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Virtual vs. In-Person Learning: A Study on Student Motivation, Experience, and Perception in a First-Year Introduction to Engineering Course

Dr. Chao Wang, Arizona State University

Chao Wang received her Ph.D. in Electrical Engineering from University of Wisconsin, Madison. She is currently a senior lecturer in Ira. A Fulton Schools of Engineering at Arizona State University.

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Abstract

This complete evidence-based practice paper examines virtual and in-person student's situational motivation responses as well as their experience and perception of virtual and in-person learning in a freshman Introduction to Engineering course. During the Fall semester of 2020, the Introduction to Engineering course was offered in a synchronous hybrid mode. While all lectures were delivered through Zoom video conferencing software, students had the choice to join labs either virtually or in-person. Situational Motivation Scale (SIMS) survey, an instrument to measure four types of motivation (intrinsic motivation, identified regulation, external regulation and amotivation) based on Self-Determination Theory (SDT), was administered weekly to students enrolled in three sections of the course during a nine-week project period. A Basic Needs Satisfaction Scale survey was given at the end of the semester, which measures the satisfaction of three fundamental psychological needs of autonomy, relatedness and competence. An additional set of survey questions on student's experience and perception of virtual and in-person learning was also given at the end of the semester. Survey results reveal that although no significant difference is observed between virtual and in-person students' perceived basic needs satisfaction, in-person learners show slightly higher motivation compared to virtual learners, and students overwhelmingly prefer in-person over virtual learning.

Introduction

Project-based first-year engineering design courses have shown to have a positive impact on student's motivation, engineering identity formation, intellectual and skill development to meet the challenges of the 21st century [1-4]. Many such courses are delivered in a makerspace type environment, where hands-on physical prototyping and teamwork are essential parts of the course experience.

Due to the COVID-19 pandemic, most courses are forced to switch from face-to-face instruction to either entirely online or to a hybrid mode. This transition poses special challenges for this type of project-based courses that require access to physical tools and building materials [5-7]. Many courses adapt to this transition by switching to computer/online simulation and/or shipping parts/project kits to students [5-7].

Besides limited access to building tools and materials, reduced interactions among students and between students and instructor pose its own challenge. Instead of students working side-by-side on the project and receiving instructor assistance and feedback face-to-face, collaboration turns remote and guidance becomes virtual. Active student engagement strategies are discussed in [8] for both synchronous and asynchronous online instructions, in which different approaches are recommended for student-content, student-student and student-teacher interactions. Many video conferencing tools and messaging apps such as Zoom [9] and Slack [10] are used to facilitate real time interactions. Zoom tools such as breakout rooms, chat, raise hands, vote and poll features are recommended and used by many to increase student engagement and collaboration in the virtual environment.

The meta-analyses cited in [8] show face-to-face and online instructions are on average comparatively effective in meeting course outcomes. Quality of instruction influences outcomes more than whether the course is online or face-to-face. This study will investigate specifically the impact of virtual and in-person modalities on student motivation in a project-based freshman engineering design course in which active hands-on learning, physical prototyping, and teamwork are vital parts of the learning experience.

Due to the pandemic, students from three sections of freshman Introduction to Engineering course in the fall semester of 2020 were given the choice of attending labs either virtually or in-person. To find out how virtual vs in-person learning would impact student motivation, they were tracked for nine weeks while working on an open-ended design project. Each week students were given a Situational Motivation Scale (SIMS) survey [11] to measure their motivation along with a report on whether they attended the lab virtually or in-person. At the end of the semester, a Basic Needs Satisfaction Scale survey [12, 13] was given to students to measure the satisfaction of basic psychological needs of autonomy, relatedness and competence. Additional questions on student's experience and perception of virtual vs. in-person learning were also included in the end of semester survey.

The rest of the paper is organized as follows. First, the structure of the Introduction to Engineering course, its virtual adaptation and self-determination theory are briefly reviewed in the background section. Methodology and experimental setup are described next, followed by results, discussion and conclusion.

Background

Introduction to Engineering Course

Introduction to Engineering is a 2-credit freshman level course spanning a full semester of fifteen weeks. During each week there is a 50-minute lecture and 2-hour 50-minute lab. Most students taking this course are first-semester college freshman. The course introduces students to engineering design process, engineering model and drawing, teamwork, technical communication, project management and entrepreneurial mindset. Technical knowledge is intertwined in the course through labs and projects, including Computer-Aided Design (CAD), 3D printing and Arduino programming. The course adopts a flipped classroom approach [14]. Most of the lecture time is dedicated to team discussion and groupwork. Labs are mainly used for hands-on prototyping and project building.

Most students enrolled in this course are from aerospace engineering, chemical engineering, electrical engineering and mechanical engineering, along with a few students from other majors such as computer science and material science. Students work in multidisciplinary teams in both lecture and lab throughout the semester. Two multidisciplinary team design projects are used. During the first half of the semester, a well-defined project is assigned to teach students Arduino programming. An open-ended project [15] is used during the second half of the semester. For the second project, students are free to choose their own design problem to create an automated solution to add economic, environmental and/or societal value using Arduino or other microcontrollers.

Virtual Learning Adaptation

Due to the pandemic, during the fall semester of 2020, all Introduction to Engineering lectures were taught virtually through Zoom. Students were given the choice to join labs either in-person or online. To satisfy the social distancing constraint, all lab occupancies were kept at below 50% capacity. Half of the students could join labs in-person (if they chose to) during alternating weeks.

Student teams were formed using the CATME [16] software like previous semesters. The only modification was that if students notified the instructor in advance that they would join the class virtually exclusively, they would be teamed up with other entirely virtual students if possible.

Teaching materials and assessment in Fall 2020 were largely kept the same as in Fall 2019. Quizzes and exams had to be done online instead of in-person. Project presentations and demos were switched to Zoom. Rather than students working with their teammates side by side in a traditional lab setting, they were assigned to their team's Zoom breakout room for discussion and groupwork. Instructor and teaching assistants periodically joined each team's breakout room to check in with them.

For rapid prototyping activities in a regular semester, students are provided with simple building materials in the lab. To accommodate virtual attendance in Fall 2020, students were encouraged to build using materials they have around the house or use hand sketches or CAD tool.

Similarly, project and lab materials are provided to students in a traditional semester. In Fall 2020, each team was supplied with one Arduino project starter kit. Students were encouraged to buy their own kit if they didn't have access to campus or had difficulty sharing the kit among team members. For building materials other than electronics, students could use what they already owed, purchase materials themselves, or come to campus and choose from the available course inventory. Due to limited access to building materials, computer simulation and CAD tools were emphasized in Fall 2020. To accommodate students overseas and students with financial hardship, they were given the option to complete labs and projects through online simulation using Tinkercad [17].

Self-determination Theory

Self-determination theory (SDT) states the importance of satisfying three fundamental psychological needs for individuals' well-being. The basic needs are autonomy, a sense of choice and control; relatedness, a sense of positive and supportive connections to others; and competence, a sense of mastery and self-efficacy [18]. The satisfaction of these basic psychological needs promotes motivation and healthy psychological and behavioral functioning.

In a virtual environment, technological tools such as Zoom are used to build social and teaching presence to help students relieve the feeling of isolation they often have in online courses. Whether these tools are sufficient to satisfy student's basic need of relatedness is unclear.

Self-determination theory [19, 20] also suggests individuals typically express multiple forms of motivation in any given activity. The different types of motivations may be described on a continuum ranging from autonomous (internal) to controlled (external) motivations. One extreme is intrinsic motivation, i.e., a deeply internalized state of engagement based on interest, enjoyment, satisfaction and passion. The other extreme is amotivation, which is a state of impersonal or non-intentional action due to learners finding no value and no desirable outcomes in a learning activity. Positioning in between the two extremes are identified regulation and external regulation. Identified regulation is a state in which actions are based on an internal sense of self and perceived value, importance or usefulness of a task, whereas, external regulation is a state of compliance with external pressure, prompted by avoidance of punishment or contingent reward. Examining learner's motivation across the whole continuum helps gain insights into the learner's motivational state.

Methodology and Experimental Setup

The author taught three Introduction to Engineering sections in the fall semester of 2020. All teaching materials and assessment were kept the same across the three sections. There were 83 students in total who consented to participate in the research study.

Student's motivation was measured for nine weeks while they were working on the open-ended design project during the second half of the semester. During the first two weeks, students worked in lecture to brainstorm pain points, collect information, conduct research and decide upon their design problem. Starting from the third week, students worked on their project during the lab following the engineering design process, including problem definition, brainstorming and rapid solution prototyping, choosing the most promising design, creating project Gantt chart and bill of materials, proposal presentation, project construction and testing, and final presentation and demo.

For each of these nine weeks, at the end of project lecture or lab, students were given a Situational Motivation Scale (SIMS) survey to measure their motivation. To investigate the impact of in-person versus virtual learning on student motivation, within each week's SIMS survey, there was one additional question asking if students joined the class virtually or in-person.

For SIMS surveys, scores for "intrinsic motivation", "identified regulation", "external regulation" and "amotivation" are calculated. A metric called self-determination index (SDI) [21], which represents students' overall motivation by weighing subscale constructs according to their position on the self-determination continuum, is also calculated. SDI is defined as SDI = 2*(intrinsic motivation) + 1*(identified regulation) – 1*(external regulation) – 2*(amotivation). The range of possible SDI scores is from -18 to 18, with higher scores indicating greater self-determination.

An End-of-Semester survey was given to students at the semester's end. It includes a Basic Needs Satisfaction Scale (BNSS) survey, which is used to measure the satisfaction of three basic psychological needs of autonomy, relatedness and competence. The survey also includes a set of questions regarding students' experience and perception of virtual and in-person learning. A free response question is included in all surveys to capture anything students want to share.

Besides comparing survey results from students attending class virtually and in-person in Fall 2020, the survey results are also compared against those obtained from Fall 2019, during which traditional in-person learning took place. The Fall 2019 and Fall 2020 classes were taught by the same instructor. Course materials were kept largely the same except for the virtual adaptation described in the previous section. The SIMS and BNSS surveys were administered in the same fashion for both Fall 2019 and Fall 2020 sections.

Results and Discussion

Project Outcome

There is a total of 26 student projects in Fall 2020 compared to 10 projects in Fall 2019. A good portion of both semesters' projects address student's pain points of everyday campus life, such as automatic light switch/window blind, a better designed alarm clock/doorbell/skateboard, etc. 23% of the Fall 2021 projects directly solve the problems/challenges posed by the COVID-19 pandemic, such as sanitization, social distancing and work productivity. Table 1 compares the project outcome of the Fall 2019 and Fall 2020 semesters. As shown in the table, most teams in both semesters, 80% and 84% respectively, are able to complete their design and have a working prototype. In Fall 2019, every team builds a physical prototype. In Fall 2020, even though students are given the choice between building a physical prototype and software simulation, all but two teams (92%) choose to build a physical prototype. Average number of distinct electronic components refer to the number of different sensors, actuators and other components such as solar module, relay, etc., that students employ in their project. It is a good indicator of the project complexity. The reason why Fall 2020 students use more components than Fall 2019 students may be because there are more readily available components in the Arduino project starter kit in Fall 2020. In contrast, in Fall 2019, students have a much-limited set and need to explicitly request extra components if needed. In both semesters, students are taught CAD modeling. In Fall 2020, 31% of all teams 3D print at least a portion of their physical prototype mostly from an on-campus 3D print lab (there are a few students who have access to off-campus 3D printers), possibly due to the lack of access to project building materials. Overall Table 1 shows the Fall 2020 project outcome with mostly virtual attendance is at least comparable to, if not better than, the Fall 2019 project outcome in a traditional semester.

Table 1. Project Outcome Comparison

	Prototype Working	Prototype Partially Working	Prototype Not Working	Physical Prototype	Average Number of Distinct Electronic Components	3D Printing
Fall 2019	80%	20%	0%	100%	2.6	0%
Fall 2020	84%	8%	8%	92%	3.7	31%

Motivation Response

Situational Motivation Scale (SIMS) survey responses are compared between the fall 2019 and 2020 semesters in Fig. 1. The variable M represents the number of unique students who responded to the surveys, and the variable N represents the number of total survey responses across the nine-week project period. The figure indicates overall students in both cohorts show low amotivation, moderate external regulation, high identified regulation and relatively high intrinsic motivation. The 2020 cohort shows slightly lower amotivation and external regulation, however, it has a noticeable lower intrinsic motivation score. The mean self-determination index, the measure of students' overall motivation, is 4.96±0.44 from 2020 compared to 5.20±0.63 from 2019.

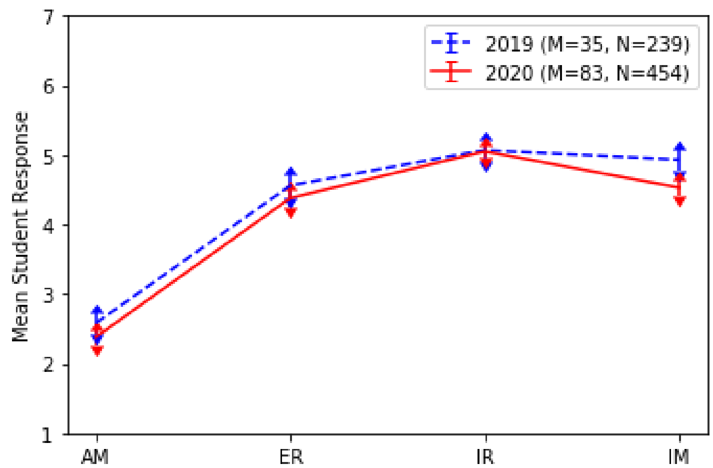

Figure 1. Situational motivation subscale responses from 2019 and 2020. Error bars show 95% confidence.

Figure 2 shows the situational motivation subscale mean values from Fall 2020 compared between virtual attendance and in-person attendance. The figure shows lower amotivation, higher identified regulation and higher intrinsic motivation from in-person attendance compared to virtual attendance. The mean SDI score is 8.27±1.53 from in-person attendance compared to 4.74±0.46 from virtual attendance. Clearly, students are more motivated during in-person lab sessions than during virtual lab sessions.

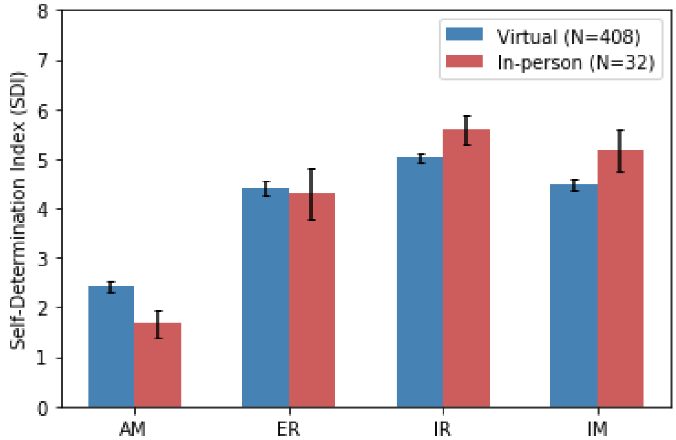

Figure 2. Situational motivation subscale responses from 2020 between virtual and in-person attendance. Error bars show 95% confidence.

Basic Needs Satisfaction

Basic Needs Satisfaction Scale (BNSS) survey is used to measures students' perceived level of autonomy, relatedness and competence. They are the three universal psychological needs that must be satisfied for people to perform optimally. Figure 3 shows the survey results from 2019 and 2020. The "Autonomy", "Relatedness" and "Competence" scores are almost identical between the two cohorts. The relatedness scores are a little surprising, since given the mostly virtual interactions in the 2020 cohort, one would expect the relatedness score to be lower. One possible explanation to the almost identical scores might be because most students worked well with their teammates, albeit virtually, as manifested by the results of peer evaluations.

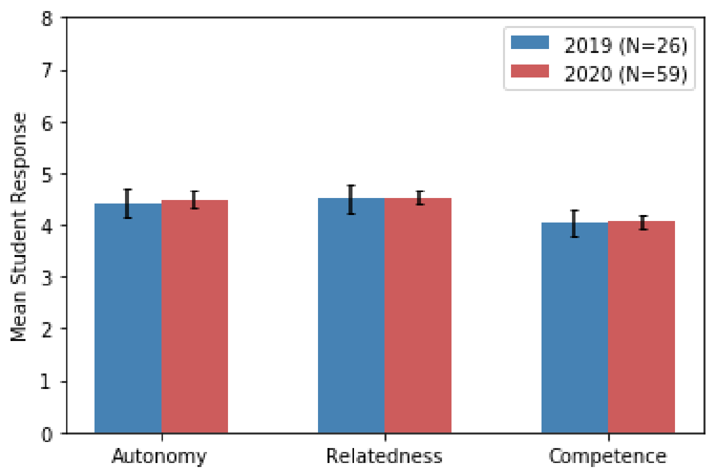

Figure 3. Basic needs satisfaction scale survey from 2019 and 2020. Error bars show 95% confidence.

Virtual vs. In-person Learning Survey

The survey has six questions. Each question is a Likert-scale question with seven choices: 1 (corresponds not at all), 2 (corresponds very little), 3 (corresponds a little), 4 (corresponds moderately), 5 (corresponds enough), 6 (corresponds a lot), 7 (corresponds exactly). There were 54 students who responded to this survey with results summarized below.

Student responses to question “I worked well with my teammates virtually through Zoom.” is shown in Fig. 4. The figure indicates 89% of students chose 4 and above, i.e., they work at least moderately well with their teammates virtually. This result could also help explain the almost identical relatedness score in the BNSS survey above.

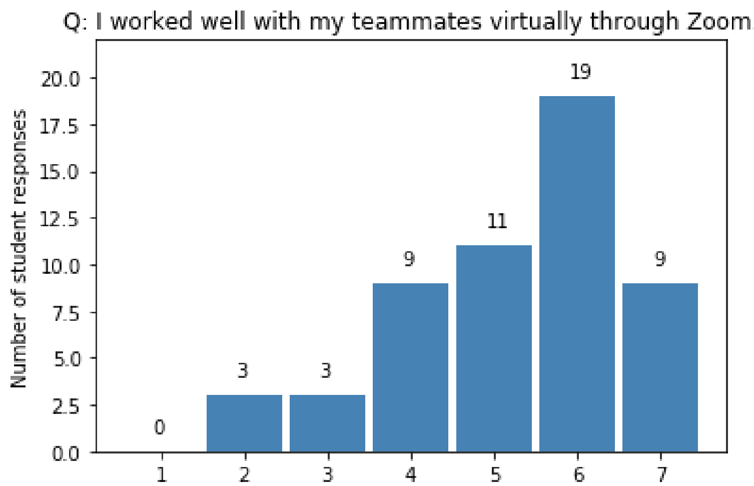

Figure 4. Student responses to “I worked well with my teammates virtually through Zoom.” Choices are 1: corresponds not at all, 2: corresponds very little, 3: corresponds a little, 4: corresponds moderately, 5: corresponds enough, 6: corresponds a lot, 7: correspond exactly.

Figure 5 shows that 76% of students felt like attending labs virtually hindered their ability interacting and working with their team at least moderately. In other words, although students work well with their teammates virtually, it is not as good as interacting and working together face-to-face.

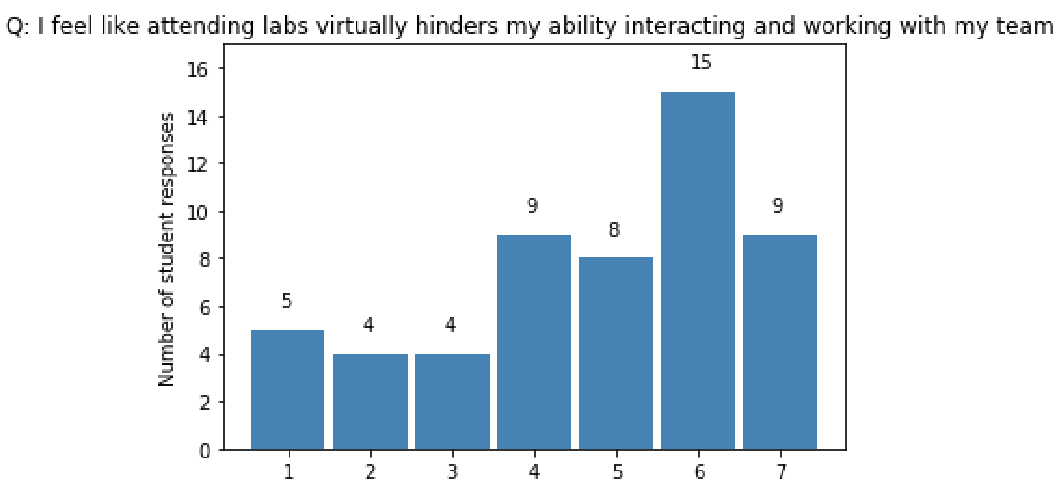

Figure 5. Student responses to “I feel like attending labs virtually hinders my ability interacting and working with my team.” Choices are 1: corresponds not at all, 2: corresponds very little, 3:

corresponds a little, 4: corresponds moderately, 5: corresponds enough, 6: corresponds a lot, 7: correspond exactly.

Figure 6 shows 83% of students responded 4 and above to the question “I was able to complete all assigned lab tasks when attending labs virtually.” A peak of 26% of students responded 4, corresponding moderately, i.e., there are lab tasks they couldn’t complete virtually.

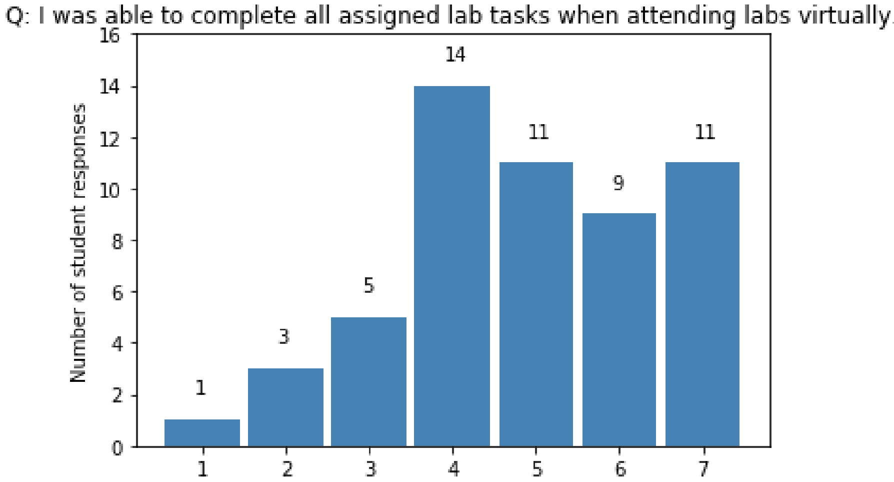

Figure 6. Student responses to “I was able to complete all assigned lab tasks when attending labs virtually.” Choices are 1: corresponds not at all, 2: corresponds very little, 3: corresponds a little, 4: corresponds moderately, 5: corresponds enough, 6: corresponds a lot, 7: correspond exactly.

Figure 7 reveals 93% students thought that they would have learned more from in-person labs than virtual labs, with 46% students chose 7, corresponding exactly.

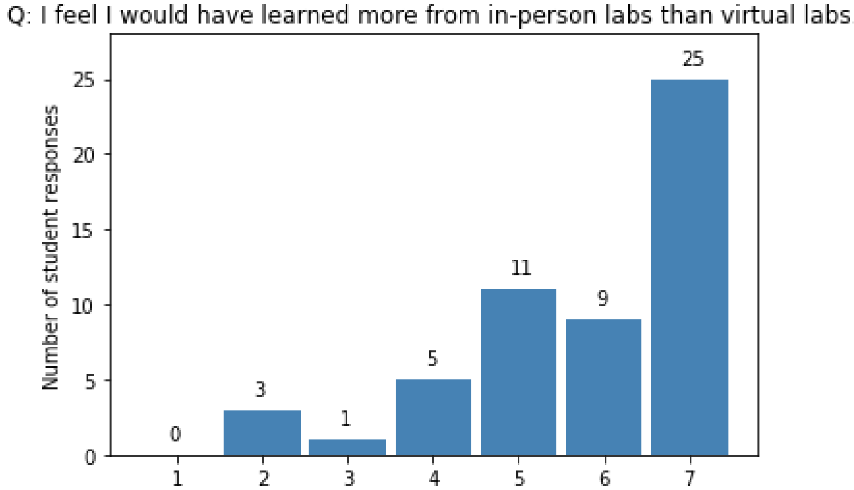

Figure 7. Student responses to “I feel I would have learned more from in-person labs than virtual labs.” Choices are 1: corresponds not at all, 2: corresponds very little, 3: corresponds a little, 4: corresponds moderately, 5: corresponds enough, 6: corresponds a lot, 7: correspond exactly.

Figure 8 indicates 91% of students preferred in-person labs over virtual labs, with 52% students chose 7, corresponding exactly.

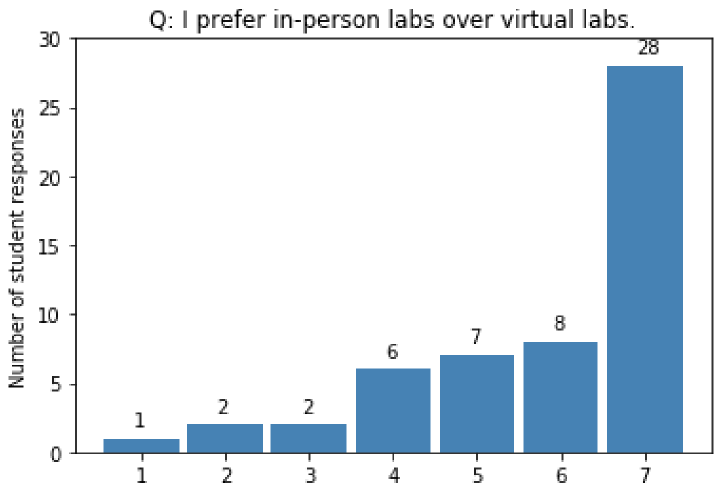

Figure 8. Student responses to “I prefer in-person labs over virtual labs.” Choices are 1: corresponds not at all, 2: corresponds very little, 3: corresponds a little, 4: corresponds moderately, 5: corresponds enough, 6: corresponds a lot, 7: correspond exactly.

Figure 9 shows 78% of students thought the format of labs met their learning needs at least moderately, with 48% of responses concentrating around 4 and 5 (corresponds moderately and enough). In other words, the lab format is OK, but not ideal.

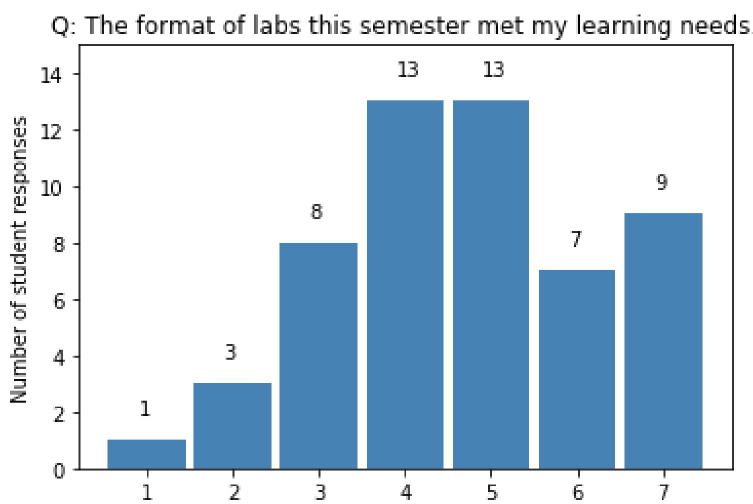

Figure 9. Student responses to “The format of labs this semester (virtual and with the option of joining in person in alternating weeks) met my learning needs.” Choices are 1: corresponds not at all, 2: corresponds very little, 3: corresponds a little, 4: corresponds moderately, 5: corresponds enough, 6: corresponds a lot, 7: correspond exactly.

Student Comments

From all the surveys and the end of semester course evaluation, it seems that overall students enjoy the hands-on lab and project experience. Some even put "working as a team" as highlight for the course:

- "I really like how interactive this course is and the hands-on projects that we get to do."
- "I really liked the hands-on lab experience."
- "I liked how we did hands-on activities."
- "Just loved the team aspect of things."
- "I liked my lab group, we worked well together."

Virtual learning seems to take a toll especially on students who have time zone difference or even take the class from overseas. There were students who acknowledged "opposite time zones, completely virtual classes (made the course experience) a bit more agonizing than what I (he) had expected my (his) first semester in college to be."

For the majority of students, their answers to the free response survey questions on the virtual vs. in-person learning are in line with the survey findings above.

There are students who are not bothered by the virtual format. For example,

- "I feel like I was surprisingly more productive while attending virtual labs."
- "I feel attending virtually put a lot of the responsibility and creative process on the group and forced us to work independently of the instructor. It was nice to have this type of control on how we completed it."
- "Attending labs virtually was more convenient for me, since I live about 30-40 minutes from the campus, and going to the campus more than I did (twice during the semester) would have been a considerable hassle."
- "I liked working with the team even though it was over zoom."

However, most students prefer in-person over virtual labs:

- "I would have preferred to do it in person."
- "Even though I was able to learn from the labs, I do believe that I could have gotten a lot more out of the course if it had been completely in person."
- "Getting to know my teammates was much harder over zoom than it would have otherwise been."
- "Attending in-person was much better than virtual, because I felt more invested in the material."
- "I really enjoyed being able to work in the lab because I got to use the tools in the classroom."
- "We were the most productive when working in person."
- "Virtual learning is certainly not as effective as attending in-person. In-person classes are very good socially, mentally, and academically for me because my brain is turned on to what is right in front of me, as opposed to passively getting through a class on a screen."

- “I feel that with remote learning, some students feel less inclined to help during group work and join class for attendance purposes, or they simply do not speak which is not good when trying to complete a group assignment.”

Overall, students feel like the face-to-face social interaction with other students and being able to work in the lab using the tools and supplies are what they miss out when they attend lab virtually.

Conclusion

Results show that the 2020 cohort, who attended the Introduction to Engineering course with virtual adaptation due to the pandemic, has at least comparable, if not better, project outcome compared to the 2019 cohort in a regular pre-pandemic semester. However, additional survey findings show that the 2020 cohort is slightly less motivated compared to the 2019 cohort who attended the class face-to-face. Within the 2020 cohort, students are much more motivated when attending lab in-person compared to attending lab virtually. Although there is no significant difference in satisfying student’s psychological need of relatedness between the 2019 and 2020 course formats, students overwhelmingly prefer in-person labs over virtual labs due to the social interaction and readily available tools and supplies, and they feel they could have gained more from in-person labs. This is consistent with the findings in [7]. Although one would expect courses go back to the normal face-to-face mode after the pandemic, nonetheless, there is still a need to find ways to improve student’s virtual project learning experience to benefit future online students.

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