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WIP: Exploring the Impact of Partner Assignment on Students' Decision-Making in Collaborative Design Projects

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Introduction

Team formation strategies are an important element of engineering task design for authentic, collaborative projects. Many engineering educators employ software such as CATME [1] to regulate team formation. These programs, which typically focus on demographics and skill levels with the goal of creating productive teams, tend to work at the individual project level and may not necessarily account for students' participation in a series of multiple projects. Indeed, engaging a classroom community in a series of projects presents the opportunity to strategically pair students such that their connections with peers are maximized over the course of the series. In turn, maximizing these connections may impact the spread of information through the student community over time. In this paper, we begin to explore this idea by inspecting the results of sequential random partner assignment across a series of four design projects in a one-semester aerospace course.

Background

We are an interdisciplinary design team at the University of Illinois Urbana-Champaign that consists of Grainger College of Engineering faculty and Siebel Center for Design (SCD) [2] researchers. Since 2019, SCD researchers have been using HCD to develop programs and design activities that can help students learn about HCD processes and practices and develop its mindsets [3]. This work started through collaborations with engineering faculty and staff to better understand where students were exposed to design topics as well as how design was taught.

In previous work, we developed an evidence-based human-centered engineering design (HCED) framework [4] that identifies connections between human-centered design processes [3] and mindsets [5], [6] and literature-based engineering design activities [7]. It can also be used to align these connections with broader frameworks such as ABET's student learning outcomes [8] and the KEEN entrepreneurial mindset [9].

To pilot the framework at the course level, we used it as a tool for iterating materials in a required 300-level aerospace controls course with the goal of incorporating human-centered design elements that included reflective activities, discussion of stakeholders and end-users, and evaluation of teamwork [4]. These were co-designed with the instructor and implemented throughout the course's series of four pair-based design projects.

Knowledge-Building Communities in Engineering Education

Collaborative technologies and other means of supporting and assessing professional and academic knowledge-building communities or communities of practice (CoPs) have been widely explored [10], [11], [12]. CoPs have also been explored in engineering education contexts, such as for means of spreading assessment methods [13]. However, the impact of team formation strategies on the spread of information through a knowledge-building community or classroom has yet to be explored. Similar studies have examined the impact of team formation on student performance [14], but not necessarily the potential cause-and-effect relationship between team formation and the subsequent spread of knowledge through the community.

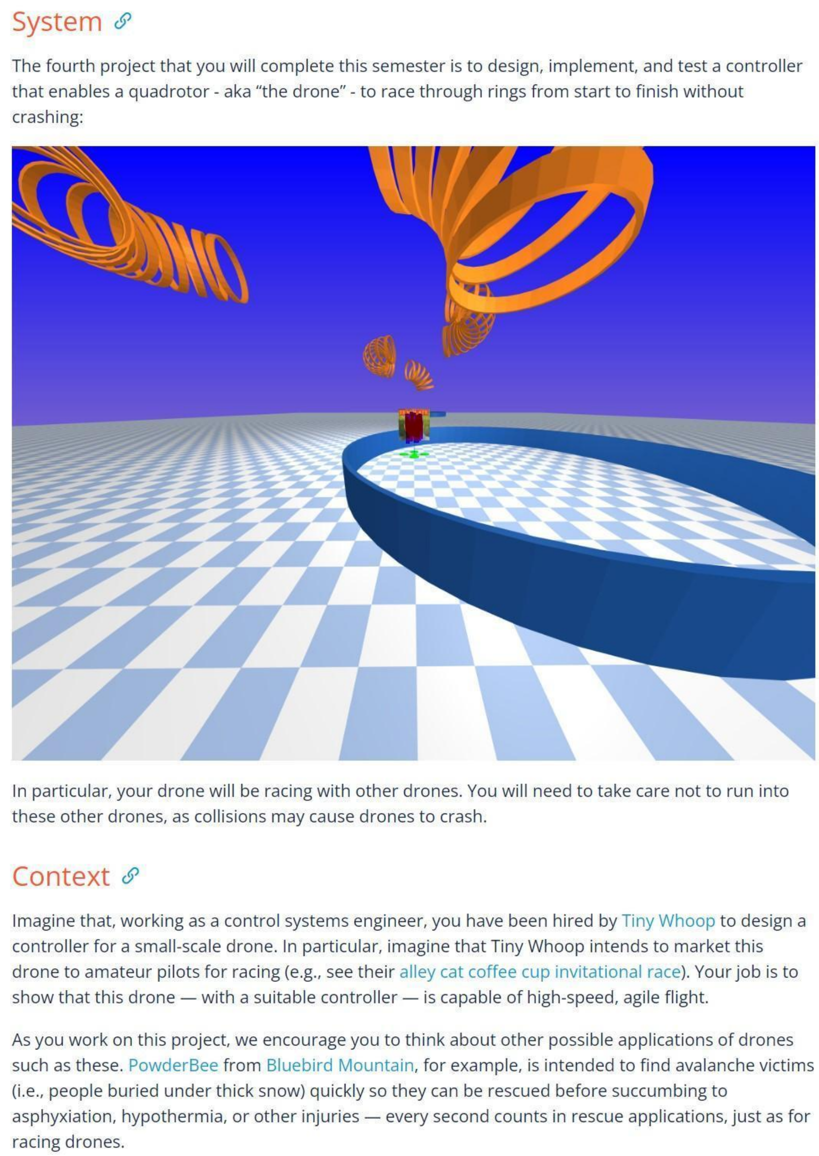
Evaluating Team Formation Strategies

Team formation software such as CATME [1] has been used both to create student teams and to help evaluate students' performance while working in the teams [15]. Indeed, team performance metrics have long been explored [16]. However, we still need to investigate how a team formation strategy (or lack thereof) may impact the ways that information spreads from student to student in a learning community. In this work-in-progress paper, we highlight the need for the investigation of strategic team formation by inspecting the spread of information through a student community and its potential relationship to the formation of teams over a series of four pairs-based design projects. Our ongoing work seeks to explore the following research question: How might sequential team formation impact decision-making trends in a classroom community?

Methods

Design Project Structure

We tracked partner assignments during the spring 2022 course, which had an enrollment of 121 undergraduate students. Over the course of the 16-week semester, students completed four design projects with three weeks devoted to each project. Each project focused on the design and implementation of a controller in simulation, the purpose of which was linked to some real-world context. Deliverables included the controller code, a technical report written through a series of drafts such that feedback from the teaching team was incorporated into the subsequent draft, a short video showing controller behavior, and a written individual reflection that each student submitted following the conclusion of the project. Figure 1 displays a segment of the prompt and context for project # 4, which tasked students with designing a racing drone.



System

The fourth project that you will complete this semester is to design, implement, and test a controller that enables a quadrotor - aka "the drone" - to race through rings from start to finish without crashing:

In particular, your drone will be racing with other drones. You will need to take care not to run into these other drones, as collisions may cause drones to crash.

Context

Imagine that, working as a control systems engineer, you have been hired by Tiny Whoop to design a controller for a small-scale drone. In particular, imagine that Tiny Whoop intends to market this drone to amateur pilots for racing (e.g., see their alley cat coffee cup invitational race). Your job is to show that this drone — with a suitable controller — is capable of high-speed, agile flight.

As you work on this project, we encourage you to think about other possible applications of drones such as these. PowderBee from Bluebird Mountain, for example, is intended to find avalanche victims (i.e., people buried under thick snow) quickly so they can be rescued before succumbing to asphyxiation, hypothermia, or other injuries — every second counts in rescue applications, just as for racing drones.

Figure 1: Portion of task for design project # 4.

At the beginning of the semester, the instructor oriented students to the design project structure and expectations. Students were provided with both Word and LaTeX AIAA-compliant templates and instructed to use either one for their technical reports.

Team Formation

Given that the class had an odd number of students, each design project had one group of three students. Pairs for projects one, two, and three were assigned using random assignment with the limitation that students could not have repeat partners. Furthermore, for each project, students could name a small number of peers with whom they did not want to work (if applicable). In project four, students had the option to request a previous partner or other peer, but were not required to do so. For this project, 35 teams of students were formed using students' mutual preferences (i.e., cases where both partners had indicated preference to work with the other). Nine teams of students were formed using singular preferences (i.e., cases in which one partner had indicated preference to work with the other). The remaining 16 teams were formed using the same random assignment criteria applied to the previous three projects.

Data Collection

Having observed that all students chose to use the LaTeX template in their fourth design project, we hypothesized that sequential partner assignments may have influenced this result. To test this hypothesis and to better understand the effect of our partner assignments, we tracked each pair's use of either template over the course of the four projects. We then used Python to create visualizations of the data to inspect students' decisions over time (i.e., across the four projects).

Student Vignettes

We also use excerpts from consented participants' written work (68 males, 10 females) to look more closely at the journeys of individual students through the project sequence.

Results

We observed that pairs' implementation of the LaTeX template increased from 60% in project one to 100% in project four. The percentage of pairs that used Word for projects 1–4 was as follows: 40%, 7%, 2%, 0%. Although students' individual experience with LaTeX prior to taking the course was not controlled, for purposes of this analysis, we assume that all students had no experience with LaTeX during the course prior to engaging in the series of projects. This allows us to inspect the likelihood of each pair's decision during a previous report to influence (i.e., result in the same selection) the next pair's decision in the subsequent report. A description per project is provided below:

For project #1, for which previous LaTeX experience was unknown as this was the first project, 60% of teams (36 out of 60) selected LaTeX. For project #2, of 60 teams total, 49 had at least one student who had used LaTeX in a previous report, and 11 had no LaTeX experience. 64% of the teams that still lacked LaTeX experience (7 out of 11) selected LaTeX. 100% of teams selected LaTeX if at least one student had used LaTeX in a previous report. For project #3, all teams (i.e., at least one student per team) had used LaTeX in a previous report and 98% of teams (59 out of 60) selected LaTeX. For project #4, all teams (i.e., at least one student per team) had used LaTeX in a previous report and 100% of teams selected LaTeX. In other words, when students were unfamiliar with LaTeX, they tended to select it roughly 60% of the time. When they, or someone else on their team, was familiar with LaTeX, they tended to select it nearly 100% of the time.

Visualization of Partner Decisions over Time

Student partner pairs and the report format selected by each pair are depicted in Figures 2–5. In each figure, a numbered node represents each student. The position and number of each student node is consistent from figure to figure. Connections (i.e., lines) between nodes indicate a pair. For example, the line connecting nodes 31 and 89 in Figure 2 indicates that students 31 and 89 were partners for project #1. The color of the connecting line indicates the report format, with blue representing Word and green representing LaTeX.

In subsequent figures, the nodes are color-coded to represent the report format selected for the previous report. For example, the colored lines in Figure 3 represent selections for project #2, while the colored nodes recall the selections from project #1. In Figures 4 and 5, concentric rings were added to include all past reports in the same figure. Each ring is labeled to indicate which project it represents.

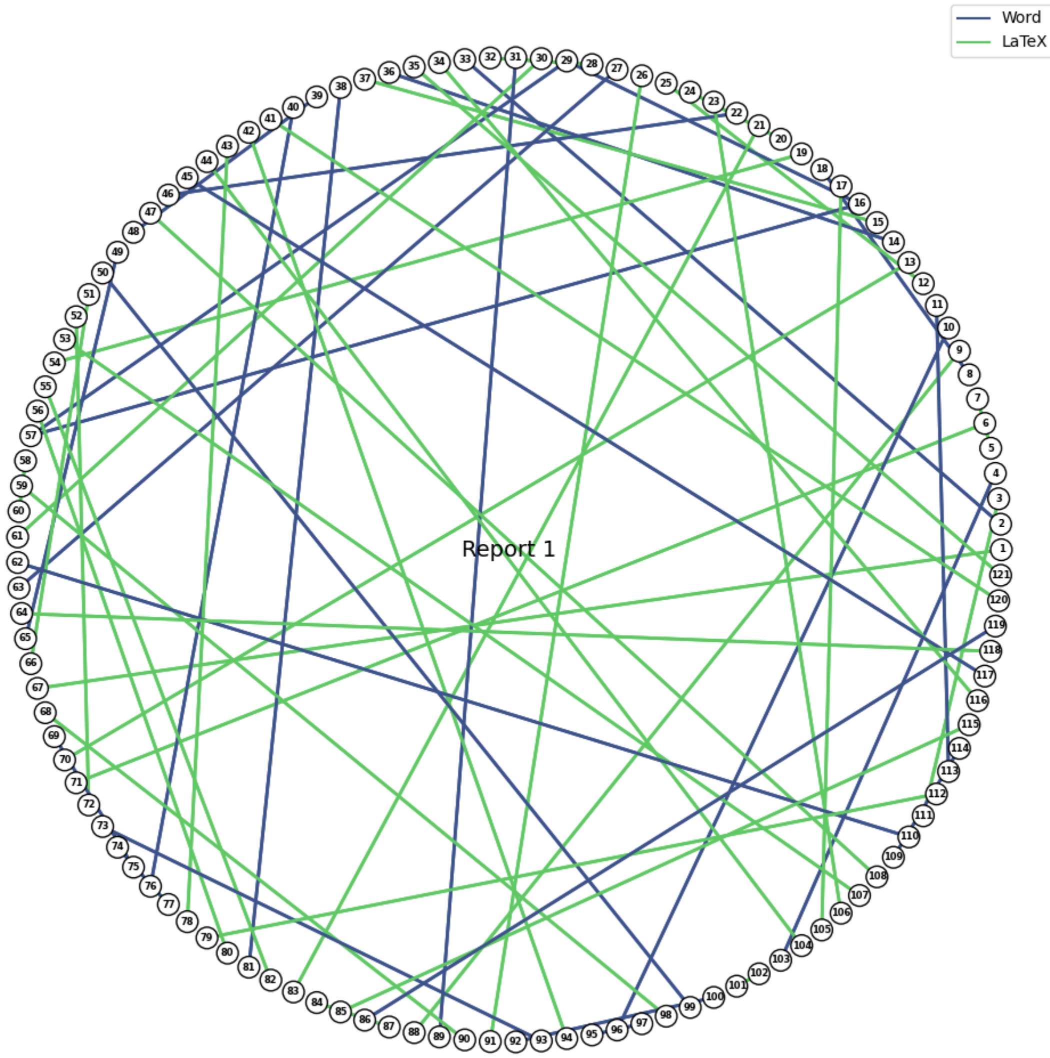


Figure 2: Template selections per pair of students for project #1.

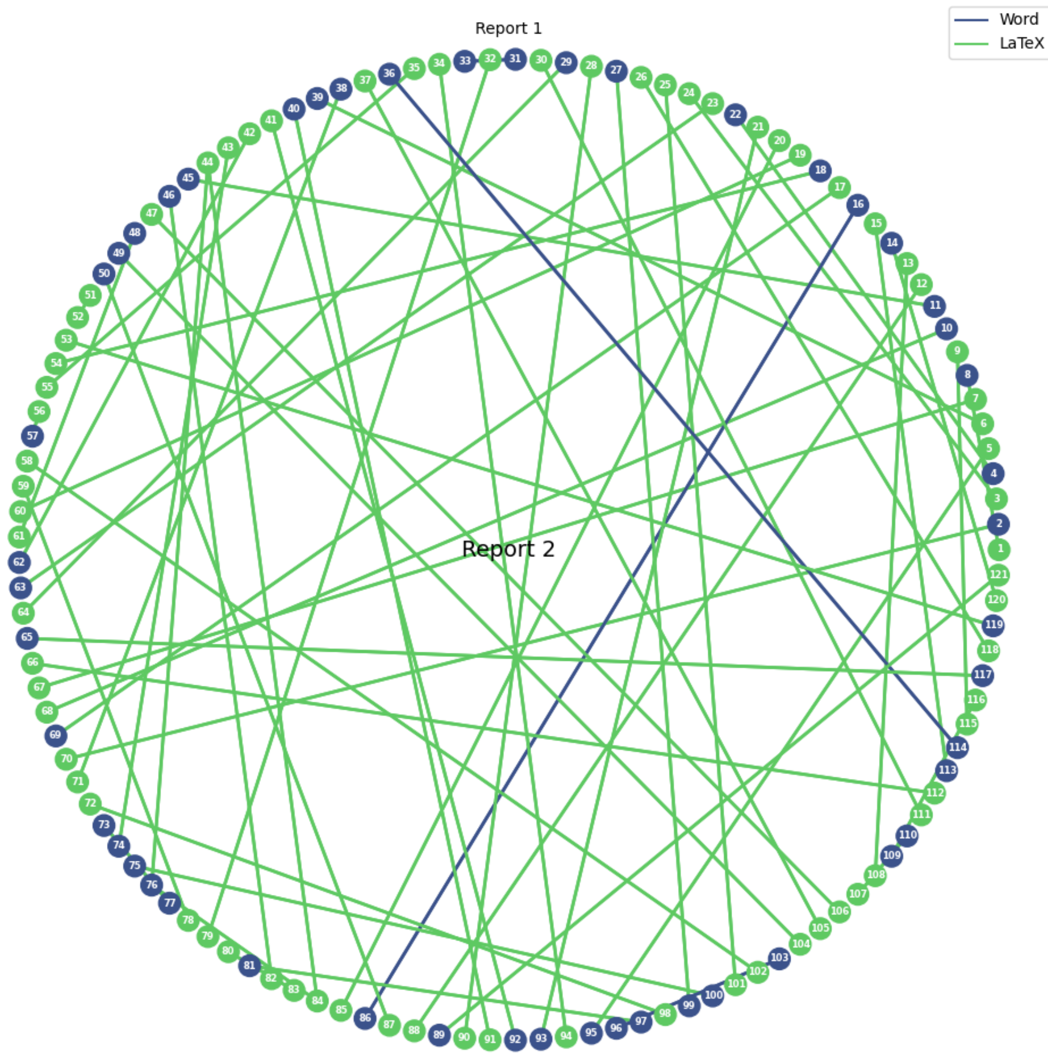


Figure 3: Template selections per pair of students for project #2. Each node is colored to reflect that student's previous decision. For example, nodes 27 and 99 are both colored blue, indicating that those students both selected a Word template for project #1, and are connected by a green

line, indicating that the students selected the LaTeX template for project #2.

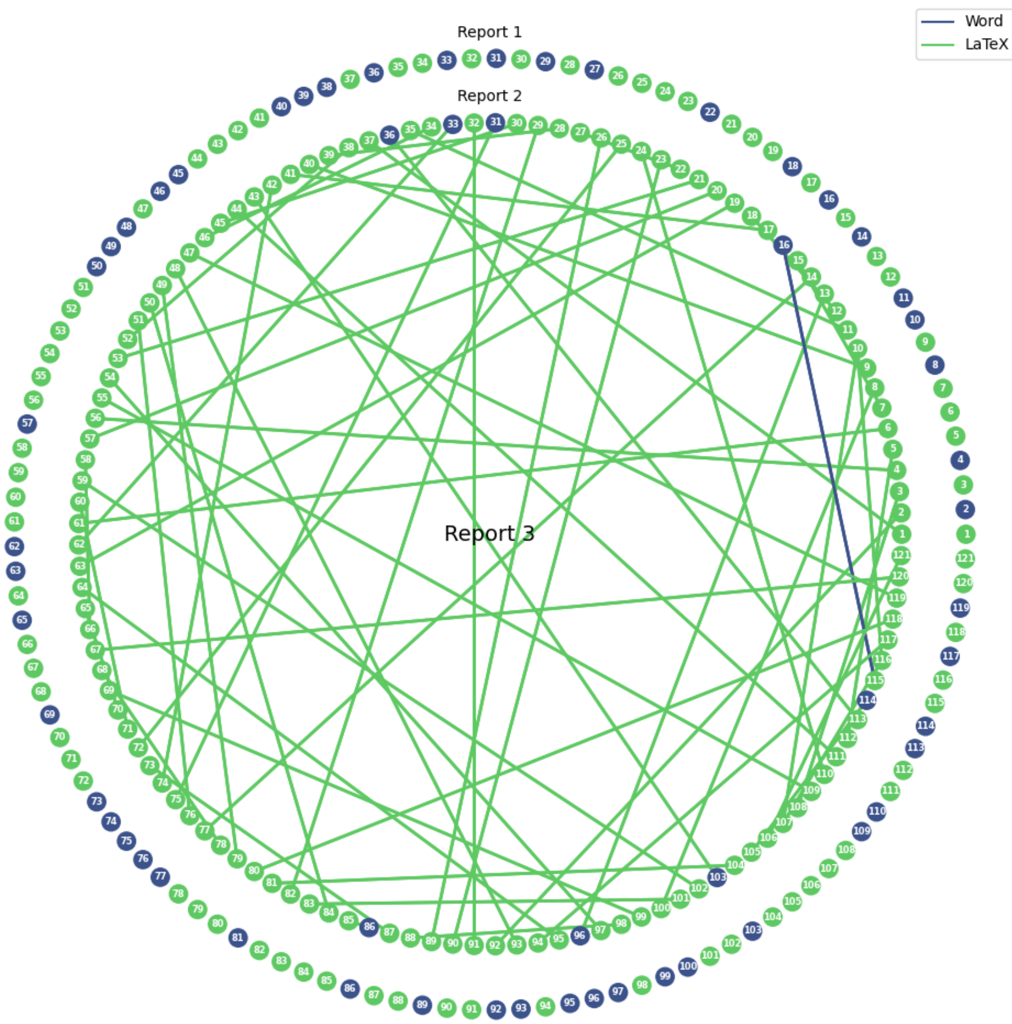


Figure 4: Template selections per pair of students for project #3. The concentric outer ring recaps the decisions made by students in project 1. Visual inspection confirms that the number of students who selected the LaTeX template increases from project #1 to project #2 and from

project #2 to project #3.

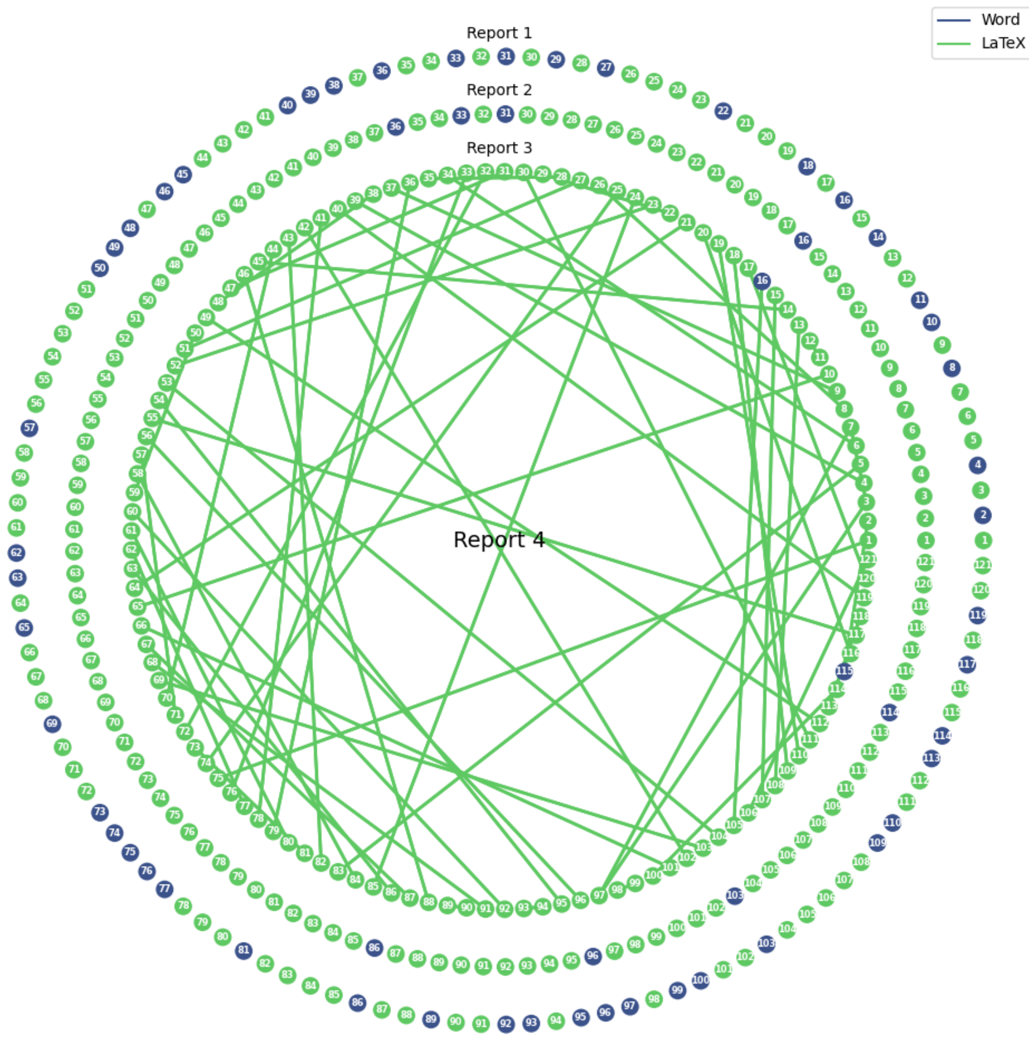


Figure 5: Template selections per pair of students for project #4, in which 100% of students selected the LaTeX template.

Inspection of Spread of Decisions from Pair to Pair

We also inspected the spread of decisions from one student to the next. Broken into three columns, Figure 6 depicts the sequence of pairs that stemmed from project #1. Reading the first line from left to right, we see that student 121 was paired with student 35 for project #1, for which they selected the LaTeX template. Student 35 was then paired with student 55 for project #2, for which they selected the LaTeX template, and so on.

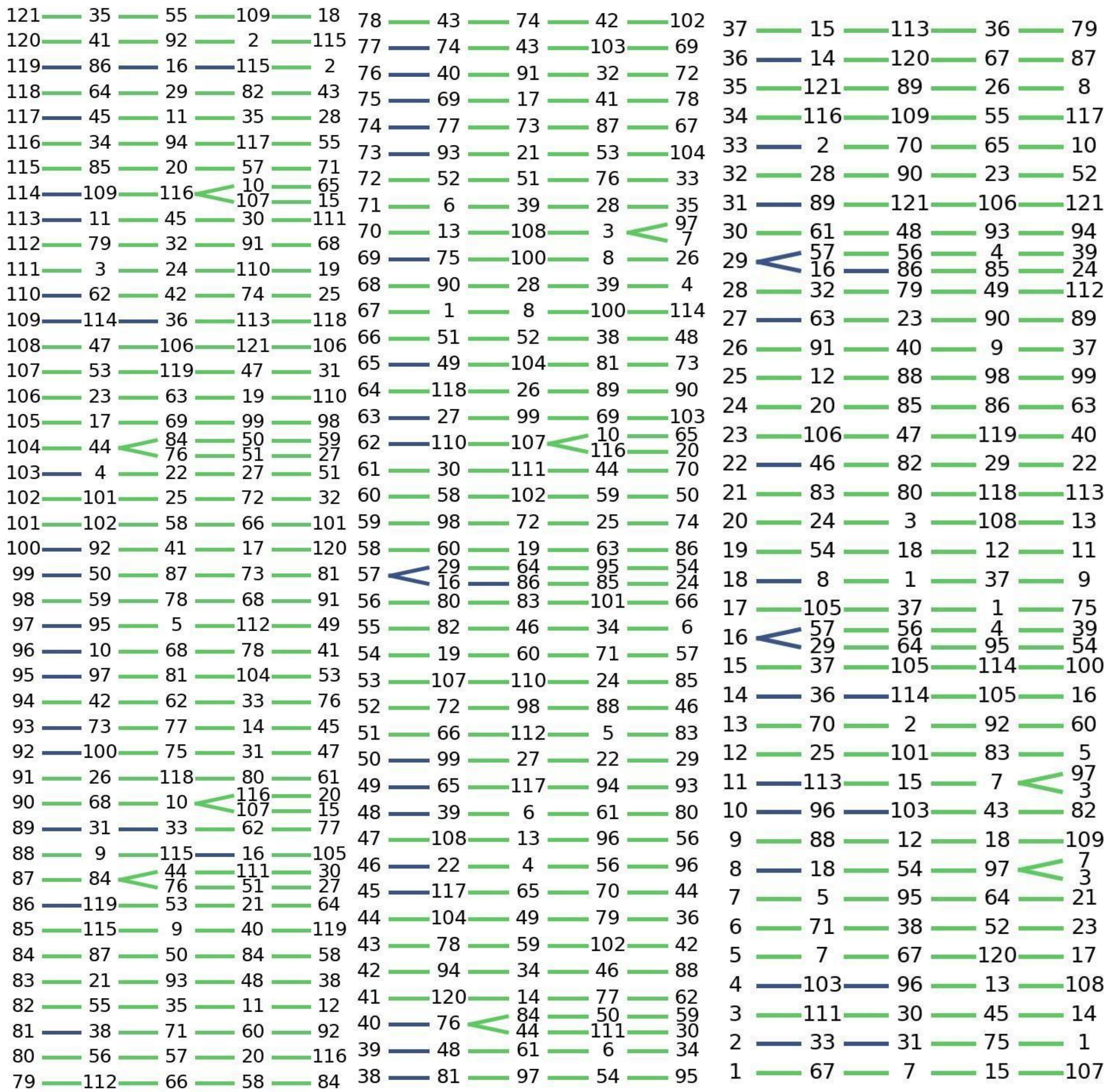


Figure 6: Flow of decisions from pair to pair across design projects.

Visual inspection of Figure 6 indicates that there were eight cases (13%) in which a student who worked in a pair that selected the Word template in project #1 then worked in a pair on project #2 that also selected Word. There were 41 cases (68%) in which a student worked in a pair that selected Word for project #1 and worked in pairs that selected LaTeX for the remaining three projects. There was one case where a student who had previously worked in a pair that selected LaTeX then worked in a pair that selected Word and one case in which the first three projects in a partner sequence had Word selections. Thus, students trended toward the universal decision to select the LaTeX template, with the majority of pairs that first selected Word selecting LaTeX for project #2.

Vignette: Students Who Selected Word After Previously Selecting LaTeX

While the network trend over time was to select the LaTeX template, inspecting the experiences of outlier nodes (i.e., students) can provide insight toward students' decision making. We observed one case in which a student who had previously selected LaTeX worked in a pair that selected Word. Students 16 and 115 selected Word for project #3, which overlaps with the single case in which the Word template selection persisted through project #3. We see that students 119 and 86 selected Word for project #1, then students 86 and 16 selected Word for project #2, then student 16 and 115 selected Word for project #3. Students 115 and 9 had previously selected LaTex for project #2, and students 9 and 88 had previously selected LaTeX for project #1. In other words, one of the two students (16) in the pair that selected Word for project #3 had previously worked in a pair that had selected Word, which occurred in a sequence of decisions to use Word that began in project #1. The other student (115) had previously worked in a pair that selected LaTeX, which occurred in a sequence of decisions to use LaTeX that began in project #1.

In their team report, these students wrote:

"Overall, the two of us were able to effectively work together as a team. We communicated with each other to set up times to meet and were very productive when we got together. There were no major issues that came up during the project."

In their individual reflections, which were shared only with the instructor, student 16 wrote, "I suggested splitting the individual and group work up more. I [implemented] this by communicating earlier in the week what I was going to accomplish before we met. Overall, we worked well as a team. We communicated more than enough, started working early in the week, and split up the workload well."

Student 115 wrote, "I really enjoyed my team dynamic during this project. Collaborating was not a problem and checkpoints were met with plenty of time to spare. If I had to improve anything, it would be the splitting up of work as it felt like it wasn't as balanced as I would have liked."

These reflections indicate that both students perceived effective teamwork during their project, which makes it unlikely that one partner dominated the pair's decision making.

Discussion

Over the course of the four projects, pairs trended toward the universal decision to use the LaTeX template despite the fact that no guidance was provided in the use of LaTeX, a system for document preparation with which the majority of students were unfamiliar at the start of the semester. Visual inspection of the data indicates the community trend to adopt LaTeX, with 60% of pairs selecting the LaTeX template in project #1. Indeed, trends in the data show that when students were unfamiliar with LaTeX, they were likely to select it roughly 60% of the time. The overall decrease in use of the Word template from project #1 to project #2 indicates a potential for the mixing of students into new pairs to have resulted in a further spreading of the majority decision. Although further information is needed to determine students' pre-conceived notions of LaTeX or Word, or lack thereof, the trend for roughly 40 % of students who did not previously select LaTeX to select Word occurring in both projects # 1 and 2 introduces the possibility that the decision to select Word in project # 1 influenced the decision to select Word in project # 2. Once these students were mixed into pairs for which their partner had previously selected LaTeX, the vast majority then selected LaTeX for project #3. By project #4, for which some students were further mixed and others were paired with a previous partner, the community unanimously selected LaTeX, demonstrating the complete spread of the majority selection.

In other words, with each subsequent mixing of students through partner assignment, the decision to use LaTeX spread. While we do not have sufficient data to support an argument for why students preferred to use LaTeX, particularly those who chose to use it after having been exposed to it by their partner, we speculate that one key reason is that report formatting requirements were seen as easier to satisfy with the LaTeX template than the Word template (it was harder to make a mistake).

The cases in which pairs of students persisted in selecting Word beyond project #1 provide insight toward ways in which the spread of information may have impacted decision making. In the vignette, student 115 had previously worked on a LaTeX-type report, while student 16 had previously worked with Word. The students commented on the efficacy of their teamwork in both the final report and their individual reflection entries. Student 16 reports that they made efforts early in the project to communicate what they were going to work on. Student 115 corroborates this by saying that checkpoints were met with time to spare. Student 16 indicates that they advocated for splitting the workload, which likely means that some of their early communications to student 115 would have made suggestions as to splitting up tasks. However, student 115 wrote that they felt the splitting of the workload was not as balanced as they would have liked. From these entries, it seems that student 16 may have delegated tasks or aspects of the project to student 115, which could have included the template selection. This would suggest that student 16's experience in project #2 may have led them to select the same template in project #3. Indeed, in project #1, student 16 worked in the group of three, which also selected the Word template. The team reflections for these two projects indicated strong teamwork and persistent communication.

Although the vignette demonstrates that individual pairs of students may make decisions that differ from the majority trend, the majority decision still spread easily through the community. Pairs were assigned so that students worked with three different partners over the first three projects, which increased the amount of connections among different students in the community. This raises the question of the extent to which deliberately assigning students to work with different peers per project impacted the spread of information (in this case, informed template selection) through the community. For example, could the spread of helpful information be maximized through strategic partner assignment? Ongoing work should investigate this trend by continuing to track partner assignments alongside characteristics of teams' collaboration such as decision making, project performance, and self-assessment.

Next Steps

We have shown preliminary evidence that student participation in different teams through a sequence of design projects has the potential to support the entire community of students in reaching a universal decision — e.g., the use of LaTeX templates rather than Word templates — that has positive outcomes. We achieved this result through random partner assignment, but emphasize that the important thing was producing a fully-connected network of students over the course of four projects, not using random assignment in itself. In future work, we plan to use deterministic methods of partner assignment subject to this constraint, perhaps in combination with existing team formation software such as CATME.

Limitations

Other factors, such as students' outside relationships with their classmates, use of office hours, and outside resources may have influenced the spread of information through the class. Furthermore, we do not know how the outcome of limited student mixing would compare to maximizing their connections with other students. For example, if the same two students worked together for all four design projects, would their selection remain the same throughout? Future work should investigate these factors to better determine the impact of team formation.

Conclusion

Sequential team formation within a student community can be an important factor for trends regarding spread of information through that community. We tracked aerospace engineering students' decisions over a sequence of four design projects for which they worked with different partners. Based on our findings, we anticipate developing a team formation strategy that more deliberately maximizes connections among students and will evaluate the impact of this strategy on trends in students' decision making. Our ongoing exploration highlights the need for educators to strategically consider connections among students and their potential impact on decision making when organizing multiple collaborative projects.

Acknowledgements

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