LET'S TAKE THIS OFFLINE: A THEMATIC ANALYSIS OF VIRTUAL CONFLICT IN HYBRID COLLABORATIVE DESIGN TEAMS

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ABSTRACT

Conflict can be both a productive and detrimental reality of design collaboration. While most studies on conflict characterize findings by type (conflict about the task, process, or interpersonal relationships), we extend this typology to understand the causes, topics, and outcomes of conflict. To do so, we analyze communications in a virtual chat platform, collected in a hybrid work environment. A thematic analysis on over 6000 messages between student design teams on the enterprise communication platform Slack revealed three emergent conflict themes: Engineering Design, Project Management, and Communication. A mapping of the themes to a widely-cited typology of conflict found an over-representation of task (productive) and process (detrimental) conflict in the Engineering Design and Project Management themes, respectively. The distribution of types of conflict in the Communication theme is representative of the entire dataset, suggesting that communication can be a cause and outcome in all types of conflict. Overall, our classification of conflict is the first step towards describing triads of the causes, topics, and outcomes of conflict, a contribution which will drive the development of interventions for design team conflict.

Keywords: Teamwork, Communication, Collaborative design, Conflict, Hybrid Collaboration

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1 INTRODUCTION

Engineering design is highly reliant on collaborative decision-making, where conflicts are likely to occur. As such, conflict is a popular topic in design literature (e.g. Badke-Schaub et al. (2007); van Onselen et al. (2019); Paletz et al. (2017)). The recent rise of virtual and hybrid work has resulted in a greater dependency on virtual communication platforms for design teams which may exacerbate conflict: teams rely on written communication, work asynchronously, and may be geographically dispersed (National Research Council, 2015).

Most existing research focuses on the *type* of conflict (i.e. conflict about a task, a process for completing a task, or interpersonal relationships), in addition to making the distinction that some conflict can be beneficial to team performance (Jehn, 1997). However, there is a lack of work about how or why conflict occurs. This makes it challenging to design interventions to promote helpful conflict. Therefore, we need to explore what *leads* to conflict, what the conflict is *about*, and how the conflict is *resolved*. Understanding these common pathways will provide design researchers with an understanding of how conflict evolves in a broader sense; therefore, we first aim to gather a comprehensive set of topics, causes, and outcomes of virtual conflict during hybrid collaboration.

This study analyzes conflict in the communication of co-located student design teams on the communication platform Slack. We ask: what are the causes, topics, and outcomes of conflict during virtual communication? In what follows, we present the emergent themes from a qualitative analysis. We then map the themes to an established framework of conflict. This study presents a motivating example of the insights that can be drawn from studying the now ubiquitous logs of virtual communication.

2 BACKGROUND

In this paper, conflict involves disagreements between team members, which can be frequent when members with differing expertise and opinions make a decision. While diversity in teams can lead to positive design outcomes (Jehn et al., 1999), it can also cause conflict if these differences are not addressed (National Research Council, 2015). Conflict can be further exacerbated by task dependencies, cross-disciplinary collaboration, or large teams (National Research Council, 2015; Sitarama and Agogino, 2022). In addition to these causes of conflict typical in traditional in-person engineering design, teams collaborating partially or entirely virtually are even more likely to experience conflict. It takes longer for dispersed teams to develop trust and cohesion (National Research Council, 2015) and the chat-like virtual tools (e.g. Slack, Teams, Google Chat) organizations increasingly use lack rich information, such as emotions expressed in tone and body language (Ge et al., 2021), increasing the opportunities for conflict to occur (National Research Council, 2015).

Scholars typically divide conflict into three types: task– disagreements about the goal of the work, process– disagreements about how the goal is achieved, and relational– interpersonal incompatibilities among group members (Jehn, 1997). Task conflict may help teams share information, solve problems (Jehn, 1997), and develop new ideas (van Onselen et al., 2019), which are all beneficial in engineering design. In contrast, process and relational conflict tend to negatively influence performance (Jehn, 1997). Existing studies often focus solely on conflict resolution. For example, Badke-Schaub et al. (2007) show that cognitive (task) conflict was most frequently solved collaboratively; however, innovative teams resolved conflict using competitive (prioritizing the needs of one) and compromising (mutually agreed on yet partially satisfying) resolution styles. Similarly, Paletz et al. (2017) found that high-performing teams leverage micro-conflicts to reduce uncertainty in the design process. While these works add to our understanding of effective conflict resolution, we lack a comprehensive understanding of how conflict occurs in design teams and the mechanisms by which performance outcomes occur.

Our study addresses this gap by identifying themes in the topics, causes, and outcomes of conflict within hybrid teams' virtual communication. While in practice, richer communication exists in in-person studies, it is typical for scholars to analyze only verbal transcripts (Paletz et al., 2017; Badke-Schaub et al., 2007). This suggests that the analysis of written communication has proven to be enlightening to our understanding of conflict. Other studies have also shown that there is a lot to learn about design activities and team dynamics from studying digital communication between engineers (Snider et al., 2017; Sitarama and Agogino, 2022). Particularly in terms of instant-messaging style digital communication that we study here, past work identified "disagreement" as one of the key response types in engineering communication (Gopsill et al., 2013). Moreover, we conjecture that the ways in which virtual communication can lack emotional information contained in body language and tone (Ge et al., 2021; National Research Council, 2015) heightens the likelihood of conflict and leads to a broader set of examples to study than in face-to-face environments. Further, our method of data collection is non-invasive, and the external validity of the design task is higher than in laboratory settings. In sum, to design interventions that promote beneficial conflict we must know when conflict occurs, how it starts, and how it evolves; therefore, as a first step towards this understanding, we aim to identify a set of topics, causes, and outcomes of conflict for hybrid engineering design teams communicating virtually.

3 METHODS

In this work, we analyze the written communication from design teams during a semester-long design project. We non-intrusively collect Slack[1] messages from a fourth-year engineering undergraduate product design capstone course at a large North American university. This course presents an ideal context to study design phenomena as it represents a shortened, though complete, design process: from ideation to a functional physical prototype. The teams of 17-20 students use hybrid communication, with regular in-person meeting times and Slack as their only text-based virtual collaboration tool. More detail on these teams can be found in Ferguson et al. (2022). Our full data set includes 46 teams from 2016-2021, totalling over 370,000 messages. To pare this data down to a reasonable amount for qualitative analysis, we selected design-focused (as opposed to administrative or social) discussion channels from two randomly selected teams per year, totalling 24 channels and 6,673 messages.

Since conflict occurs between two or more people (Sibai et al., 2017), we study *conversations*. We define a conversation as a collection of messages within a channel regarding one topic (Paletz et al., 2017). In Slack, conversations can happen in parallel, so we manually assembled messages into conversations by analyzing threads, timestamps, users, and message content. Two researchers separately completed this process for half of the data, then arbitrated any disagreement, resulting in 1,149 conversations.

Next, we identified which conversations contained conflict. We defined conflict similarly to Paletz et al. as disagreement where "one team member directly opposes or contradicts statements or plans by another team member" (2017, p. 40). Conflict involves the opposition of values, needs, interests, opinions, goals, or objectives; therefore, a question and answer is not inherently conflict. Two researchers collaboratively coded all 1,149 conversations as either "conflict" or "no conflict", resulting in a dataset of 67 conflict conversations (5.8%). A random 25% sample of the conversations was selected, keeping the ratio of conflict to non-conflict consistent with the initial coding. A third researcher independently coded this subset for instances of conflict, resulting in a Cohen's Kappa value of 0.78, a substantial agreement (McHugh, 2012) indicating adequate confidence in the repeatability of our methods.

We then coded each instance of conflict by type: task, process, or relational (Jehn, 1997), as defined in the background. This process was conducted independently on the entire conflict-only dataset by two researchers, resulting in an overall Cohen's Kappa value of 0.72; a value of 0.88 for task conflict, 0.64 for process conflict, and 0.86 for relational conflict. Any disagreements were arbitrated. We further refined our conversation disentanglement such that each conversation only contains one instance of conflict.

To understand how and why the types of conflict occur, we thematically analyzed the conflict conversations. Due to the size of our study dataset, and to ensure complete agreement on all instances of conflict, we opted to thematically code all conversations collaboratively with two researchers. Following the framework for thematic analysis by Braun and Clarke (2006), we began with open coding. Each conversation was assigned an open code relating to the **topic** discussed when conflict occurred and the root **cause** of the conflict. In conversations with a resolution, an open code was also assigned to the **outcome**. After identifying duplicate or overlapping codes, 57 open codes remained. These codes were then organized into axial code groups that represent general patterns in the data, such as product decision, operations, and team communication. The patterns were grouped into three themes: **engineering design, project management, and communication**. The open codes, axial codes, and themes are listed in an online appendix [2].

[1] https://slack.com/

[2] https://doi.org/10.5683/SP3/YRKHWQ

4 THEMATIC FINDINGS

We found that 5.8% of the conversations studied contained conflict. This aligns with previous research on in-person design teams that found that only 6% of the blocks studied contained conflict (Paletz et al., 2017). The thematic analysis revealed three themes: **engineering design, project management, and communication**. In what follows, we present examples of the causes, topics, and outcomes of conflict within each theme. We use the notation of [letter][number] to indicate communication within a conversation, changing letters to indicate a new conversation and numbers to indicate a new speaker. We italicize the outcome in conversations to be easier for the reader to recognize.

4.1 Engineering design

The first theme we identified was how discussions of the **engineering design** activities required to build the product often acted as both the cause and topic, and occasionally, the outcome, of conflict in design teams. These conversations were related to the axial codes: product decisions, risk analysis, and testing. Table 1 presents examples of the cause, topic, and outcome for each of the axial codes under this theme. Conversations marked as **product decision** discussions related to the architecture (size, material, position), features, mechanisms, and building of the product. It was common for teams to experience conflict over **risk** and ways to analyze it. Some of the risks discussed included competitive market analysis, market risk, general risk analysis, and margins of error. Commonly, a misalignment of risk tolerance would lead to conflict, teams would discuss how to mitigate risk, and teams would implement margins of error. The last axial code here was **testing**, used any time the team discussed product or user testing and results. Teams discussed the quality of models for user testing, the requirement for testing or further investigations, successful tests, testing equipment, and unexpected test results. Further, teams experienced conflict caused by a misuse or misunderstanding of the testing equipment, and a common outcome was further investigation, which involved more research or testing.

4.2 Project management

The second theme we identified from the coded data was that **project management** was the topic, cause, and outcome of instances of conflict. We identified three axial codes that comprise the **project management** theme (operations, time, and money), examples of which are included in Table 2. Conversations about the general **operations** of the project focused on what tasks had to be done, specifying details about file organization, software used, and task allocation, a pattern that also emerged in van Onselen et al. (2019). Conflicts were often caused by a lack of initiative, confusion about the current version of a file, and disagreements about task prioritization and dependencies. Outcomes involved developing a revised plan or postponing a decision to a later date, ultimately delaying future conflict. There were also many conflicts related to **time**: conflict arose because of time limits from the course, other teams using equipment, or poor time management. Time constraints also emerged as a topic of conflict in discussions on scheduling logistics. The final pattern of codes related to **project management** was **money**. Most open codes in this axial code grouping were related to budget and product ordering.

4.3 Communication

The third theme in the dataset was how the nature of **communication** within teams influences predominately the causes and outcomes of conflict. We identified three axial patterns within this theme: external, team, and virtual communication – examples of which are included in Table 3. Considerations of communication with **external** project stakeholders caused conflict such that teams did not always agree on what to communicate. Team members also disagreed regarding communication within the **team**. Conflict arose when shared files were unclear, teams did not trust each other's work, or communication broke down between sub-teams. The outcomes of team communication conflict involved agreement, conceding to the opinions of teammates, or collaboration strategies such as team voting.

Since we analyzed virtual communication data, it is unsurprising that we noticed a pattern of conflict related to the limitations of **virtual** collaboration. We found that team members were often confused because of missed messages or conversations that happened offline, causing tension. Additionally, because these teams were hybrid, one particularly interesting conflict occurred when only part of the team was in the lab experiencing a frustrating test result.

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Table 1. Examples for engineering design theme. (Outcomes italicized, AC = Axial Code)

AC	Cause Example	Topic Example	Outcome Example
Product Decisions	**A1:** "We can switch to the 12V power supply...buy a long PC power cable...Or we could just provide a mount for a 12V lead acid battery" **A2:** "I don't think we should shift to battery now" **A1:** "Just saying solves the cabling problem and would be as simple as a mounting bracket and some alligator clips" **A1:**"I think having the electronics within or... outside the housing is ideal- because (1) extra set-up is needed if we put it somewhere else and (2) if we add it to the strap/back... breaking risk increases"	**B1:** "so it's just mostly acrylic with the clippy things being screwed on and we aren't worried about acrylic breaking [because] we don't expect this to be super weight bearing??"... **B2:** "Uh...then where is the weight load if not there?" **B1:** "I thought we said it would be mostly over the two wheels?" **B2:** "Okay if you trust acrylic" **B1:** "I wasn't saying I definitely trust it...I thought...it was going to be metal but then you said it was being lasercut so I assumed acrylic."	**C1:** "@C2 @C3 @C4 can one of you guys also put the CAD pictures in the slides...This will be for getting user feedback" **C2:** [To be quite honest] not sure how useful it will be because our concept is pretty different [right now]... **C1:** "Isn't the looping in just the strap without buckle idea the same? And we have a CAD for that right?"... **C2:** "oh [yeah] sorta do. The clamp has changed though so that may need some edits" **C3:** "*I can change the clamps later tonight*."
Risk Analysis	**D1:** "...if u want u can use the current U Channel for testing.." **D2:** "I'm not sure how representative that test would be of the final outcome..." **D1:** "it might be beneficial to also test the very basic case that I mentioned? Just to make sure because if there are problems there then there will definitely be problems in the future?" **D2:** "There will definitely be problems in the future even if there are no problems in the very basic case..Which is why I'm not sure the test would be very informative. But we can go ahead and do it..."	**E1:** "Okay so the yellow door is currently 143 and we are getting all three colors between different readings" **E2:** "143 being the internal temp?" ... **E3:** "It's been 143 steady for the past 30 minutes and I made sure I put the device in the same location on the doorknob.." **E2:** "I don't think we can accurately debug the issue until we measure the external temps" **E1:** "But fam the lab guys are not confident about how accurate they can make it on stage. And if we're getting all 3 colors at 143 we need a bigger range"	**F1:** "What number should we be telling ... people for the battery life? 36 hours?" **F2:** "I would stick with 90 hours with expected amount of use" **F1:** "if sleep mode is max 36 hours then shouldn't that be the upper limit?"... **F2:** "*If we just put a huge safety margin on it: say every fire it's sensing for an hour and buzzing for .25 hours that would leave us with a quarter of our battery left (25 days). So 90 hours would give us a safety factor of 7.*"
Testing	**G2:** "I think it's meant for water though? And I was using it on a metal hot plate"... **G4:** "well I think this is sort of the thing – this was the sensor we were expecting to work the least well and it worked poorly because it's really meant for fluids..." **G3:** "In the end the actual sensor shouldn't matter [because] we should be able to more or less guess the temperature based on the setup..." **G2:** "Wait I'm pretty sure that's not right.."	**G1:** "@P2: how did testing go?" **G2:** "Testing went well for proof of concept for test set up not so well for the sensor itself" [conflict continues in quote under Cause]	**H1:** "@H3 did a very rough estimate of how hot the electronics will get without a heat sink"... **H2:**"...is there a reason we can't use the giant aluminum plate? **H1:** "...that's without a heat sink" **H2:** "but the heat sink adds height which makes mounting more annoying" **H1:**" It would be hard to mount due to the curved surface of the aluminum plate...Heat sink would add very small amount of weight and would decrease temp most likely...*I'll do a more in depths analysis [right now] and give you a more accurate number*"

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Table 2. Examples for project management theme. (Outcomes italicized, AC = Axial Code)

AC	Cause Example	Topic Example	Outcome Example
Operations	**A1:** "I don't want to be task force lead" **A2:** "I don't want to be a task force lead either"... **A3:** "i dont wanna be lead either" **A4:** "Not very interested in tf lead."	**A1:** "hello team !!!!!! maybe we can start a thread here on task force lead...?" [conflict continues in Cause]	**B1:** "Hi guys! Do you have some sort of tablet or interactive display ordered to implement?..." **B2:** "If anybody knows how to make an app for a tablet then go ahead and order one. But as explicitly stated in lab... the only interface that...the current electronics team have the knowledge to implement is an android phone via Bluetooth." **B3:** "Were u planning on communicating through the serial and then use bluetooth to a phone?" **B1:** "After tech review when we reorganize the task forces for the next milestone *you can definitely explore all these options*."
Time	**C1:** "So we have to make another PCB?" **C2:** "Potentially yeah" **C1:** "I don't have time to do that" **C3:** "Can't we reprogram one that's already on a pcb?" **C4:** "No we can't...People need to chill"	**D1:** "Okay team we are welding 8am tomorrow" **D2:** "We need to mill a slot in the frame for the height brace... I know you all are welding at 8 but the gas spring mounting holes are final... If we have time before welding it would be easier to mill those first." **D1:** "okay but how long is that going to take? We have to weld tomorrow- surface is dropping their stuff off in the afternoon so ideally we would be done before them."	No examples.
Money	**E3:** "[You] want to think about design decisions and how they might affect product cost but (supplier) prices $\neq$ product cost. If the budget allows, buying things that help increase knowledge... is... a good thing." [conflict continues in Outcome]	**E1:** "i thought we could just buy the whole thing like this" **E2:** "i mean we could but the size we need to replicate our ramp would cost about \$600" [conflict continues in Cause]	**E2:** "[Conflict continuing from Cause] so i guess we can *go ahead and order a large sheet then*"

We found that our data sometimes lacked detail on outcomes of conflict because teams chose to continue the conversations in another channel, or in person. Interestingly, this axial code contains the only instance where **communication** was the *topic* of conflict. From this, we suggest that it is rare for conflict to be about communication; rather, the manner in which teams communicate is more likely to be a cause of conflict and a strategy for its resolution.

We also identified a few instances of ambiguous conflict which could be interpreted as joking or sarcasm. In studies observing face-to-face interaction, additional context, like body language and tone of voice, would make it clear that there was no conflict. In our study, however, we lacked this information. Therefore, whenever there was no indication that something was clearly a joke (such as an "lol", meaning "laugh out loud"), we followed our coding scheme strictly and labelled these instances as conflict. For example, as human investigators, we can assume the following instance is sarcasm and not conflict: P1: *"I also accidentally was using my solid works 16...I'm sorry"* P2: *"APOLOGY NOT ACCEPTED"*. However, this does raise questions of the limitations of using text-based data to study conflict.

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Table 3. Examples for communication theme. (Outcomes italicized AC = Axial Code)

AC	Cause Example	Topic Example	Outcome Example
External	**A1:** "Wait so what number should we be telling presentation people for the battery life? 36 hours?"... **A2:** "Sleep mode is max 200 days if we productized it" **A1:** "Yeah but we haven't yet...we should be honest and say 36 hours" **A2:** "I disagree completely everything else we are presenting is as if it were the finished thing in terms of materials, cost, use."	No examples.	No examples.
Team	**B1:** "Is it possible to weld the main frame at the end of the day tomorrow...? Locking mechanism is pretty dependent on building off of welded frame."... **B2:** "We can try but this timeline should have been communicated beforehand from the Locking Mechanism team."	No examples.	**B1:** "I'm having second thoughts on getting rid of the feeding mechanism... How are you guys feeling..." **B2:** "@B3 are you comfortable vouching for this? Should we run more tests or can we run with dropping sweeping?" **B4:** "*I vote drop*" **B3:** "*in my opinion / from experience soldering* I think we can easily drop the sweeping mechanism"
Virtual	**C1:** "Okie but it's not" **C2:** "But it's not in practice. Theory is great but we're here doing this s**t and it's not working. I agree it should be but aluminum doorknobs are finicky [as f***]"	**D1:** "hey I'll actually be ready in 10" **D2:** *reacts with nauseated_face * **D3:** "D1 thats so mean. Why would you put that react?"	**E1:** "Wait I'm pretty sure that's not right...*Let's talk about this in the lab*"

5 FRAMEWORK MAPPING

Past research applies a typology whereby conflict can be one of three types: task, process, and relational. Based on the coding of the typology in our dataset, 67% (45) of the instances of conflict were identified as task conflict, 21% (14) were process conflict, and 12% (8) were relational conflict. Since task conflict is related to the project and has been shown to benefit a team's performance (Jehn, 1997), it is optimistic that the conflict in our dataset is mostly task. The proportions of types of conflict in our dataset follow those in other research studies (e.g. Paletz et al. (2017)).

As seen in Figure 1, task conflict is over-represented in the **engineering design** theme (93% of **engineering design** codes vs. 67% in the entire dataset), and process and relational conflict are underrepresented (4% vs. 21%, and 3% vs. 12%, respectively). Conversations about size, position, material, and features, among other product decisions, tend to focus on the task, as these considerations make up the majority of design decisions (Krishnan et al., 2001). However, **engineering design** codes were sometimes also the *topics* of process or relational conflict. For example, a discussion of how to account for risk in part ordering led to a process conflict around what to order, and deciding on a position of a component led to frustration and relational conflict. Therefore, while there is some nuance to the mapping, we can see the theme of **engineering design** may be analogous to task conflict and the contained codes describe what task conflict looks like in a design context.

As depicted in Figure 1, the proportion of process conflict is much greater in the **project management** theme than in the entire dataset (58% vs. 21%). However, project management has an under-representation of task (36% vs. 67%) and relational conflict (6.7% vs. 12%). Many instances of conflict in the **project management** theme focused on *how* the team was going to accomplish a task, the definition of process conflict. We can therefore argue that the **project management** theme reflects

what process conflict looks like in design. While there were a few instances where conflicts related to **project management** were task conflicts (e.g. a disagreement about ordering) or relational conflicts (e.g. frustration about a project management decision), most **project management** codes represented process conflict, a type of conflict previously shown to be detrimental to team progress (Jehn, 1997). As such, more research linking the **project management** theme and team performance is needed.
The codes in the **communication** theme had proportions of task, process, and relational conflict similar to the entire dataset. As depicted in Figure 1, the **communication** theme was comprised of 66% task conflict (vs. 67% overall), 20% process conflict (vs. 21% overall), and 14% relational conflict (vs. 12% overall). Teams tend to not discuss their communication as topics; instead, we found most codes in the **communication** theme were causes and outcomes of conflict. Our results suggest that relational conflict may be over-represented in the **communication** theme, but further research with a larger dataset may be needed to fully understand the relationship. The presence of all three types of conflict in the **communication** theme supports the notion that poor communication can lead to all types of conflict.

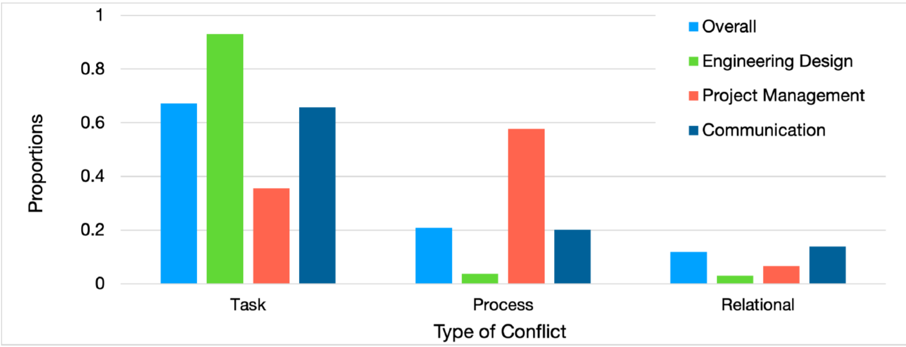

Figure 1. Proportions of task, process, and relational conflict by theme

6 DISCUSSION

In this work, we analyzed a novel dataset of Slack messages containing conflict between members of student design teams. While we expected that virtual communication may exhibit different patterns of conflict, we found that the proportions of both overall conflict and the types of conflict (task, process, and relational) are comparable in our study to previous studies on face-to-face conflict (e.g. Paletz et al. (2017)). Many of the causes of conflict we identified exist in face-to-face scenarios (e.g. disagreeing about the viability of a solution), but we also found interesting ways the nature of virtual communication influences conflict (e.g. geographical distribution, messages lacking detail, navigating the nuance of written communication like jokes), including instances when teams moved their discussions "offline" for resolution. Such a finding suggests that there are some unique characteristics of conflict occurring on virtual platforms; although, each virtual communication platform may influence conflict differently: Wasiak et al. (2009) found no evidence of disagreement in email. Slack communication (and ECPs more generally) is less formal than email (Brisco et al., 2020) and help to build trust between teammates (Bharati et al., 2021), perhaps indicating a middle ground between email and face-to-face communication. These factors might explain why our findings are more similar to studies of conflict in face-to-face settings than in virtual, a relevant finding as the world increasingly relies on remote working conditions.
Our thematic analysis identified three emergent themes: design teams experience conflict related to **engineering design, project management, and communication**. Codes within each of these themes account for the causes, topics, and outcomes of conflict. The emergent themes suggest that making complex design decisions can lead to conflict within teams and even though each team had two project managers, conflict still arose. Project managers are not only responsible for managing conflict, but also for anticipating potential sources of conflict and when in the project timeline conflict is likely to emerge (Thamhain and Wilemon, 1975). Therefore, more exploration into how project managers handle virtual conflict is needed. We also found that aspects of the communication itself led to conflict. Conflict occurred when teams miscommunicated or did not provide enough detail in their message. Conflicts resulting from communication failures are a top concern for managers (Thomas and Schmidt, 1976).

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When we mapped our themes to the established conflict typology, we saw an over-representation of task conflict in the **engineering design** theme. Past research has established a positive relationship between task conflict and team performance (Jehn, 1997); therefore, we hypothesize that conflicts about **engineering design**, which are predominately task conflicts, contribute positively to team performance. We also found an over-representation of process conflict in the **project management** theme which may be harmful to team performance (Jehn, 1997). The one-to-one mapping of the themes onto commonly accepted conflict types provides evidence to validate our emergent themes and suggests that future work can apply the body of knowledge built on the conflict typology to engineering design.

These findings give insight into how and why conflict occurs in hybrid engineering design teams communicating virtually. By investigating beyond the type of conflict to further identify topics, causes, and outcomes, we provide a comprehensive set of codes that thematically describe instances of design conflict. Examples of these topics, causes, and outcomes can be used to teach educators and managers when to intervene in team discussions, and can also be used to train automated conflict detection algorithms that nudge teams towards a better outcome for their current conflict topic and cause.

6.1 Limitations and future work

This work is solely qualitative and the analysis was conducted by two researchers. While efforts were made to reduce subjectivity (e.g. calculating inter-rater reliability for coding the types of conflict), we recognize that different research teams may identify different themes. Future work can explore a larger dataset with a larger research team to determine the reproducibility of our results.

The next phase of this work includes an exploration into how conflict evolves over time and a social network analysis to determine key players in instances of conflict. We then wish to connect conflict with team performance, exploring the ways in which each type of conflict associates with overall creativity.

We see many other extensions of the work presented in this paper. First, identifying common triads: are there archetypes of causes, topics, and outcomes? Methodologies such as linkography (Goldschmidt, 2014) can be used to identify conflict pathways by coding links in the design decisions made during instances of conflict, further illuminating the nuances in the relationship between conflict and team performance, and contributing to design interventions that support beneficial conflict. Second, our findings indicate that process conflict was found at a higher rate in discussions about project management, indicating that project management may be a fruitful target for further conflict-focused studies. Third, our study population was composed of student groups; it would be interesting to expand the study with more experienced designers to explore the relationship between expertise and conflict.

7 CONCLUSION

This qualitative study explores conflict in the virtual communication of hybrid teams. We found:

- Approximately 6% of written communication contains conflict, most of which is task conflict.
- Conflict about **engineering design** included discussions about product design, risk, and testing.
- Conflict about **project management** included discussions on operations, time, and money.
- The nature of **communication**, particularly virtual, influenced the causes and outcomes of conflict.
- Studying virtual communication limited findings on outcomes as teams would sometimes resolve interactions “offline” (face-to-face).
- The emergent themes can be mapped to the widespread understanding of types of conflict: task conflict was predominately captured by the **engineering design** theme, process by **project management**.

In sum, this paper contributes to our understanding of the causes, topics, and outcomes of conflict. It offers an extension to existing work on conflict, exploring how the nature of the communication platform can influence conflict. We hope this paper inspires conflict researchers to identify specific qualities of instances of conflict that can further describe the relationship between conflict and team outcomes.

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