ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37604

Lessons Learned Adapting a First-Year-Engineering Project-Based Course to an Online Format

Juan David Ortega-Alvarez (Collegiate Assistant Professor)

For several years after earning my engineering degree in 2001, my professional duties included working full-time as a process engineer at a chemical company and teaching engineering courses as an adjunct instructor. In 2009 I left a seven-year long career in industry—interrupted only by my time abroad earning a master's in engineering—to become a full-time faculty member, mostly in pursuit of one goal: professional and personal fulfillment. To be sure, the most gratifying experience I have had in my career is participating in the intellectual development of students and earning their gratitude. Propelled by this motivation, I chose an academic life focused on quality engineering teaching, which ultimately led me to pursue a Ph.D degree in Engineering Education. Teaching engineering and scholarly exploring ways to excel at the job are my professional passions.

Matthew B James (Associate Professor of Practice)

Matthew James is an Associate Professor of Practice in Engineering Education at Virginia Tech. After working in the Civil/Site Development engineering field for a number of years, he returned to Virginia Tech to pursue teaching. His primary role is teaching within the first-year general engineering undergraduate program. He also is interested in study abroad, expanding service learning opportunities for students, and serves as the faculty advisor for the Engineers in Action student design team.

Catherine Twyman

Catherine Twyman has been an Instructor in the Department of Engineering Education at Virginia Tech since 2019, teaching ENGE 1215 and 1216. Ms. Twyman also taught the first-year engineering classes at New River Community College from 2016-2019. Prior to this, she completed a M.Eng. in Mechanical Engineering in 2015 and a B.S. in Mechanical Engineering in 2011 at Virginia Tech.

Benjamin Daniel Chambers (Associate Professor of Practice)

Dr. Ben Chambers is an Associate Professor of Practice in the Department of Engineering Education at Virginia Tech, and Director of the Frith First Year Makers program and of the Minecraft Museum of Engineering. His research focuses include creativity-based pedagogy, the interactions of non-humans with the built environment, and the built environment as a tool for teaching at the nexus of biology and engineering. He earned his graduate degrees from Virginia Tech, including an M.S. Civil Infrastructure Engineering, M.S. LFS Entomology, and a Ph.D. in Environmental Design and Planning.

Tahsin Chowdhury

Tahsin Chowdhury is an Engineering Education Doctoral candidate who focuses on engineering in the 21st century. He is passionate about enhancing professional competencies for engineering workforce development in academia and beyond. He is trained in Industrial and Systems Engineering and has a combined 6 years experience spanning both academia as well as lean manufacturing at Fortune 500 companies. Tahsin's long term goal is to bridge the engineering competency gap between industry demand and academic fulfillment. A global engineer and researcher, Tahsin is an advocate and ally for better inclusion in STEM and beyond.

Lessons Learned Adapting a First-Year-Engineering Project-Based Course to an Online Format

Juan Ortega-Alvarez; Matthew James; Catherine Twyman; Benjamin Chambers; Tahsin Chowdhury*
*Virginia Tech; *Virginia Tech & Universidad EAFIT*

Introduction

Prompted by the COVID-19 pandemic, a group of instructors of the first-year engineering program at Virginia Tech embarked on the challenge of adapting a traditional project-based course to an online learning format. Project-based learning (PjBL) is a widely adopted active learning pedagogical approach, which promotes student critical thinking and problem-solving skills [1], [2]. PjBL has been proven to be effective among engineering students, especially in the development of both technical and professional competencies among first-year engineering students [3].

The transition from in-person to online PjBL required some significant changes, though many aspects of the existing infrastructure and program coordination were useful. Changes and innovative practices that were implemented to facilitate the online version of the course included new ways of dividing up team roles to accommodate social distancing guidelines, virtual analysis where in-person testing was no longer possible, and recorded video presentations in lieu of in-class poster sessions. Lessons learned during this experience include administrative and pedagogical practices our team first implemented for online learning, some of which have been maintained to enhance the in-person PjBL experience.

Context and background

The program

The First-year Engineering program at Virginia Tech is coordinated by the department of Engineering Education and contributes to the broader First-Year Experience. At its core, the program consists of a two-course sequence and access to a maker space. The two-course sequence, denominated *Foundations of Engineering*, aims at helping students develop 1) an understanding of different engineering disciplines to make an informed choice of major; 2) professional skills in engineering like communication, teamwork, and ethical reasoning; 3) an ability to apply engineering design to solve problems. This paper focuses on the second course in the sequence, referred to as ENGE 1216, which is a PjBL course that emphasizes engineering design and teamwork outcomes. In Fall 2020 the entirety of the first course in the sequence was offered online for the first time, and a few of the practices discussed in this paper were first piloted then. Online teaching and learning strategies were refined and adapted for ENGE 1216 in Spring 2021. This course comprised 29 sections with an average enrollment close to 70 students per section. Each section was taught by one instructor of record with the support of graduate teaching assistants (GTAs) and graders (UTAs), with one GTA and one UTA usually supporting two sections.

The project

ENGE 1216 is centered around a semester-long team project typically divided into two design iterations, each featuring a single design/build/test phase, carried out by teams of 5-6 students. Teams are usually formed using CATME [4] to group students by similarity of schedule, while trying to increase diversity in terms of characteristics like gender identification, experience with CAD software, and writing confidence. During Spring 2021, the instructors selected from a pool of different projects to frame the class, namely designing an autonomous model airplane, a solar oven, an aesthetic wind turbine, and solving an open-ended problem chosen by the students through the design of an artifact. Each instructor worked with one of these projects over all the sections they taught.

Due to the COVID-19 pandemic, students were required to attend class, check-in with the instructor, and work with their teams via online platforms (e.g., Zoom). In the in-person class, students normally collaborate to build and test prototypes. The main challenge working online was to give students the opportunity to build and test something; to have the experience of trying something, seeing how it goes, and then trying again. To make this happen, we decided to operate the projects in two phases: in phase 1 students were to individually ideate, build, and test a low fidelity prototype; beginning phase 2, teams were asked to collaboratively analyze the phase 1 outcomes and select a design for refined modeling (both physical and computer-aided) and additional testing. Typical major deliverables of the project included a team contract, an individual design, a phase 1 summary memo, a phase 2 design proposal, a testing and validation plan, and a final project report and presentation. Instructors had the latitude to adjust these assignments to better fit the project they chose, and to introduce additional assignments like individual and group reflections, and progress reports and presentations. Instructors were mindful of both diversity of and limitations in resources available to our students, which resulted in different strategies to mitigate the necessity of any of them spending their own money without reimbursement.

Lessons learned

In this section, we describe the most salient lessons learned during our experience teaching a PjBL class online, and how we would apply what we learned back in the physical classroom. As expected, our experiences did not always align, so multiple perspectives will be presented when necessary.

Mailing prototyping kits

One of the key components of the in-person semester design project involved students building a physical prototype. In the past, this was facilitated through in-class build sessions as well as independent work time in our first-year maker space. Because the instructional team saw maintaining a physical prototype as an important component of the class in an online setting, several changes were made to successfully implement it based on the type of project students were working on.

For projects with a narrow enough scope, kits consisting of common building materials were assembled and mailed to the students. For one project, the materials in the packets that were mailed cost on the order of $10, but the shipping costs were higher. One instructor noted that, in hindsight, it may have been more cost-effective to have the students purchase the materials themselves and be reimbursed in this situation. In contrast, another instructor noted that it was less expensive to purchase these materials in bulk and distribute to the students directly, which may have outweighed the additional shipping costs incurred. Overall, this instructor noted that shipping worked out well and even fragile materials, such as foam board, generally arrived without damage. There were a few problems, such as packages being lost in the mail or held in customs, minor damage, or logistical errors in which students received the wrong materials. Beyond the logistical aspects, assembling prototyping kits to be mailed to students individually allowed us to consider new ideas for light prototyping and testing in the classroom that some of us continue to use.

For the project option that let teams choose their own open-ended problem to solve, it was less feasible to develop kits to mail to students due to the wide variety of materials that would be needed. In this case, each design team was given a modest budget of approximately $60 and submitted a proposal for materials they wanted to purchase, which would later be reimbursed. The instructor and GTAs reviewed the materials and approved them prior to the students making their purchases to ensure that the costs would qualify for reimbursement. This worked quite well in the majority of cases, but there were one or two teams that deviated from their pre-approved list and couldn't get reimbursed for all items, and several other teams that did not submit reimbursement requests for the materials they purchased.

Maker space reinvented

At Virginia Tech we have a dedicated maker space for first-year engineering students to work on class and personal projects, called Frith Lab. Student access to the lab was highly restricted due to guidelines concerning positive COVID-19 cases and close contacts. Due to continued closures, we unfortunately lost talented undergraduate assistants who worked in the lab. That said, the people who could stay found new and meaningful ways to leverage the tools and skills at their disposal for the benefit of the students and the first-year program. Just to list a few examples:

- A graduate lab assistant led the development and 3D printing of face masks and shields to be distributed around campus.
- Working with the instructors, lab assistants ordered materials and processed them (i.e., cut, drill, fold, and pack) to assemble and mail the prototyping kits described previously.
- Due to space restrictions, lab assistants developed ways for students to physically test their designs outside of the lab, in a bigger classroom, by bringing to the classroom simplified versions of testing equipment available at the lab. Very few students took advantage of this opportunity.
- In collaboration with instructors and graduate teaching assistants, a graduate lab assistant developed an instruction's manual for students to test their CAD designs using the CFD capabilities of SOLIDWORKS®, the design software used in class.

There is untapped potential in a maker space and its staff that can be actualized through collaboration. A communication channel between the instructors and the lab already existed via the lab director, but now we aim for a more direct and frequent interaction through a newly hired assistant manager that allows lab staff to know what is going on in the classroom, and instructors to know what is happening in the lab.

Virtual testing and analysis tools

As mentioned above, a lab assistant developed a manual to help students test their designs using CFD in SOLIDWORKS®. There was previous experience using CFD in the airplane project, but this time it was extended to the wind turbine project, and required as a necessary team deliverable given the restrictions for physical testing. One instructor noted that this was the kind of thing that when it worked, it worked great, but when it didn't work, it was hard to troubleshoot. However, it did become a nice object lesson for critically thinking about the results you get from a software. Many students would get results that made no sense (very large or very small force values) and I would ask them what surfaces they used for the model. It was good for having a conversation about their analysis process and getting them to think about how their choices impact the results and that those results don't necessarily tell them about the design. Those of us working with projects where it makes sense will keep using CFD to leverage the critical thinking benefits obtained through analysis and comparison of physical and simulation results.

A renewed use of computer and information technologies
Course instructors identified several other changes that they made as part of a shift to online that they may continue to use once courses transition back to an in-person modality. For example, the use of a shared Google Doc that could be accessed by the entire class section proved useful for teams to report-out during class, and allowed teams to read over what others were working on, which could inform their own work. Similarly, recorded presentations instead of live poster sessions or class presentations gave students the opportunity to work individually and then revise the final team outcome. Paired with discussion boards where students could watch the videos presentations and submit comments, this strategy was effective in facilitating the achievement and assessment of outcomes related to the communication of technical information. Several instructors plan to continue using video recorded presentations in their classes.

Conducting office hours over Zoom was also found to be a fantastic addition to the class, with several instructors finding increased attendance and an ability to provide support equal or better to conducting office hours in person. The increased attendance may have been due to the fact that the instructional space and offices are located approximately a 15-20 minute walk from the residential side of campus, so joining virtually saved time on the students' part. Zoom office hours were found to be especially useful when troubleshooting computer-related questions, since the students could share their screens as opposed to instructors looking over their shoulder.

Remaining teamwork
The online modality and COVID-related restrictions also forced instructors to reimagine the division of workload and team roles. In past course iterations, each student on the team was encouraged to take on a role in every part of the project, such as coding, prototyping, and CAD. Because of restrictions on in-person gatherings, some projects were revised in such a way that students were split into smaller subteams that focused on one part of the project for the final design iteration. This was supplemented with an assignment where each subteam needed to demonstrate that they were still coordinating closely with the others and reviewing each other's work, which more closely reflects how many professional engineering projects are organized. This had the added benefit of allowing students to self-select the part of the project that interested them the most, and several instructors have indicated they plan to continue with this structure moving forward.

Take-home message
Adaptability, creativity, and collaboration were key to offering a sound online PjBL learning experience. Retrospective, collaborative discussion is now key to identify what changes worked well and are worth keeping in the physical classroom. We encourage our readers to ponder and try what we learned, but more importantly to reflect with their own teams on the useful practices implemented during the contingency that may give a boost to their PBL classes as they transition back to in-person interaction.

In addition to the experiences of this group of instructors, we also captured students' perceptions of their learning about engineering design in this class. These perceptions, collected through class survey assignments, suggest that students believe they learned important aspects of engineering design. Grades and overall performance, as assessed by the instructors, support that perception. A separate study further describes and analyzes students' responses to this course. Future work will explore individual instructors' approaches in a more nuanced way to identify differences with potential impact on student learning and class experience, namely the level of autonomy versus structure built into students' projects.

Acknowledgments

Our gratitude to the Frith Lab staff and former director for their adaptability and for succeeding in providing thousands of students the chance to have a real prototype-building experience outside the lab. Thanks also to our Business Office staff for processing student reimbursements and making that process fairly painless.

References

[1] M. J. Prince and R. M. Felder, “Inductive teaching and learning methods: Definitions, comparisons, and research bases,” *J. Eng. Educ.*, vol. 95, no. 2, pp. 123–138, 2006.

[2] M. Mosgaard and C. M. Spliid, “Evaluating the impact of a PBL-course for first-year engineering students learning through PBL-projects,” in *2011 2nd International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace Electronic Systems Technology (Wireless VITAE)*, Feb. 2011, pp. 1–6. doi: 10.1109/WIRELESSVITAE.2011.5940927.

[3] K. M. Yusof, A. N. Sadikin, F. A. Phang, and A. A. Aziz, “Instilling professional skills and sustainable development through Problem-Based Learning (PBL) among first year engineering students,” *Int. J. Eng. Educ.*, vol. 32, no. 1, pp. 333–347, 2016.

[4] C. S. Simmons, “Using CATME team-maker to form student groups in a large introductory course,” presented at the 2015 ASEE Southeast Section Conference, University of Florida, Apr. 2015.