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Within-team Task Choices: Comparison of Team-based Design Project Engagement in Online and Face-to-face Instruction

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Introduction

Team-based design projects are commonly used as a pedagogical tool in foundational undergraduate engineering courses. Traditionally, these learning activities have been designed for use in face-to-face (F2F) settings to foster extended interaction among team members and engagement in a variety of hands-on engineering activities. An important goal of team-based learning is to give students experience making collaborative decisions about how to work together and independently in the service of engineering a high-quality product within technical specifications. The advent of COVID and the shift to online (OL) instruction changed the nature of engineering education in profound ways. First-year engineering students enrolled in OL courses completed team-based design projects under conditions that differed from their F2F counterparts in two important ways. First, OL team members worked remotely, distanced from instructors and peers, because they were unable to collaborate in the same physical space. Second, OL team members did not have access to on-campus materials and tools.

The purpose of this *work-in-progress* paper is to explore whether and, if so, how students enrolled in OL and F2F introductory engineering courses differed in the ways they engaged with a team-based design project. More specifically, the aim is to understand differences in how much time students contribute to total man-hours, what kinds of work students contribute, and how students describe their identity within a team under different learning conditions.

This research is part of an overarching research agenda aimed at facilitating research with the potential to explain how working in teams shapes the development of professional identity and discipline-specific skills among undergraduate engineering students. It advances the development of the *Within-team Task Choice Survey* (WTCS) and offers new insights into the pedagogical complexity of team-based design projects.

Literature Review and Significance

A thorough understanding of the ways team-based design projects operate as an instructional tool – for teams as a whole and team members as individuals – is essential for engineering educators. There is evidence that the use of team-based instructional strategies is wide-spread in engineering education [1-7]. In general, teamwork is viewed as an essential means to support the development of important durable professional skills [8, 9]. Notably, demonstrations of the ability to communicate and collaborate effectively within a team are requirements for completing a post-secondary program of study in engineering [10]. Team-based design projects, specifically, are used as a pedagogical tool because they approximate professional conditions and offer emerging engineers opportunities to develop soft skills in the process of applying engineering knowledge and skills. Despite the theorized benefits, team-based engagement among students has the potential to invalidate or reinforce stereotypes related to, for example, gender and race [11-13]. Pedagogical knowledge about how team-based learning strategies support learning has implications for designing productive educational opportunities, facilitating team collaboration, and supporting individual students' development.

The nature of team-based design project assignments can vary across engineering disciplines. However, they tend to have three features in common. First and foremost, a team-based design project requires a small group (i.e., team) of students to solve an open-ended design problem within specifications. Second, it requires research in the form of gathering information and conducting technical analysis. Third, it requires production in the form of developing and testing processes or prototypes. Often, the complexity of the design problem demands multiple iterations (i.e., cycles of research and production) to generate a solution within specifications. The combination of these three elements are aimed at supporting the development of collaboration skills and communication skills, offering students technical and non-technical mastery experiences [14, 15], and engaging novice engineers in the application of theory [1, 16].

A variety of research studies of team-based learning– and team-based design projects specifically – exist in the engineering education literature. Some studies offer insights into the conditions for success. Results suggests that good outcomes require well-designed assignments, well-managed groups, student accountability, and instructor feedback [14, 17, 18]. Not surprisingly, various kinds of conflict can undermine the potential of team-based learning [19]. For example, lack of trust among teammates can sow discord. In particular, learning in the context of a team-based design project may be limited when there is a perception that one or more teammate(s) is not making a sufficient or fair contribution to the team. This kind of individual disengagement, characterized by allowing others to carry out the more difficult or time-consuming work, is commonly referred to as social loafing [19].

Some studies suggest ways to promote team cohesion and prevent team dysfunction. Team formation processes can be developed to ensure each team has sufficient variation in, for example, educational experiences, technical skills, and demographic characteristics to bring multiple perspectives to the design project [1, 20-22]. Explicit descriptions of professional expectations can help students understand the kind of time-management, communication, and conflict resolution skills they are expected to develop as emerging engineers [8, 23, 24]. Having students write self-reflections [2] and report their perceptions of teammates' contributions [14, 23, 25] appears to support within-team accountability.

The literature suggests aspects of identity is an important consideration in team dynamics. For example, Mentzer [4] found that even when female engineering students reported similar effort as their male counterparts on a team, their efforts towards the project were taken less seriously by males [26, 27]. More generally, it appears that, when a member of a minority group is assigned to an all-majority team, their ability to make a meaningful contribution may be limited or underestimated [4, 12, 26]. Some argue that ideas about identity-related differences in communication and work styles derive from perceived cultural conditions (e.g., institutional climate, instructor expectations, assignment structures) rather than actual individual differences [11-13].

Three kinds of complications that disrupt design teams have been discussed [14]: (1) interpersonal incompatibilities related to diversity among teammates, (2) interpretation inconsistency related to understandings of the requirements of the assignment at hand, and (3) process conflicts related to the assuming and delegating responsibility for tasks. The pedagogical premise of team-based design projects is that, given a well-structured reduced-complexity engineering problem, students can learn to attend to team dynamics and navigate conflicts in a professional manner that facilitates the solution of the problem. Helping team members establish norms, periodically reflect on challenges, and identify strategies for improving collaboration requires dedicated time and regular use of peer assessment [14, 15].

This comparative study of the use of a team-based design project in online and face-to-face formats of the same course explores whether the instructional mode influences how students operate within a team. The study was conducted among students enrolled in a first-year engineering course. The team-based design project at the core of the course was developed for use in either OL or F2F modes of instruction [28]. The primary data collection tool, the WTCS, emerged as part of a research agenda aimed at understanding how members of underrepresented groups (URGs) experience team-based design projects [22, 29, 30]. The WTCS was designed for the express purpose of supporting research aimed at gaining a nuanced understanding of how individual students allocate time, complete tasks, and refine their identity as an engineer within team-based design projects [31]. This study fills gaps between research related to what makes a team effective in terms of generating a high-quality engineering product [2] and in terms of the professional formation of engineers [12, 25].

Research Questions

The purpose of the study is to explore whether students in an OL version and F2F versions of the same course differed in their experience of a team-based learning project. Each research question addresses the purpose of the study by examining a different aspect of teamwork. They are organized to reflect the methodological perspective adopted to answer each question.

Quantitative

1. Do team members receiving OL and F2F instruction differ in terms of…
    - Individual time spent on the project?
    - Actions taken to support elements of the project?
    - Roles adopted within the team?

Qualitative

2. Is there evidence of consistency or dissonance in the ways students describe…
    - The nature of their engagement?
    - Their roles within the team?

Mixed methods

3. In what ways might instructional mode (OL vs. F2F) relate to students' engagement in and experience of a team-based design project?

Methods

Research Design

This exploratory study was conducted as an extension of a larger study aimed at understanding disparities between majority group members and members of underrepresented groups in the context of a team-based engineering design projects [22, 29, 30]. Conducted over multiple years, the former study entailed iterative cycles of research design, data collection, data analysis, and instructional adaptations in the style of design-based research (DBR) [32, 33]. The WTCS was a product of the former study [31]. The current comparative study was conducted using mixed methods research (MMR) principles (i.e., the integration of quantitative and qualitative strands of inquiry to generate meta-inferences beyond what can reasonably be inferred independent strands of inquiry) [34]. In this study, the rationale for using MMR includes complementarity and expansion (i.e., to enhance interpretability of both strands of inquiry and expand understanding of the data) [34, 35].

Sample

The sampling procedures reflect the COVID-era safety precautions at the US-based, mid-sized, research-intensive university where the study took place. The OL participant pool included students enrolled in a first-year engineering computer-aided design course during the Fall 2020 semester. The F2F participant pool included students enrolled in the same course during the Fall 2021 semester. The OL and F2F versions of the course were taught by the same lead instructor. The counts of valid survey responses collected were 584 and 537 for the OL and F2F, respectively. Responses were excluded if the survey was incomplete or the project was incorrectly identified. The incomplete rate was 10% and 17% for OL and F2F, respectively. Only 2 students (in F2F) made an error in identifying the name of the team-based project assigned.

All students completed the UDGears Project [28] working in teams of three to six with support from their assigned undergraduate teaching assistant. The project involved eight design elements: (1) Problem Definition, (2) Concept Selection, (3) Design Schematics, (4) Engineering Analysis, (5) Prototyping, (5) Design Validation, (7) Project Management, (8) Technical Communication. The assignment was completed over the course of 15 weeks in four temporal phases: (1) Problem Definition, (2) Concepts, (3) Design, and (4) Design Validation. One member of the team acted as a single point of contact (SPOC) to submit periodic milestone deliverables. At major milestone markers, students provided peer evaluations via Comprehensive Assessment of Team Member Effectiveness (CATME).

Measurement

The WTCS is a four-part data collection tool implemented in Qualtrics [31]. Each part elicits information about students' choices within the team from a different perspective. Instructions for each section orient students to the shift in perspective. The first three sections are constructed of close-ended items in the quantitative tradition. In contrast, the final section solicits open-ended responses in the qualitative tradition.

1. *Time investment*. Enter numeric estimates of personal and peer time expenditures in the context of the total manhours.
2. *Action verbs.* Identify one of six Bloom's taxonomy verbs that best describe personal engagement with each of eight project elements.
3. *Identity nouns*. Select up to two nouns among 14 labels connoting leadership, fellowship, or followship that best describe personal role within the team.

4. *Elaboration*. Describe, from a personal perspective, what shaped engagement choices within the team.

Analysis

The OL and F2F data sets are being analyzed using quantitative, qualitative, and mixed methods techniques. For the quantitative analysis, SAS was used to run descriptive statistics and t-tests. For the qualitative analysis, MAXQDA was used to iteratively test a priori codes as well as generate and challenge emergent themes [36]. Finally, mixed methods analyses involved the development of joint displays [37] to juxtapose, compare, and contrast data and findings from the quantitative and qualitative strands of inquiry.

Results

During the last week of the semester, students were given time to complete the survey during a synchronous class meeting. Students who were not in attendance had the opportunity to complete the survey at another time.

Quantitative

The distribution of time taken to complete the survey was skewed to the right. The median time students in OL and F2F expended to complete the survey was 9 and 8 minutes, respectively. Table 1 compares the OL and F2F samples in terms of sample size and identity characteristics.

Comparison of students' time estimates suggest more similarities than differences across instructional modes (see Table 2). Given the exploratory nature of the study, *p*-values were compared to the liberal benchmark of 0.10 to assess statistical significance. There were differences in the group means for three variables. First, OL students spent more time, on average, in team meetings. Second, OL students spent a larger portion of time on Design Schematics. Finally, OL students spent a smaller portion of time on Project Management. The variances differed across groups for a number of variables. For example, there is more variability in the estimates of time spent in group meetings with team members for the OL students. Further analysis will include an exploration of differences among identity subgroups.

Qualitative

Qualitative analysis is ongoing. We expect both OL and F2F data will reveal themes related to delegation, effort management, desired outcomes, and resource allocation similar to previous

Table 1. Comparative summary of samples sizes and minority group membership

		Gender		International		URM	
	N	Female	Male	Yes	No	Yes	No
Online	584	31%	67%	5%	92%	16%	81%
Face-to-Face	537	32%	68%	3%	97%	17%	83%

Note: Demographic data were available for more than 97% of participants who completed the survey.

		Online		Face-to-Face				Equality of Variance
		Mean	SD	Mean	SD	*t*	*p*	
Time Expended (hours)	Individual: Weekly average	4.8	3.4	4.8	6.0	-0.09	0.93	No
	Individual: Independent work	9.8	18.5	9.3	22.6	0.42	0.67	No
	Team: Group meetings	11.5	27.1	9.0	16.0	1.90	0.06*	No
	Team: Total manhours	70.8	107.7	68.1	169.5	0.31	0.75	No
Time Allotment (% of manhours)	Problem Definition	9.4	5.1	9.8	5.4	-1.16	0.25	Yes
	Concept Selection	10.9	4.5	10.5	4.6	1.38	0.17	Yes
	Design Schematics	14.8	7.5	13.8	6.4	2.36	0.02*	No
	Engineering Analysis	12.5	5.6	12.2	5.8	1.00	0.32	Yes
	Prototyping	17.6	9.2	17.7	9.0	-0.05	0.96	Yes
	Design Validation	11.7	5.1	11.8	5.9	-0.44	0.66	No
	Project Management	11.3	6.1	12.0	6.6	-1.96	0.05*	Yes
	Technical Communication	11.8	6.1	12.2	7.7	-1.00	0.32	No

findings [31]. Also, we also expect to find themes related to leadership, fellowship, and followship. However, we anticipate that the variations in leadership, fellowship, and followship may differ across instructional modes.

Mixed methods

Mixed methods analysis will be conducted after the completion of the quantitative and qualitative analysis. We suspect qualitative data will offer some potential explanations for the group (OL vs. F2F) mean differences found in time spent in team meetings and portion of time spent on Design Schematics and Project Management. We also expect the quantitative data, particularly subgroup (e.g., team, gender, etc.) analysis, will generate portraits of teams that may exist in similar engineering classrooms.

Discussion and Conclusion

This study offers engineering educators important glimpses of students' experience of team-based design projects. Importantly, it provides insights into how instructional mode (OL or F2F) might relate to team-based design project engagement even when the course and design project are implemented as similarly. Preliminary results suggest that, in terms of time investment, experiences did not differ substantially across instructional mode. This was expected given that the assignment was developed for implementation in either OL or F2F modes. Upon completion of this work-in-progress, there will be additional insights into similarities and differences in how individuals in teams collaborated to complete the design project under different conditions.

This work extends previous research related to theories of team effectiveness [19, 38] and our research agenda. In the future, we plan to analyze end-of-semester WTCS data in conjunction with mid-semester Comprehensive Assessment of Team Member Effectiveness (CATME) data. This will allow for a better understanding of the degree to which WTCS and CATME data are complementary. For example, such a study may suggest ways of using mid-semester CATME responses to identify students who need support to choose tasks and roles in line with their developmental needs, learning goals, and emerging engineering identity. Eventually, we hope to develop a robust study to develop a teaching assistant (TA) team-mentoring training program.

The generalizability of this study will be limited in a number of ways. First and foremost, the nature of the COVID-19 pandemic was not the same during Fall2020 and Fall2021. Therefore, any differences may be, at least partially, attributable to the differences in the broader educational context than the instructional mode. For example, several university-wide policies changed between Fall2020 and Fall2021.

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