



Rapidly Converting a Project-Based Engineering Experience for Remote Learning: Successes and Limitations of Using Experimental Kits and a Multiplayer Online Game

LIANG LI WU

EDWARD ZHU

CAITLIN CALLAGHAN

DEREK IRWIN

DYLAN REINSDORF

VERONICA SWANSON

AUSTIN ZWIRN

DAVID REINKENSMAYER

University of California, Irvine
Irvine, CA

ABSTRACT

To provide a project-based learning experience during the COVID-19 outbreak, we mailed experimental kits to 285 undergraduate students and developed curriculum for a multi-player online robot simulation game. Students successfully achieved cognitive objectives and rated the remote learning experience comparably to the prior-year in-person implementation. However, there was a 10% decrease in self-reported motivation for the project and only 15% of students endorsed offering the course online in the future. Students most frequently felt that reduced quality of interaction was a key difficulty (43%) and seldom identified reduced hands-on experiences (7%) as a difficulty, a course aspect they identified as the most motivating. Preserving the known benefits of project-based learning for engineering retention will likely require improving remote collaboration strategies for hands-on activities.

Key words: Remote learning, project-based learning, collaborative learning

INTRODUCTION

Project-based engineering courses increase student retention and improve student learning (Pomalaza-Ráez and Groff 2003; Yadav et al. 2011; Knight, Carlson, and Sullivan 2007), particularly



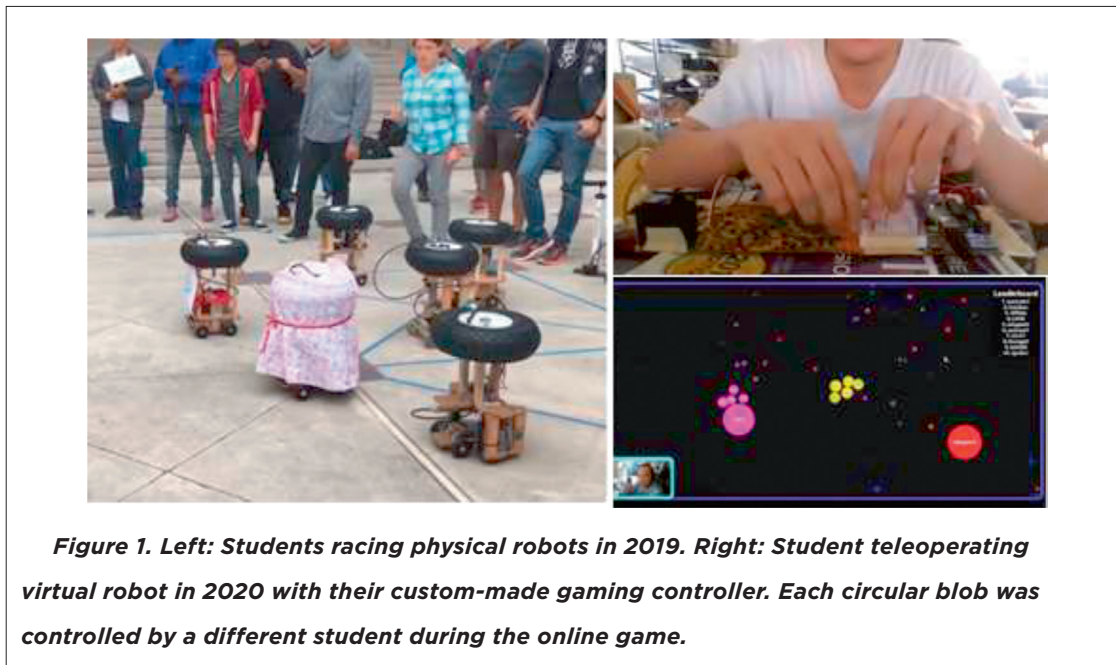
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if they emphasize hands-on and collaborative experiences (Razzaq 2003; Jones et al. 2013), which are also highly valued for personal and professional growth (Alpay et al. 2008; Chanson 2004). Unfortunately, remote learning requirements due to COVID-19 now make it difficult to provide these valuable experiences. Practical challenges include supplying equipment, fabricating at home, ensuring safety, remote troubleshooting, and facilitating collaborative learning.

METHODS

In Spring 2020, 285 students enrolled in “Mechanical Systems Laboratory”, a required upper division course whose cognitive objectives are to understand the theory, implementation, and measurement of linear dynamical systems and controls. Students traditionally perform six three-hour long experiments in teams of three in a campus laboratory staffed by teaching assistants (TA). For the final project, they design and build a robot that competes in a race (Figure 1).

UC Irvine announced classes would be online three weeks before course onset. When considering how to replicate the course hands-on experiences remotely, we decided to utilize the accessibility of consumer mechatronic parts. Within three weeks, we assembled and mailed 285 experimental kits to students, comprised of various user-friendly mechanical and electrical components. We redesigned the laboratory experiments for kit compatibility, preserving the integrity of the learning content. Three international students in shipping-restricted areas eventually used an online platform (Tinker





CAD) to simulate the physical circuitry for experiments. We provided a safety lecture and required students to display safety rules at home.

To provide a similar project-based learning experience while remaining in the scope of our cognitive objectives, we changed the project from building an in-person robot to building an online multiplayer game controller and using it to steer a simulation of the robot (Figure 2). In Phase 1, we assigned students to work in teams of three to design the traditional mobile robot in CAD software (SolidWorks). In Phase 2, students simulated control of their robot (MATLAB). Some students had difficulty reaching teammates in Phase 1 due to the lack of physical accountability of lab attendance. Therefore, while we still encouraged teamwork in Phase 2, we required each student to write code, run simulations, and describe results individually. In Phase 3, we pivoted from physical fabrication through shop processes to developing a homemade gaming controller that controlled the virtual robot. Each student constructed the controller circuitry from the provided kits, coded the control law for their virtual robot, then steered their robot in a multiplayer online game competition that we designed and hosted (Figure 1).

The teaching staff developed the required hardware and software architecture throughout the first five weeks of the course, engaging students throughout the process. Students tested the game server performance on their personal computing environment and provided feedback. Involving students in the development process helped identify bugs, improve server robustness, and engage students in the project.

To analyze achievement of the cognitive objectives, we compared scores from the 2020 to 2019 midterm (multiple choice covering similar content). We encouraged academic integrity by testing in a constrained time window, randomizing question order, showing one question at a time, and requiring signing of an academic integrity statement.

PRELIMINARY RESULTS

All students who received a kit were able to develop a gaming controller and compete in the online game with no safety incidents. As an example of collaborative gameplay, we asked students to demonstrate that they could spell UCI with their virtual robots – an activity that replicated an exercise the prior-year students had done with their physical robots (Figure 3).

Although we required team presentations only for Phase 1, 80% reported continuing to work on a team for the other phases. However, while only 21% reported dissatisfaction with their team-based learning experiences, 65% reported wishing they could have worked more in teams. A hub for informal teamwork was a student-initiated group-chatting platform (Discord) joined by 67% of students.

We compared cognitive and affective outcomes from the 2020 remote (N=272) and 2019 in-person (N=257) versions of the course. Students achieved comparable midterm scores ($69 \pm 14\%$ SD vs. $71 \pm 12\%$ SD in 2019). They rated the course similarly (3.43 ± 0.79 in 2020 vs. 3.55 ± 0.62 in 2019).



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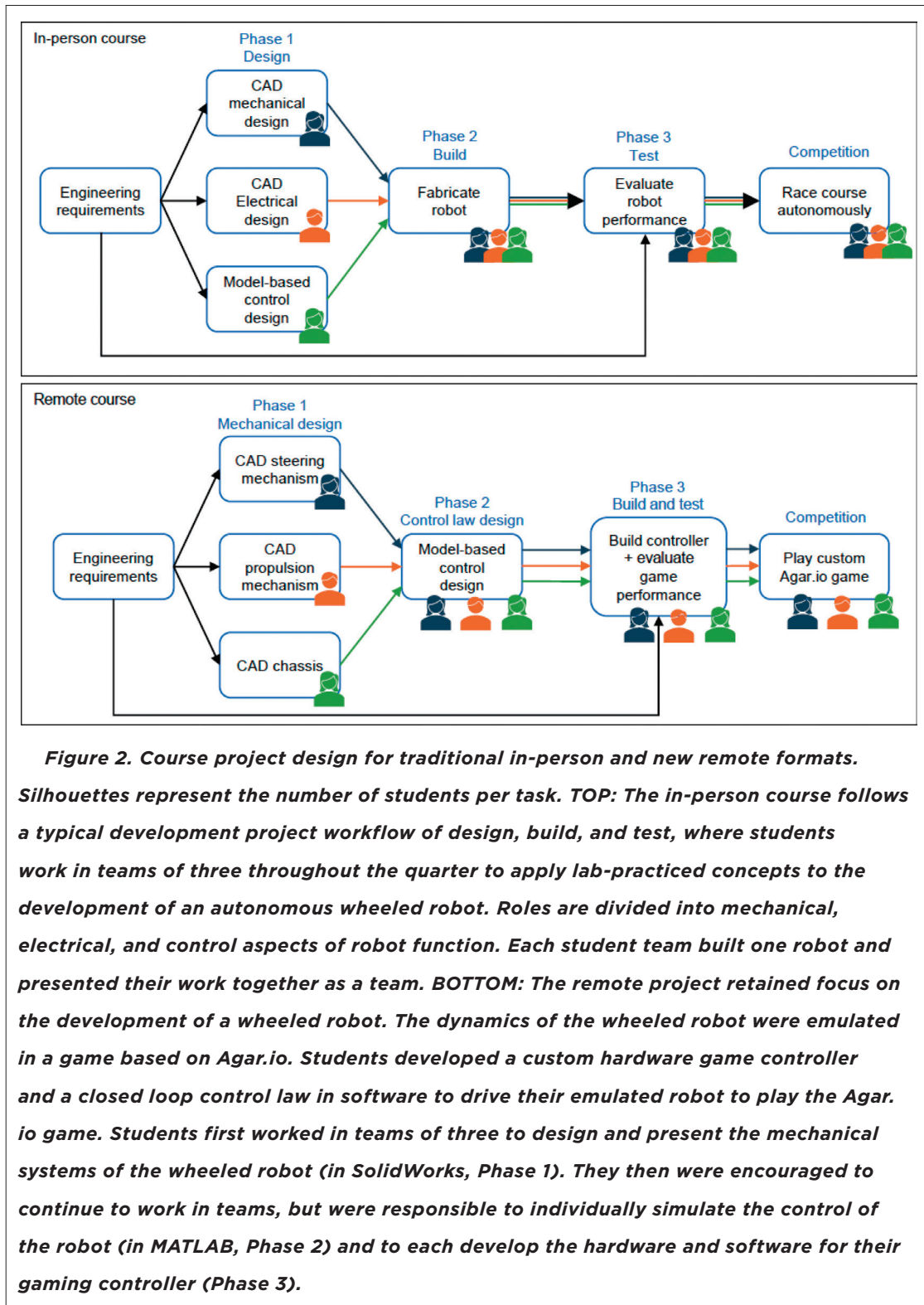
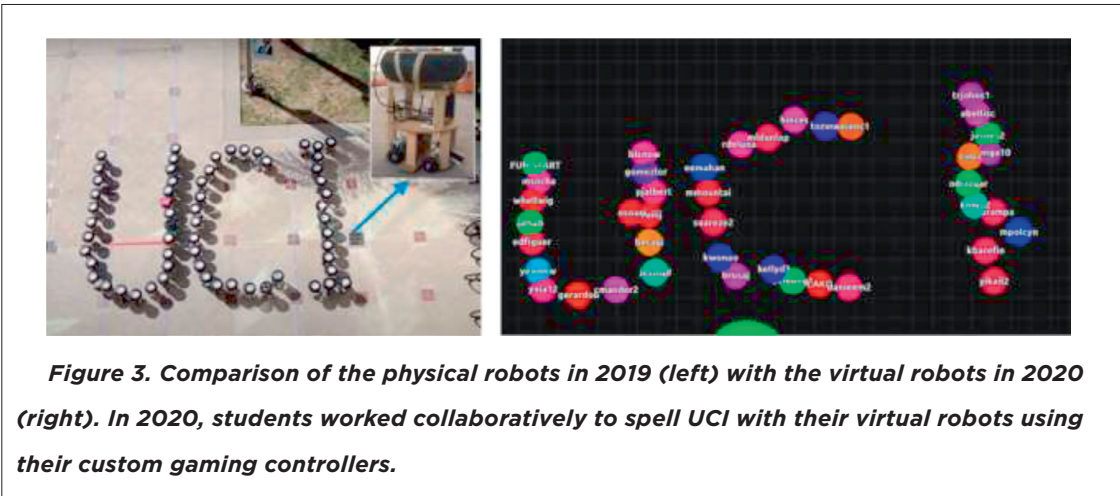
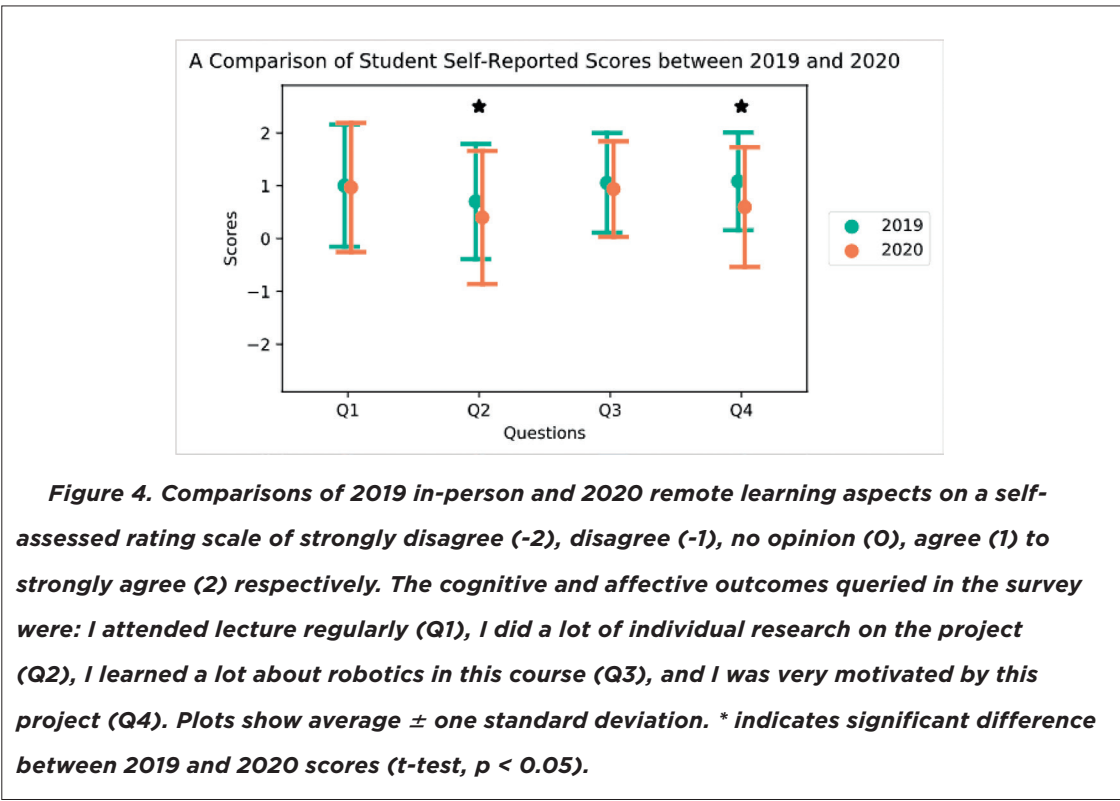


Figure 2. Course project design for traditional in-person and new remote formats. Silhouettes represent the number of students per task. TOP: The in-person course follows a typical development project workflow of design, build, and test, where students work in teams of three throughout the quarter to apply lab-practiced concepts to the development of an autonomous wheeled robot. Roles are divided into mechanical, electrical, and control aspects of robot function. Each student team built one robot and presented their work together as a team. BOTTOM: The remote project retained focus on the development of a wheeled robot. The dynamics of the wheeled robot were emulated in a game based on Agar.io. Students developed a custom hardware game controller and a closed loop control law in software to drive their emulated robot to play the Agar.io game. Students first worked in teams of three to design and present the mechanical systems of the wheeled robot (in SolidWorks, Phase 1). They then were encouraged to continue to work in teams, but were responsible to individually simulate the control of the robot (in MATLAB, Phase 2) and to each develop the hardware and software for their gaming controller (Phase 3).

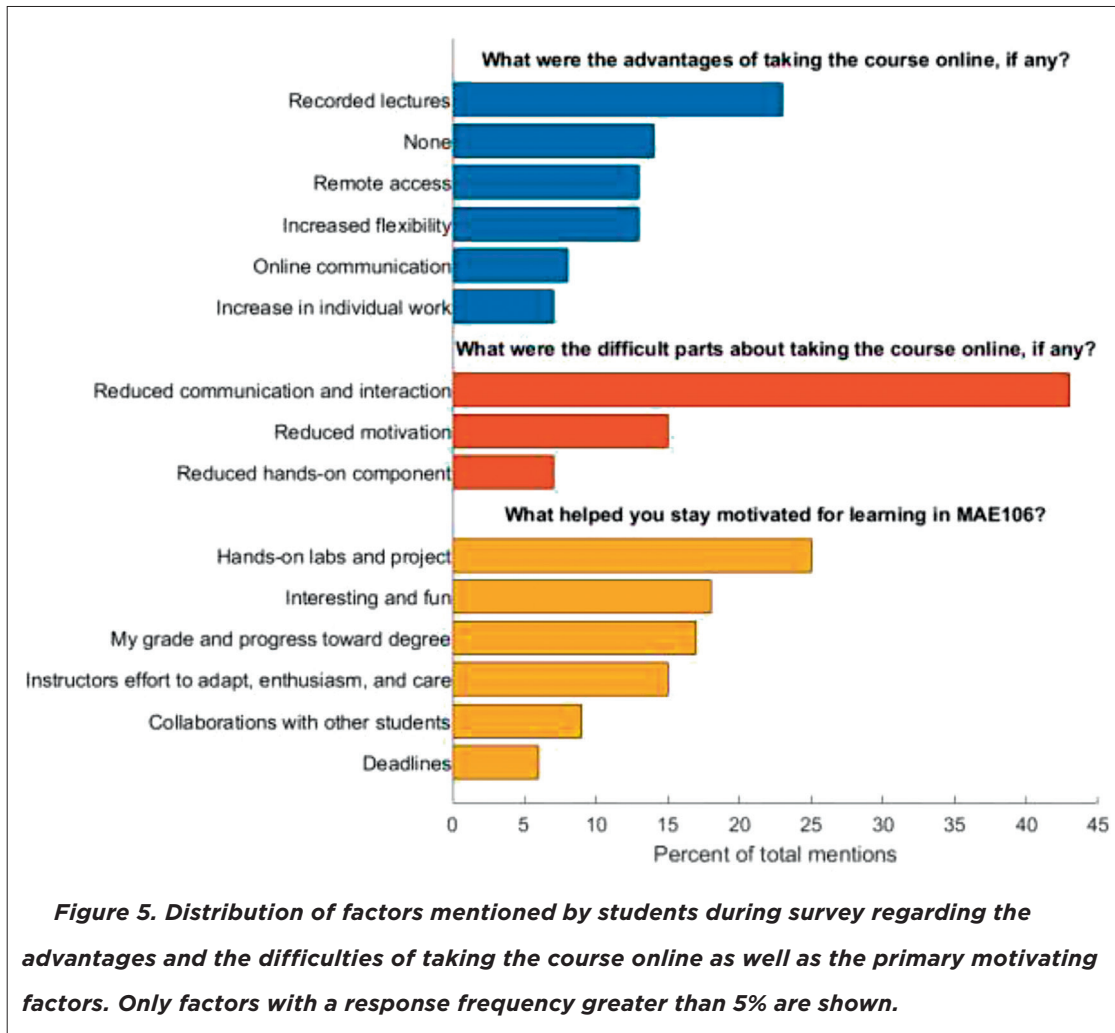


on a 0 (inadequate) to 4 (excellent) scale, “What overall rating would you give this course?”. They reported attending lecture equally regularly and felt they learned a lot about robotics (Figure 4). In a free response question about advantages of remote learning, they most often noted recorded lectures and the flexibility of remote access (Figure 5).





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However, in response to this question about advantages of remote learning, the second-most frequent entry was “None” (Figure 5). Self-reported scores for self-learning and motivation for the project also significantly decreased by 6.0% and 9.8% respectively (Figure 4). Further, only 15% of students endorsed offering the course remotely in the future. They also rated the remote course more difficult (59% reported “very challenging” vs. 43% in 2019). They most often identified the following difficulties with remote learning: reduced communication and interaction (43%), reduced motivation (14%) and reduced hands-on activities (7%) (Figure 5). Students who found the course more stressful were more likely to identify reduced quality of interaction as a notable difficulty of the remote format (linear regression, $p < 0.01$), particularly with the teaching staff. When asked “What helped you stay motivated for learning in MAE106?”, the top response was “Hands-on labs and project” (25%) (Figure 5).



NEXT STEPS

The remote, kit-based experience was successful based on exam performance and overall course ratings. However, students reported decreased motivation and did not advise using this format in the future. They primarily identified reduced interaction quality rather than reduced hands-on activity as a difficulty (indeed, they identified hands-on activity as the primary motivator for learning). Notably, students had the same contact duration with the instructors during lecture, lab, and office hours as in prior years. Yet, mediating these interactions through videoconferencing was dissatisfying.

As mentioned above, project-based learning incorporating hands-on learning and collaboration is beneficial for engineering student retention. While students in our course were largely satisfied with and motivated by the hands-on component, their unmet affective needs might negatively impact retention, which we intend to assess next. A key need is therefore determining how remote interactions can be improved in a way that better facilitates the collaborations inherent to traditional project-based learning.

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DECLARATION OF INTERESTS

The authors declare no conflict of interest.

**AUTHORS**

Liang (Lily) Wu is the Director of Academic Innovation, Programs at the Henry Samueli School of Engineering, University of California, Irvine. Dr. Wu is responsible for implementing, overseeing and assessing the first-year engineering program and international programs to enhance and support the engineering education at the School of Engineering. Dr. Wu received her Ph.D. degree in Materials Science and Engineering from the University of California, Irvine with primary research focuses on the design, development and integration of microfluidic systems for biomedical applications.



Edward Zhu is a M.S. student in Mechanical engineering at the University of California, Irvine under the guidance of Dr. David Reinkensmeyer. His research work investigates the impact of robotic therapy in a non-human primate system. He has also been a member of multiple instructional teams at UC Irvine and was most recently the lead teaching assistant for the ENGRMAE106 course in Spring 2020. Zhu received his B.S. in Mechanical Engineering from UC Irvine.



Caitlin Callaghan is a Teaching Assistant and M.S. student of Mechanical Engineering at the Henry Samueli School of Engineering, University of California, Irvine. Miss Callaghan earned her Bachelor of Science Degree in Mechanical Engineering from University of California, Irvine, where she was honored with the Dean's Choice Award for her work on the Project "Rehab Robotics - Mpowrd Wheelchair". Miss Callaghan's research focus is on the design of machines for somatosensory assessment and training after stroke. She was a member of the Teaching Assistant team for the Spring 2020 MAE 106 course.



Derek Irwin is a Lab Technician of Mechanical Engineering at the Henry Samueli School of Engineering, University of California, Irvine. Mr. Irwin has been in the engineering industry since he was 16 years old and through many years learned real world practices. During his 10 years working in electron beam and laser welding, Mr. Irwin contributed to designing and programming a welding parameter for a revolutionary ventricular assist device as well as numerous other products in the mechanical and aerospace industries. Mr. Irwin



now assists with undergraduate projects at the Henry Samueli School of Engineering sharing real world hands on experience with future engineers.



Dylan Reinsdorf, M.Sc., is a Ph.D. student in the UCI Department of Mechanical and Aerospace Engineering. He is investigating proprioception training of the hand to optimize motor learning after neurological injury. He was a TA member of the Spring 2020 MAE 106 course instruction team. Dylan received his B.S. from California Polytechnic State University, San Luis Obispo and M.Sc. degree from University of Washington, Seattle.



Veronica Swanson is a Ph.D. student in UCI's Mechanical Engineering department. She is currently researching questions of uptake for robotic rehabilitation technologies in clinical and home settings. She was a member of the Teaching Assistant (TA) team for the Spring 2020 MAE 106 course. Mrs. Swanson has been involved in a variety of educational programs for K-12 and college students including the first-year engineering program, developed by Dr. Wu. Mrs. Swanson received her B.S. and M.S. degrees in Mechanical Engineering from UC Irvine.



Austin Zwirn is a B.S. student of Computer Engineering at the Henry Samueli School of Engineering, University of California, Irvine. He is currently working on various independent software projects geared toward Robotics. Austin helped to design the project game server and user interface for the Spring 2020 MAE 106 course. He worked closely with the Teaching Assistant team to verify that all necessary conditions were met.



David Reinkensmeyer is Professor in the Departments of Mechanical and Aerospace Engineering, Anatomy and Neurobiology, Biomedical Engineering, and Physical Medicine and Rehabilitation at the University of California at Irvine. He is co-director of the NIDILRR COMET Robotic Rehabilitation Engineering Center, co-director of the NIH K12 Engineering Career Development Center in Movement and Rehabilitation Sciences, and Editor-in-Chief of the Journal of Neuroengineering and Rehabilitation. He recently received the Innovator of the Year Award from the Henry Samueli School of Engineering and the Distinguished Midcareer Faculty Research Award from UC Irvine. He was the Dean's Honoree for Teaching Excellence in 2019 and is a fellow of the AIMBE. He was the lead instructor for MAE 106 in Spring 2019 and Spring 2020.