Online, Open, and Equitable Education

Lessons from Teaching and Learning during the Global Pandemic

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CHAPTER 3

The Importance of Teamwork for First-Year Students' Motivation and Belonging During COVID Online Delivery

A Canadian Engineering Case Study

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How do you design, facilitate, and evaluate a large, first-year, credit/no credit, multi-section, team-based engineering design course during a pandemic? These are the questions we asked ourselves as we prepared to offer Engineering (ENGG) 160, Introduction to Engineering Design, Communication, and Profession, for the second time in the winter 2021 semester. Some of the regular challenges of this course include offering an engaging foundational design experience to a large number of students (typically three sections of approximately 400 students each) in a blended format with only one face-to-face hour per week, incorporating guest lectures from instructors representing each of our program's sub-disciplines, and introducing and assessing a wide variety of learning outcomes related to learning the design process, teamwork skills, and information about the profession (Jamieson et al. 2022).

First-year engineering design is rarely taught online, and offering this course remotely during a pandemic presented additional technical, delivery, and teaching challenges. How could we effectively facilitate teamwork when everything was online and there was only one synchronous hour scheduled per week? Would students be motivated to engage in the course with credit/no credit competency-based grading? Further, since design experiences have been

shown to be crucial for students' sense of belonging and identity in engineering (Godwin and Potvin 2017; Rohde et al. 2019), we wondered if we would be able to cultivate a sense of belonging and community while students were isolated at home.

This chapter briefly describes the relevant literature on online learning and intrinsic motivation that guided our course redesign, our research methodology and key findings from our post-course cross-sectional survey, and the implications of our findings for future iterations of the course as well as for online and blended team-based learning in other contexts.

Literature Review

An ability to design solutions for complex, open-ended engineering problems and an ability to work effectively as a team member and leader are important attributes of engineering graduates (Kaupp et al. 2012). Therefore, design courses typically have a team project and are taught as an integrative component that crosses all engineering sub-disciplines and years. While design experiences have been shown to increase students' identification and sense of belonging with engineering, poor team experiences can have negative impacts on students' engineering identity, self-efficacy, and sense of belonging (Ong, Jaunt-Pascual, and Ko 2020). Because the team experience is so critical, the literature on online learning informed our work in redesigning and evaluating the team aspect of the course.

Some of the challenges of online learning include students feeling isolated, disoriented or unmotivated (Mazza and Dimitrova 2004) and instructors lacking visual cues to interpret and evaluate students' learning and engagement (Dringus and Ellis 2005). Facilitating connections is critical; students' lack of connection to each other and lack of online learning opportunities in a course have been shown to lead to feelings of isolation and disengagement with a course (Rose 2017; Burke and Lamar 2021). Considering our students were in their first year during COVID remote learning and therefore may not have had a chance to develop a strong community before taking our course, we knew that attention to their affective

and socio-emotional processes would be particularly important (Kılınç 2021). Therefore, we used the lens of Self-Determination Theory to help us understand their experiences in ENGG 160.

According to Self-Determination Theory, social and cultural factors can facilitate or undermine people's intrinsic motivation, well-being, and the quality of their performance. The three basic psychosocial needs which must be met for motivation and well-being are autonomy, competence, and relatedness (Deci and Ryan 1985; Ryan and Deci 2000). In education contexts, autonomy is defined as the need to regulate one's own behavior and have a degree of choice and control over one's learning strategies (Deci and Ryan 1987; Niemiec and Ryan 2009). Competence is the need to feel capable and effective with the taught subject matter, and self-efficacy is the belief in one's own competence (Bandura 1982; Niemiec and Ryan 2009). Relatedness is the need to feel a sense of belonging and connection (Ryan and Deci 2000) which, in the learning environment, can be moderated by both instructor and peer interactions (Meeuwise, Severiens, and Born 2010; Strayhorn 2012). The gamified redesign of ENGG 160 was intended to encourage intrinsic motivation and competence development by leveraging autonomy, relatedness, and self-efficacy. The learning activities were individual and team based to create an engaged online community balanced with individual autonomy and interest.

A number of self-report instruments have been developed to study self-determination and its related constructs. The Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al. 1991) has been used extensively in higher education, including in online and engineering contexts (e.g., Duncan and McKeachie 2005; Ramírez et al. 2016). Instruments for sense of belonging and self-efficacy have also been developed and validated specifically for STEM contexts (e.g., Hurtado and Carter 1997; Baldwin, Ebert-May, and Burns 1999; Mamaril et al. 2016). Finally, in reviewing instruments developed for online and blended learning environments, we found some of the questions about engagement from Owston, York, and Murtha (2013) to be useful for our context.

However, no instrument we reviewed, or even a set of items for a specific construct, consisted entirely of questions relevant to our context. To build a questionnaire that was aligned with both our course and research questions, we chose a mix of relevant scale, domain-specific (engineering), and task-specific items from existing instruments in a collaborative and iterative process. A full literature review and a description of our questionnaire and development process is provided in Miller-Young, Beck, and Jamieson (2021); we discuss the validity of our questionnaire in the methods section, below.

Context

The study took place at a large, research-intensive university in Canada. The course was first offered in winter 2020, in a blended format with one face-to-face hour per week, consisting of live guest lectures and a team design project for which students were randomly assigned into teams and expected to work together mostly outside of scheduled class time. Teams reported struggling to find time to connect, and many students appeared to follow the minimum path to obtain credit for the course, although it is difficult to say how much of this was due to course design, and how much was due to the course being interrupted by the lockdown during COVID-19 (Jamieson et al. 2022). Therefore, for the winter 2021 iteration, we shifted more weight to the project deliverables, focused formative progression assessments on feedback and used competency-based grading with the opportunity to rework the assignments, increased the minimum activity completion requirements, and added gamification elements to improve student autonomy and engagement (Jabbar and Felicia 2015; Bodnar et al. 2016). Game elements included flexibility in deadlines for much of the individual work, badges for completion of various aspects of the course, and a dashboard indicating progress. However, knowing that this second iteration would have to be delivered fully remotely, we remained especially concerned about how to facilitate a positive team experience.

In order to facilitate online team interactions during the course, and therefore hopefully increase students' sense of belonging and intrinsic motivation, the team design project group size was reduced from eight to six students and they were allowed to pick their own teams. The main team conceptual design project was broken down into weekly progress assignments connected to the relevant weekly individual work, which included asynchronous weekly readings, recordings, and quizzes. Finally, the synchronous class time was used for team activities, which were facilitated by the instructor and eleven teaching assistants (TAs) who assisted with project management, team concerns, technical advice, and mentorship. Each team had their own Zoom breakout room to facilitate TA/student interactions during class, and teams had their own Discord text and voice channels which helped facilitate continued informal communication during the rest of the week and gave the TAs an additional way to monitor the groups. TAs also kept regular remote office hours on Zoom or Discord to answer student questions during the week. The instructor and the TAs answered questions during class as well as on the course LMS page and Discord during the week.

Finally, although we employed a survey design and attempted to be as objective as possible in our research, we recognize our own positionality in this study. Our research question and methodological choices were influenced by three key aspects: a) our mutual concern for students' online experience during COVID-19, b) Seth's recent experience as an engineering undergraduate student and design teaching assistant, and c) our literature review of studies which have used Self-Determination Theory and belonging in higher education (Miller-Young, Beck, and Jamieson 2021). Our choice to use a cross-sectional, multi-method survey allowed us to gain insights from as many students as possible, however it may also have limited us from exploring other important aspects of students' experiences. Therefore, we also conducted eight follow-up interviews which are reported elsewhere (Miller-Young, Jamieson, and Beck 2023).

Methods

The purpose of our study was to explore students' experiences during remote delivery of our team-based, competency-based, first-year course, using the lens of Self-Determination Theory. Our research questions were:

- How did students feel the course satisfied their basic psychosocial needs, i.e., autonomy, self-efficacy, and sense of belonging?
- How and why did students perceive that the various course elements influenced their autonomy, self-efficacy, and sense of belonging?

This study employed a multi-method survey design, using a questionnaire with both quantitative and qualitative items. Quantitative data was analyzed using descriptive statistics; qualitative data was analyzed using conventional content analysis (i.e., inductively, looking for themes that helped explain the quantitative findings [Hsieh and Shannon 2005; Neuendorf 2017]). Finally, we used extreme case sampling to choose quotes from students who responded with either high or low scores to Likert-scale items asking about autonomy support, self-efficacy, and belonging/relatedness.

Data collection

The questionnaire was developed by selecting appropriate items from several validated instruments in order to answer our research questions. Questions were selected and/or modified from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al. 1991); Hurtado and Carter's (1997) sense of belonging questionnaire; Biology Self-Efficacy Scale (Baldwin, Ebert-May, and Burns 1999); Owston, York, and Murtha's (2013) blended learning questionnaire; and Mamaril et al.'s (2016) engineering self-efficacy instrument. A detailed literature review and description of the development process as well as the full questionnaire which had six demographic, forty-seven Likert-scale, and seven short-answer items is provided elsewhere (Miller-Young, Beck, and Jamieson 2021). Because the purpose of the questionnaire was for course feedback as well as research, we organized the questions in the order we thought would be most useful for students when

replying; therefore, validated construct measurement questions were mixed with course-specific feedback questions, and not all questions related to each construct from the original sources were included. For the purposes of this study, we analyzed responses to four Likert-scale questions related to autonomy (questions 9, 14, 47, 49), ten Likert-scale questions related to self-efficacy (questions 16–25), nine Likert-scale questions about belonging and relatedness (questions 29–31, 33–36, 39, and 40), and four Likert-style questions about the effectiveness of various aspects of the course using a 5-point scale (questions 48, 50, 53, and 60), as well as the qualitative responses to the five short-answer question at the end of each section, "Is there anything else you'd like to tell us about ___?"

The questionnaire was deployed online using Google Forms in the last week of classes. Announcements and the link were posted on the class website and emailed to all 903 students enrolled in the course. All participant information was managed and kept confidential by Seth, who is not an instructor. Additionally, the two research team members who were not affiliated with the teaching of the course that semester (Janice and Seth) introduced the research project during the final (synchronous) class time. All students were asked to complete the questionnaire for feedback purposes, and they had the option to indicate if they were willing to have their responses used for research purposes. Reminder emails were sent to those who had not yet responded up to four times over the following five-week period. The study was approved by the University's human research ethics board.

Sample

Of the total 903 eligible students who were invited to participate, 223 responded to the survey and 186 indicated they consented to their data being used for research purposes, resulting in a 20.6% response rate for the research. All participants responded to all quantitative questions. After examining the data set, we removed six participants from the data set because their responses to reverse score questions did not align with their other responses, resulting in a final sample of 180 participants and a completion rate of 97%.

Of these participants the majority identified as male, were 19 years of age or below, identified as Caucasian, South Asian or Chinese, and self-reported a GPA in the B or C range (figures 3.1 and 3.2). These participant demographics are representative of students in our program as well as within engineering programs across Canada (although the university registration system does not collect race- or identity-based data, the faculty collects an annual "Diversity in Engineering" survey which includes demographic data).

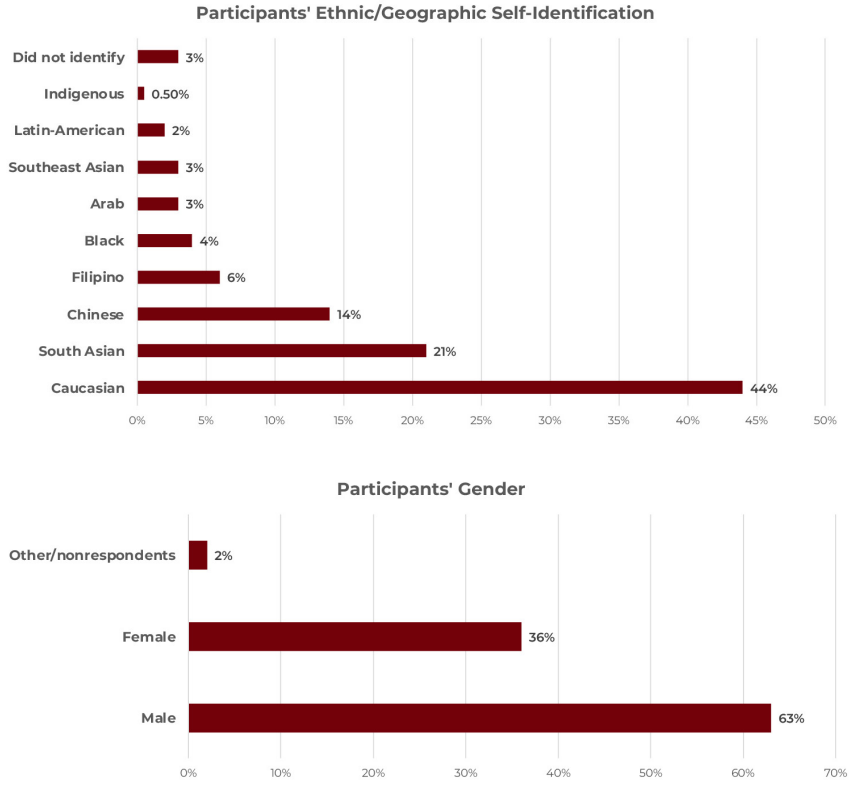

Figure 3.1. The participants' gender and ethnic/geographic self-identification. Note: The respondents had the choice to select more than one box for ethnic/geographic identification with four students identifying as more than one category listed.

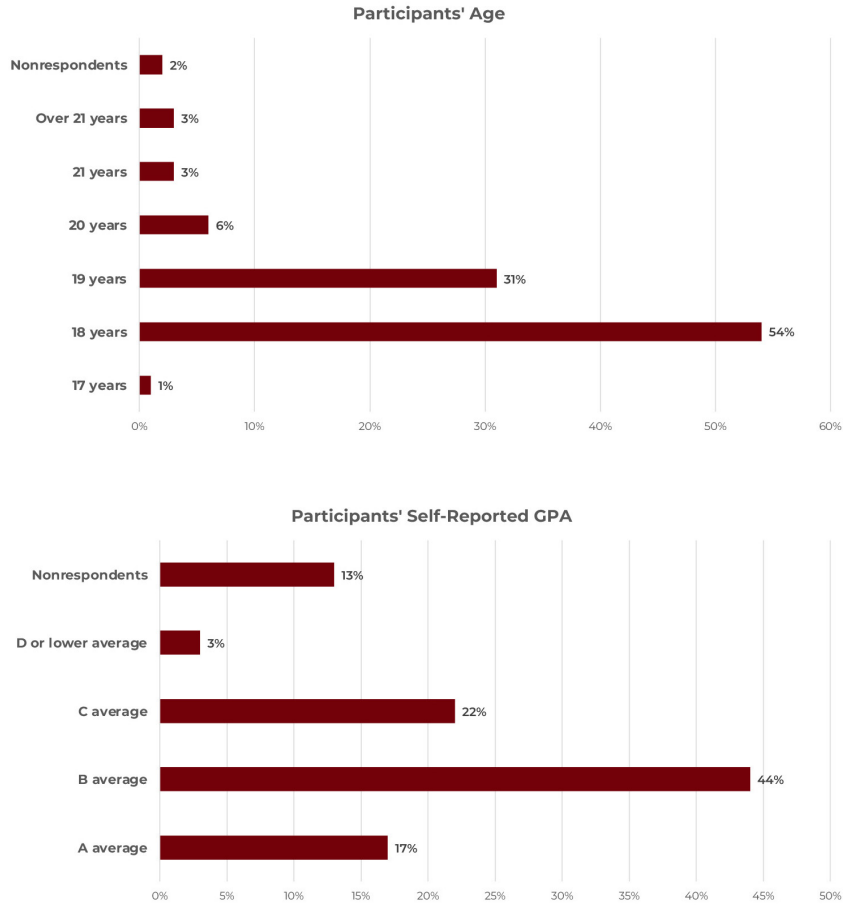

Figure 3.2. The participants' self-reported GPA and age

Data analysis

As a first step, we examined our data and realized that it was not normally distributed; Likert-scale responses for almost all questions were skewed towards higher responses (using Matlab, the skewness was calculated to be negative for responses to all questions except Q7 "I was likely to ask questions in this course" which was normally distributed, and Q39 "The game elements improved my motivation to do work in this course" for which skewness = 0.01). This is a positive result from a teaching perspective, however it has implications for statistical analysis. Although in quantitative research

it is common to conduct a factor analysis to test the validity of an instrument, we took a different approach to this case study for several reasons: the items had been validated previously in other studies and similar contexts, the responses for our study were highly skewed, we were interested in understanding student experience rather than correlating variables using inferential statistics, and students' qualitative responses aligned well with and helped explain their quantitative scores. Instead, we decided to re-score our quantitative data into three categories: 4,5=agree, 3=neutral, and 1,2=disagree, and report frequencies of these responses. Descriptive statistics (mean and standard deviation) for relevant questions were also calculated.

In addition to gaining useful feedback about various aspects of the course, we were surprised at the overwhelmingly positive responses related to teamwork. Also, we noticed that most students who reported higher scores on questions related to one construct reported higher scores on all constructs, and vice versa; further, students in the high and low groups gave different reasons for their responses. Therefore, we divided respondents into these two groups and conducted descriptive statistics and a content analysis of their qualitative survey responses. A total of 134 students (~74%) elaborated (explained beyond a simple one word reply, e.g., "no") on their Likert-scale survey responses in at least one of the short-answer questions. Of these 134 responses, 62% identified as male, 37% identified as female, and 1% preferred not to answer or identified differently. Furthermore, 54% identified with an ethnic/geographic origin of Caucasian, 18% identified as South Asian, 11% identified as Chinese. For comparison, individuals were separated into two groups based on their average Likert-scale response to the set of questions identified as being relevant to that survey section, e.g., Q16–25 for the self-efficacy section. The high group corresponded to individuals who averaged responses greater than three for that section, whereas the low group corresponded to individuals who averaged responses less than or equal to three for that section. The high and low groups' average and standard deviation were calculated.

The content analysis involved looking for comments that described students' perspectives on how and why any aspects of the course influenced their autonomy, self-efficacy, and sense of belonging (either positively or negatively). These were initially identified by one author who was not the instructor, and discussed and agreed upon by the whole team. Finally, from all the students who had qualitatively responded to questions related to autonomy support, overall self-efficacy, belonging and relatedness, and overall team experience, we chose an exemplar quote from the students who reported highest and lowest Likert scores on each of these constructs, and gave pseudonyms to each student.

Findings

Autonomy Support

The majority of students agreed that the course supported their learning autonomy. Specifically, students felt they had choice in how to learn the material and that both the individual and team activities allowed them some control over their learning process (figure 3.3). The average responses to Q9, Q14, Q47, and Q49 were 3.60 (SD = 1.05), 3.54 (SD = 1.22), 3.83 (SD = 1.04), 3.65 (SD = 1.02), respectively.

Self-Efficacy

The majority of respondents also agreed that they understood the ideas taught in the course and were capable of applying those concepts to new engineering problems (figure 3.4). Some example questions to assess the student's perceived competence (self-efficacy) include, "I'm certain I understand the ideas taught in this course" and "I'm confident I could critique a design report written by another team" (Miller-Young, Beck, and Jamieson 2021). The average response to the overall perceived competence construct was 3.70 (SD = 1.00).

Relatedness and Belonging

The majority of students felt their interactions with the other students as well as the teaching team were positive; additionally, most

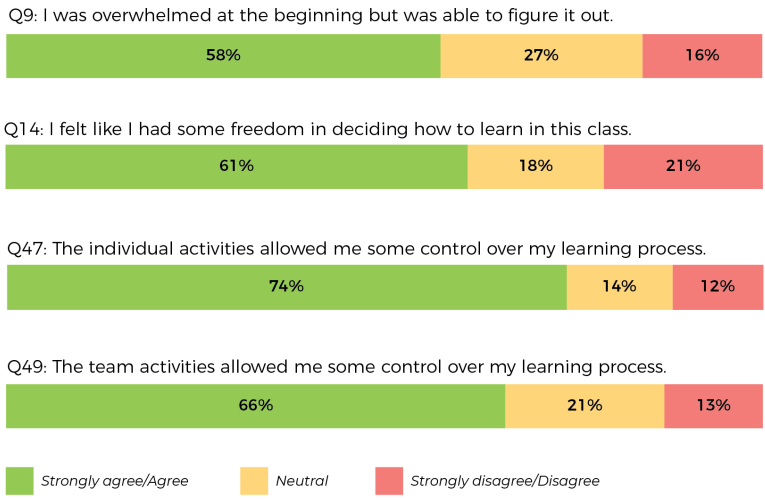

Figure 3.3. Overall responses to four Likert-scale questions related to autonomy support, n=180. Note: Charts are rounded.

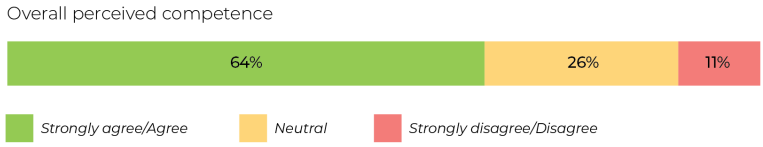

Figure 3.4. Students' overall perceived competence, calculated as their average response to Q16–25, n=180

students felt a sense of belonging in the engineering community as a whole (figure 3.5). The average response to the overall belonging construct was 3.66 (SD = 1.11). The average response to the quality and amount of interactions with other students, the instructor, and teaching assistant constructs were 4.05 (SD = 0.98), 3.50 (SD = 1.08), 3.64 (SD = 1.14), respectively.

Course Elements

Overall, more students felt the team aspects of the course improved their motivation in the course than did the game elements (figure

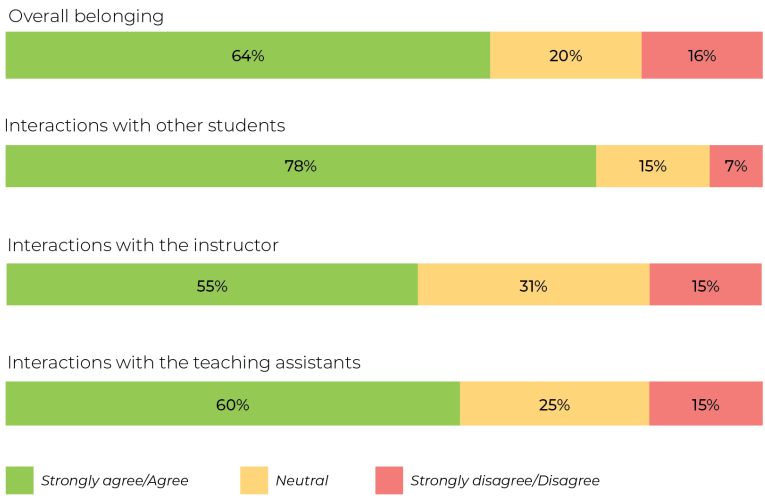

Figure 3.5. Students' responses to questions regarding relatedness and belonging. Note: Overall belonging is the average of Q31, Q39, and Q40; interactions responses are the average of two questions each about quality and quantity, n=180.

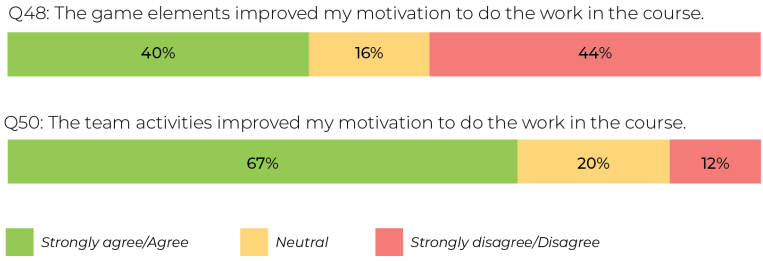

Figure 3.6. Students' perceptions of whether the game elements and team elements improved their motivation to do work in the course, n=180.

3.6). The average response to Q48 about game elements was 2.82 (SD = 1.41), and the average response to Q50 about team activities was 3.76 (SD = 1.02).

Although over three quarters of the students were satisfied with their online team experience, 94% indicated they would still prefer

a face-to-face component in the course (figure 3.7). The average response to Q60 was 4.07 (SD = 1.00).

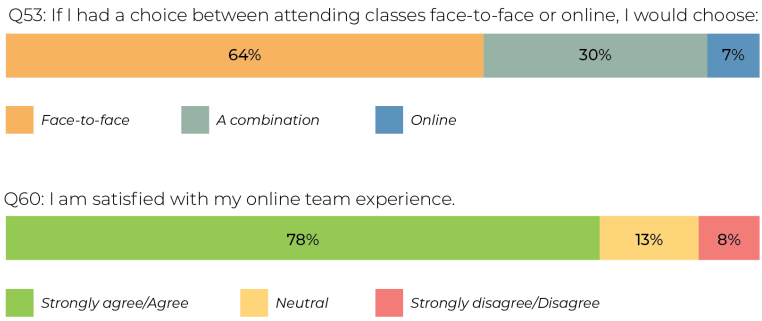

Figure 3.7. Students' preferred course format as well as their satisfaction with the online team experience, n=180.

Differences between High and Low Responders

After examining the qualitative data, we realized that although overall quantitative responses were skewed towards the positive, there were a handful of outliers who overall reported a fairly negative experience in both the quantitative and qualitative data. Comments from students who scored the course high on the various constructs indicated that their teams played an important role in their autonomy, self-efficacy, and belonging. For example, Shang, Mary, and Emily reported the value of their teams for helping each other, while Samantha felt that she learned more about what being an engineer is like, which was motivating for her (table 3.1). On the other hand, among those who scored the course low, three reasons were given: Amir's comment displayed a less mature approach to learning by indicating a lack of understanding of the course's competency-based pass requirements, Jennifer and Sarah reported that being online for the year was overall not a positive experience, and Fatima had a team where not everyone put in equal effort.

	n	Avg.	STD	Exemplar Quote
Autonomy support				
High group (>3)	114	4.17	0.47	*"I like the way that the course separated students into different groups, let students work by themselves, and if they have questions, they can ask someone. This really helped us cultivate the skill of self learning and self investigating." —Shang*
Low group (<=3)	66	2.54	0.60	*"Learning the course was fine, but the structure was not good because you HAD to PASS everything which is not how a class should work." —Amir*
Overall Self-Efficacy				
High group (>3)	148	3.95	0.46	*"I learned that engineering is all about teamwork, and I was really motivated to be an engineer after working with my amazing team." —Samantha*
Low group (<=3)	32	2.56	0.56	*"I have retained so close to nothing in the online year it's horrific. I really really regret enrolling and not taking a year off and find this to be a very common sentiment amongst other university students." —Jennifer*
Belonging and Relatedness				
High group (>3)	147	3.99	0.52	*"My team and I helped each other with understanding concepts." —Mary*
Low group (<=3)	33	2.45	0.58	*"Being online is very isolating and does not contribute to the engineering community vibes." —Sarah*
Overall Team Experience				
High group (>3)	164	4.37	0.50	*"I thought teams were an awesome way to get people more involved with fellow students, especially in a year like this. My teammates helped keep me motivated to finish all of my work, more efficiently and better than I would have done on my own." —Emily*
Low group (<=3)	15	2.65	0.54	*"I'd say only half my team really put in effort this term. This was difficult for me to accept because at the end of the day everyone has exams and assignments and things to do, but dishing off your work to someone else only makes their lives more difficult." —Fatima*

Table 3.1. Quotes relating to teamwork from students who reported high and low scores for autonomy support, self-efficacy, belonging/relatedness, and overall team experience.

Discussion and Implications

Our primary goals in reimagining our first-year design course for remote delivery were to engage students on design teams, encourage engineering and professional identity development, form a supportive learning community, and motivate students to develop competency in the course learning outcomes. Nearly 80% of the students responding to the survey were satisfied with their online team experience, which appears to support our decision to dedicate the available synchronous class time to progressive team design project learning activities supported by the teaching team. About two-thirds of the students responding indicated they agreed the course increased their feelings of relatedness, belonging, and competence while between 11% and 16% disagreed. A similar response split was observed for the item "*The team activities improved my motivation to do the work in the course*" suggesting the synchronous team component was essential for belonging, motivation, and a positive online experience.

For a similar teaching context, Mazur (2021) reports teaching a large, first-year physics course to non-majors which has a strong team-based component. Having taught the course for multiple years, Mazur uses Self-Determination Theory to evaluate his course on a longitudinal basis; for the winter 2021 remote delivery, he found that students' self-efficacy, reported autonomy, and sense of community all went up compared to previous years (Mazur 2021). He speculated that perhaps because the teams met in Zoom rooms, it didn't feel like such a large class to them. Since teamwork requires students to develop empathy and social responsibility towards each other, the more "intimate" environment may have improved the sense of community for most students. This observation is consistent with what Marnie, as instructor, experienced as she moved between Zoom breakout rooms to interact with student teams. In general, the students who were participating were developing connections, interacting with the material, asking questions, and working together. Also, the asynchronous aspects of the course gave students more flexibility and therefore autonomy. Being online and

connected with a Discord server may have facilitated even more course-specific interactions among students and between students and the teaching team than usual. In summary, Mazur's (2021) findings are very much in line with our own, with the addition of longitudinal survey data to demonstrate an increase in all three constructs from traditional to online delivery, which strengthens our assertion that team projects are important for positive student experiences in large, first-year classes if they are to be taught online.

Our new gamified course design with competency-based assessments was intended to improve student engagement with the asynchronous course materials. As two-thirds of the course delivery time is asynchronous and online, intrinsic motivation is a key contributor to student success in the course. For this first iteration of the gamified course, a software issue contributed to some students being able to reach the maximum levels in the early stages of the course. While we were able to mitigate the issue, we hypothesize that this was discouraging and potentially demotivating for some students as only 40% of the students found the game aspects motivating. We are hopeful the software fixes will be in place for the next iteration of the course, and in the meantime we have refined the badge progression and structure to encourage cooperation and individual work.

One pre-pandemic study found that students are strategic when choosing online courses and are more likely to prefer online courses if they've taken one before (O'Neill et al. 2021). Our students did not have a choice—their only option was the online course. Despite this constraint, two-thirds of our students agreed the course supported their learning autonomy. Students felt they had freedom in deciding how to learn the material and they had some control over their learning process. According to O'Neill et al. (2021), the more important a course was for a student and the more inclined they were to seek help when they were struggling, the less likely they were to prefer the online version. Our qualitative data provides additional insights into students' perceptions, particularly those whose perceptions were negative. These negative experiences, at least for students who responded, seemed to be more caused by isolation due to COVID

rather than other online factors, and only one student cited team issues as a reason for their lower scores. The next iteration of our course will be a hybrid mode to accommodate both in-person and remote students at the same time (offered in winter 2022). It will be interesting to see if their increasing experience with online delivery will affect students' perceptions and experiences going forward.

While more studies are needed from different contexts in order to make strong generalizations, these combined results suggest semi-structured, synchronous, online team and student instructor interactions contributed to student autonomy, belonging, community, and motivation for most first-year students. Further, the study provides strong evidence of the need to attend, through course design, to factors related to self-determination and intrinsic motivation during exceptional circumstances such as a pandemic, also raising questions for online and hybrid courses of the future. How can we optimize active learning in large classes? What is best done synchronously versus asynchronously? Will the tools we used for connecting students during the pandemic continue to be a useful part of course design? And how can we adjust our courses over time as both instructors and students gain more experience with online learning?

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