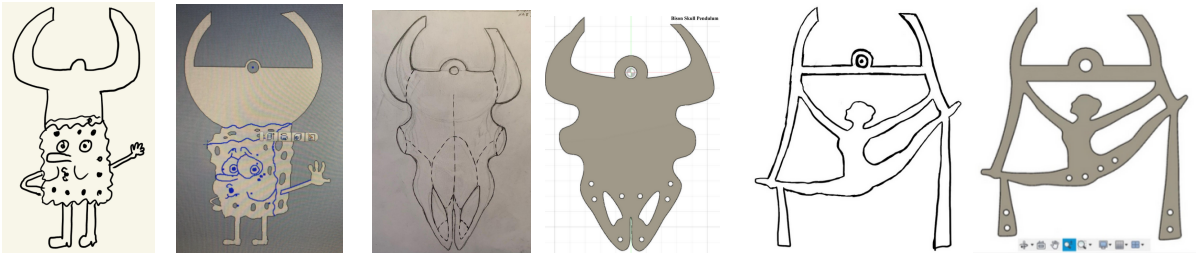
3. Results: assessing the success of the course transformation

This section presents an assessment of the transformed course. Both quantitative and qualitative data are used to assess how the course transformation helped students achieve the course learning objectives during remote instruction. The assessment process followed the ethical principles and federal regulations for the protection of human subjects approved by the UCSD Institutional Review Board. Some of the data was compared between three quarters: Fall 2019 for in-person teaching, Spring 2020 when the class was taught remotely for the first time and which presented the most challenges, and Fall 2020 when the class was taught remotely for the second time, implementing the changes developed during summer 2020.

A. Student performance and instructor observations

Clock Project

The final deliverables of the clock project assess Cognitive Learning Objectives 1 and 4. Students from both the in-person and remote quarters demonstrated a high level of proficiency with hand-sketch graphics and CAD modeling for the clock pendulum. While the clock timing function can be achieved by a pendulum with a simple geometric design, the majority of students chose aesthetic designs with high levels of creativity, rather than simple shapes. Figures 5 and 6 show examples of hand-sketches, and CAD and hardware examples from different quarters. To some extent, this is an indicator that students are highly engaged in the class content. The overall quality of students' final clock fabrication from the Fall 2020 quarter, is also similar to the quality level for in-person instruction. However, students from the Spring 2020 quarter did not have the opportunity to work on the clock hardware. Potentially, this negatively impacted students' perception of the role of the course in their identity formation as engineers, which will be discussed in the next section.



(a) (b) (c)

Figure 5. Sample hand-sketch and CAD work for the clock pendulum design from (a) fall 2019 "sponge bot" , (b)spring 2020 "Bison Skull", (c) fall 2020 "Dancer"

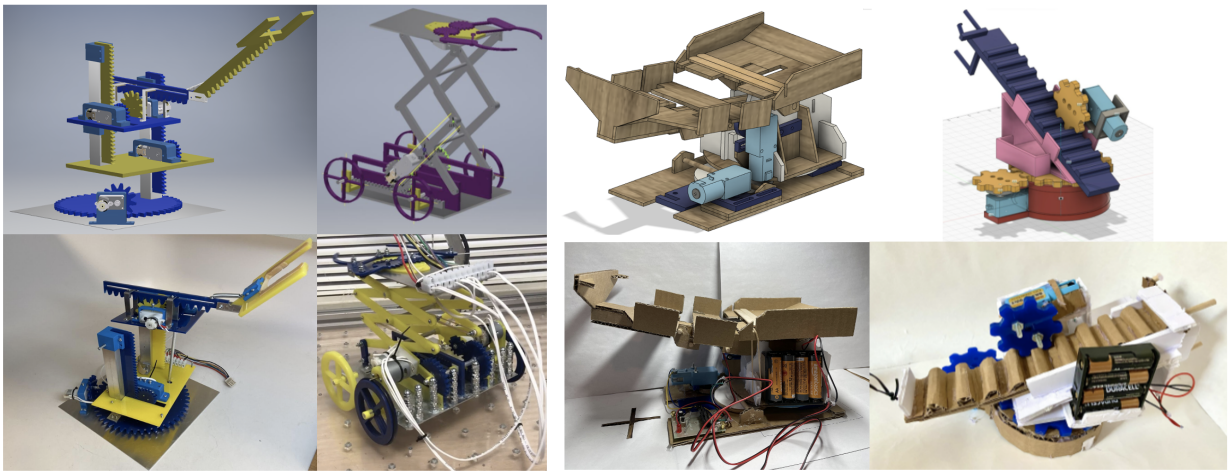
(a) (b)

Figure 6. clock from fall 2019 in-person instruction (a) clock from fall 2020 remote instruction (b)

Robot Project

The robot project requires that students comprehend and apply all the knowledge and skills learned from the course to creatively solve an open-ended problem; thus, it is an appropriate assessment for all the Cognitive Learning Objectives. Because the robot project is team-based, it also effectively measures Affective Learning Objective 1. During the Fall 2020 remote course, students demonstrated proficiency in CAD modeling, machine design and analysis, fabrication, and they also effectively applied engineering design processes to meet desired objectives, and written and oral communication through the robot project deliverables. For the final project report and presentation, the same grading rubrics were used for the in-person (Fall 2019) and redesigned remote versions of the course (Fall 2020). Assessment of the final report and presentation, includes an engineering analysis of the key components of the robot, CAD models, and a review of their video of their working robot. We also use the final report and presentation to evaluate students' written and oral communication abilities. The final project report and final presentation average grade was 78.8% and 87.5% for Fall 2019, and 83.3% and 88.5% for Fall 2020. The robot hardwares was inspected to evaluate the fabrication quality and functionality of the robot. Although the in-person and remote quarters use different tools and materials, the rubric consistently assesses the quality of the robot hardware fabrication based on the given resources, as well as the ability to score. The final robot hardware check-off average grade was 90.8% for Fall 2019, and 86.6% for Fall 2020. In both Fall quarters, students presented a large variety of creative robot designs using different machine elements, such as gears, pulley, rack and pinion, friction drive, linkages, timing belt, flat belts, as shown in Figures 7 and 8.

The project grades are given based on the design documentation and analysis, as well as the final hardware quality and functionality. The final robot competition is an event for celebrating the students' achievement without an impact on their grades. In Fall 2020, 100% of the teams participated in the final robot competition. All teams demonstrated a high level of enthusiasm and engagement during the contest. This was slightly different from the previous quarters. In the past, even when the course was offered in-person, about 90%-95% of the teams participated in the final competition.



(a) (b)

Figure 7. Examples of robot designs from in-person instructions using gear, rack and pinion, and scissor lift (a), Examples of robot designs from Fall 2020 using friction drive, rack and pinion (b)

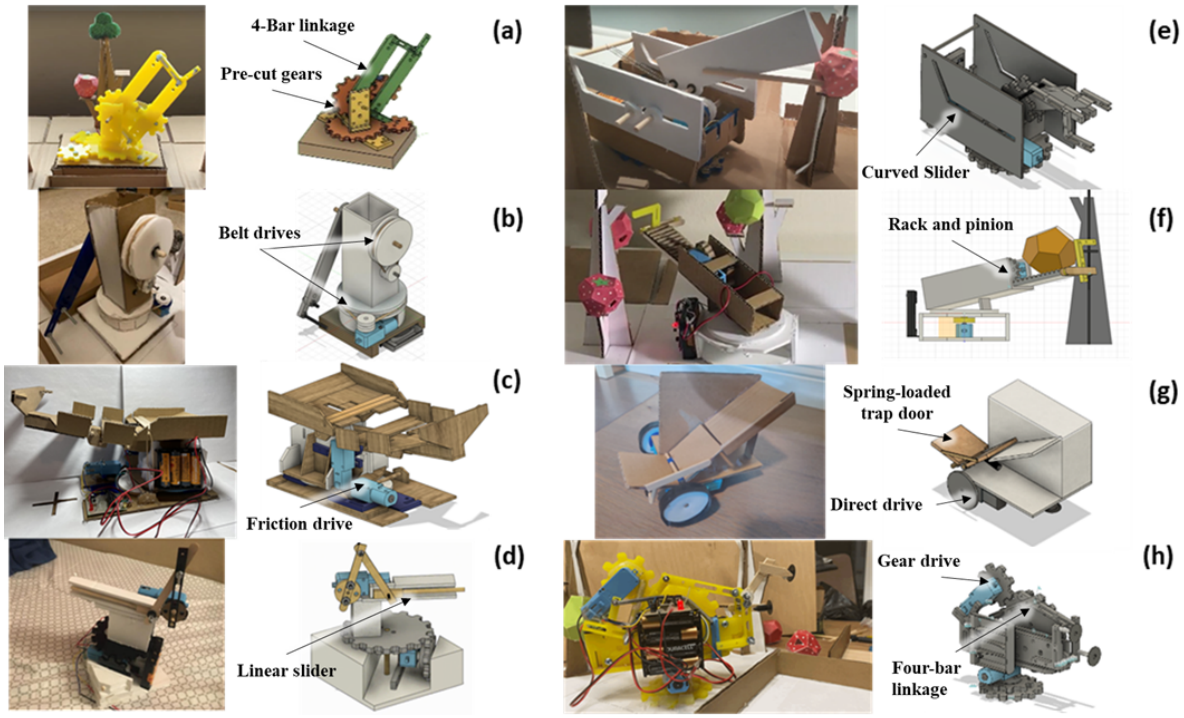


Figure 8. Different design of robots with the hardware kit

Robot using pre-cut gears and four-bar linkage (a)
Robot with two belt-driven components (b)
Robot with friction-drive base design (c)
Robot with linear slider design (d)
Robot with curved slider design (e)
Robot with rack-and-pinion design (f)
Robot with direct drive and spring-loaded trap door(g)
Robot with four-bar linkage and gear mechanism (h)

B. Students feedback

Analysis of Quantitative Feedback

There are two main sources used to collect students' feedback on the course and instructor: the official university Course and Professor Evaluations (CAPE) and a survey created by the instructor. Both sources of feedback provide good metrics to measure Affective Learning Objectives 1 and 3. Figure 9 shows student responses from the CAPE for five questions that aim to measure students perceptions on how the course, especially the hands-on learning experience, shaped their engineering identity by preparing them for engineering (Q1), deepened their understanding of engineering theory (Q2), and motivated them to continue to pursue an engineering degree(Q5). While the responses from the remote courses are slightly lower than the in-person course, the results were a big improvement compared to Spring 2020.

Q3 and Q4 from the self-report evaluations present student perceptions on effective project management and teamwork and show that 68% of the class from Fall 2019, 78% from Spring 2020, and 84% from Fall 2020 agree or strongly agree that the project management was effective. The results also show that 70% of the class from Fall 2019, 86% from Spring 2020, 86% from Fall 2020 agree or strongly agree that the teamwork was effective. One reason we observed is that students developed more empathy and understanding for each other since the COVID-19 pandemic. This provided a good foundation for effective teamwork and project management. In addition, the instructional team was able to foresee the increased difficulty in teamwork, thus conducting additional interventions and proactive actions as described in the previous section, which successfully mitigated the risks.

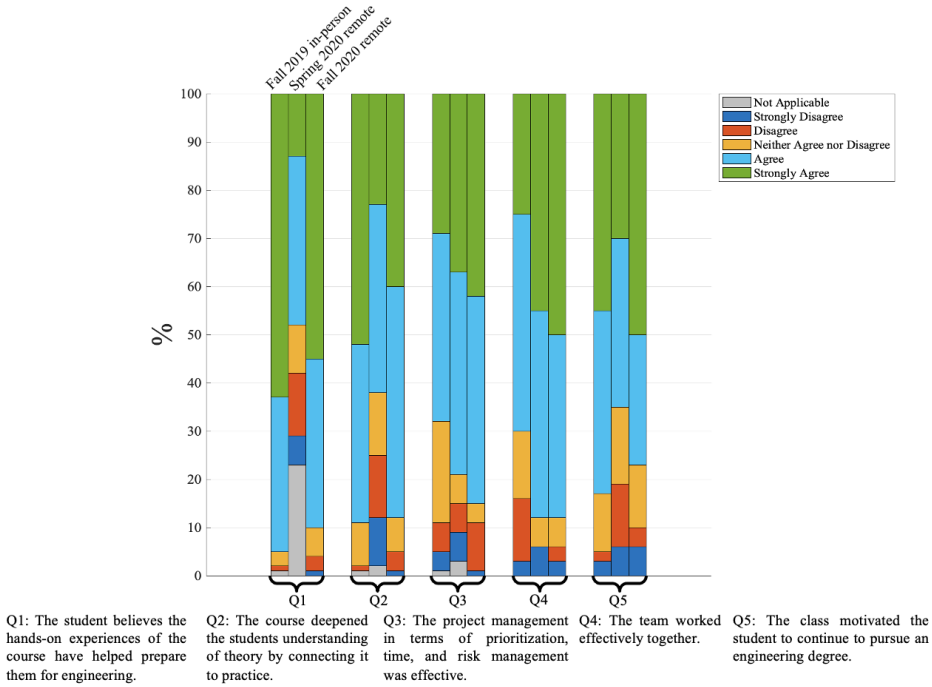


Figure 9. Students' evaluation of how the course elements help to achieve the Affective Learning Objectives

Based on data collected from a Fall 2020 course exit survey, 87.5% of the survey takers (79% of the class population) expressed they felt included and welcomed in the class and lab activities. This provides satisfactory results for Affective Learning Objective 2- build a sense of belonging to the learning community. Finally, 40.8% and 52.1% of the students expressed that the course exceeded and met their original expectations for learning in a remote environment respectively.

Analysis of Qualitative Feedback in Course Evaluations

To assess the extent to which our course transformation addressed our concerns about student mastery of concepts, student engagement in the course, students' interactions with each other and with the instructional staff, we also analyzed student responses to open-ended questions on the course evaluations. These questions invited students to comment on the course itself, the instructor, and to provide examples of the ways the instructor did or did not create a learning environment that welcomed, challenged, and supported all students. We used Atlas.ti to thematically code the qualitative responses from the Fall 2019 (in person), and Fall 2020 (fully remote) quarters. There were too few qualitative responses in Spring 2020 to make any meaningful comparisons or interpretations.

Theme	Fall 2019 Number of related comments from 104 submitted evaluations.	Fall 2020 Number of related comments from 72 submitted valuations
Collaborative Learning and Engagement	13	10
Knowledge and Skills Gained	14	10
Instructor Support	67 - Positive responses 6 - Negative responses	121-Positive responses 10-Negative responses *This number includes comments from each co- instructor's independent course evaluation.

Table 2. Course Evaluations - Text Analysis

Collaborative Learning and Engagement

Student feedback related to collaborative learning and engagement in the course was fairly similar for the in person and remote versions of the course. In both quarters, students note the robot project as a highlight for their learning both engineering and teamwork skills. In Fall 2020 students also noted the teamwork benefits of the robot project, and also commented that the lab sections and virtual breakout rooms were a great way to encourage discussion among students, get to know peers, and to get help from section tutors.

Knowledge and Skills Gained

Feedback from both the in person and remote versions of the course indicate that students appreciate both the hands-on and theory-based nature of the course. Specific skills that students mention learning from the course include: CAD, applied physics, engineering design principles, and teamwork. Their comments made it clear that the toolkits provided them with meaningful hands-on learning experiences. It is important to note that in the Fall 2020 course evaluations, there were only six student comments that specifically mentioned learning in a remote environment. Of those six comments, three related to the time and effort required of the course, which is no different than when taught in person. One student mentioned that there were "elevated communication requirements" as a result of being remote. Two students expressed gratitude to the instructors for their efforts and said the class was fun. Only one student commented that they felt the course did not translate well into a remote environment.

Instructor Support

There appeared to be no differences in the nature of student responses related to the course instructors in the in-person and remote versions of the course. Given the higher levels of stress students have experienced during the pandemic, as well as their own learning curve related to learning in a remote environment, this was somewhat surprising. As noted in an earlier section, we were concerned about the relationship distance the virtual environment might create between instructors and students. Student feedback in the course evaluations for both academic quarters indicates that students felt: 1) Challenged and supported by the instructors; 2) that instructors were knowledgeable, engaging, caring, helpful, and encouraging; 3) instructors were passionate about the subject matter and teaching; and 4) instructors were approachable and available.

While feedback from students related to the course instructors was overwhelmingly positive in both quarters, in Fall 2020 several students noted, in particular, how much work the instructors put into designing and teaching the course. Feedback from student course evaluations related to instructor support that was negative in nature focused on the amount of work assigned in the course, the fast lecture pace, and availability.

Finally, related to feedback that was negative in nature, consistently across quarters, students commented about the significant amount of time and effort required for the course. Although many of these comments are prefaced with, "This is a great, fun, engaging, etc. course," the number and nature of these comments warrant consideration from a curriculum standpoint. Scaffolded instruction is essential to problem-based learning and the assignments and projects intentionally build on each other so that students have a solid foundation of essential concepts, as well as opportunities to work independently and with a team. A consistent concern we face as instructors is providing these essential learning experiences in a ten-week quarter and we recognize the challenging nature of the course.

4. Discussion and Conclusion

The course transformation was a great success in terms of being able to retain the original learning objectives. Compared to in-person learning, one major limitation of the transformation is that students did not have an opportunity to manufacture components by using the actual machines (such as a laser cutter and 3D printer) and tools (such as a bandsaw and drill press) that engineers use to build high fidelity designs. This limitation will be resolved by implementing a "Design Studio machine shop makeup" program when we return to in-person instruction.

Our experiences with transforming the course has inspired us to make improvements to the in-person version of the course when we return to campus. First, when the course is taught in-person, students need to access the design studio to fabricate and test their robots on the six contest tables shared by all students. The design studio is open to students for project work for a limited time and during peak usage times, students need to wait in line to test on the contest table. To solve this problem in the future, the course could consider using portable contest fields, so that students do not need to rely on testing on the only one contest table in the design studio. Secondly, when taught in-person, the final robot competitions were held in a campus stadium. Faculty and students' friends and family are invited, but usually with a low attendance rate due to the fact that they have to be physically present and likely experience scheduling difficulties. During the remote instruction quarters, the competition was held over zoom and streamed through Youtube to the public. This has increased participation from friends and family, as many of the students reflected that their parents watched the competition, and were very proud of them. The instructional team has already received more comments than ever from faculty, and previous MAE 3 students, who were able to watch part of the competition online. The higher participation rate is encouraging for the students, as they put a lot of work into their projects. Thus, the online streaming will be a helpful component to be kept during in-person contests.

In conclusion, this paper describes the transformation made in a first year engineering design class to successfully achieve the original course learning objectives during remote instruction. The course transformation has also inspired ideas on how first year engineering could be better structured in general. The success is a result of careful planning and tremendous support from the institution. The course transformation described in this paper would have not been possible without the support of the UCSD Course Development and Instructional Improvement Program (CDIIP) grant and the Teaching + Learning Commons. The grant financially supported the development of the hardware kit, as well as part of the cost of the hardware kits shipped to the students.

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