Groupnamics: Designing an Interface for Overviewing and Managing Parallel Group Discussions in an Online Classroom

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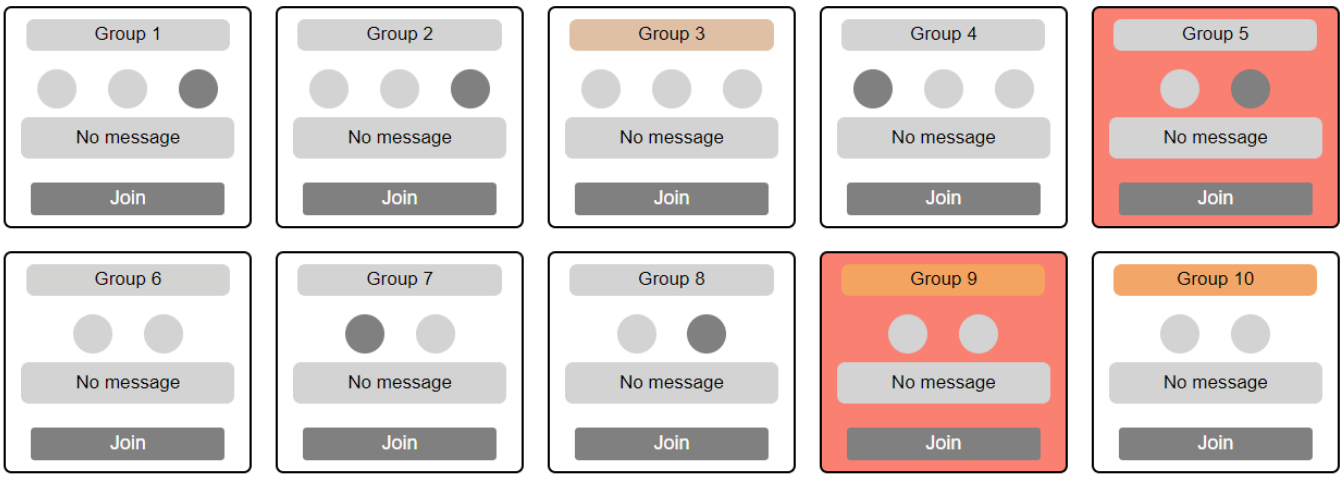

Figure 1: A screenshot of *Groupnamics*, an online classroom support tool to overview parallel group discussions. Each box represents a group, and contains four kinds of visualizations (see Fig. 3 for more details).

ABSTRACT

Instructors facilitating online classes have a limited ability to see and hear interactions of student groups working in parallel, which prevents them from interacting with students effectively. In this work, we explore interface design for providing an overview of parallel group discussions in online classrooms. We derive design considerations through a participatory design process and instantiate them in our visualization interface, *Groupnamics*. *Groupnamics* visualizes recent vocal activities and discussion statuses of each group in a one-page view, facilitating identification of groups where intervention may be needed. Our user study with 16 instructors confirmed that *Groupnamics* can successfully provide cues for when instructors should join group discussions and improvements on the perceived usefulness and ease of use over the baseline interface representing existing videoconferencing tools. Our qualitative results suggest future research directions in interface design for online parallel group discussions.

CHI '23, April 23–28, 2023, Hamburg, Germany

ACM ISBN 978-1-4503-9421-5/23/04…$15.00
https://doi.org/10.1145/3544548.3581322

CCS CONCEPTS

• **Human-centered computing → Information visualization**.

KEYWORDS

Group visualization, online classroom, parallel group discussions

ACM Reference Format:
Arissa J. Sato, Zefan Sramek, and Koji Yatani. 2023. *Groupnamics*: Designing an Interface for Overviewing and Managing Parallel Group Discussions in an Online Classroom. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), April 23–28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 18 pages. https://doi.org/10.1145/3544548.3581322

1 INTRODUCTION

Synchronous online classes have become an integral part of the learning experience amid the COVID-19 pandemic [53, 81, 82]. Schools and universities use videoconferencing software to support synchronous online classes [81]. While online classrooms offer unique advantages over in-person classrooms (e.g., the ability to accommodate a larger number of students[8]), this teaching format creates new challenges. In particular, common videoconferencing tools lack ambient cues regarding students readily available in an in-person class, such as the sound of their voices and their physical behavior. This issue of a digital *"wall"* [29] becomes more salient when students are split into small groups and perform discussions and collaboration.

Existing videoconferencing tools offer the capability to run discussions in small groups in parallel (e.g., using breakout rooms in Zoom), but are not tailored well to online teaching, in particular from the instructors' perspective. For instance, instructors lack context as to how discussions are progressing and often feel as though they are "talking to a void" [82]. Moreover, students are often hesitant to turn on their video during online classes [36, 52, 82], thus further limiting student information available to instructors. These challenges have encouraged researchers to design and investigate systems to support instructors during online classes [18, 19, 53, 61]; however, these projects primarily focus on a traditional lecture format and are not aimed to support instructors to oversee parallel group discussions. As group work is an important activity for students to strengthen their discussion and collaboration skills [20, 58], we argue that an interface for instructors should offer more explicit support for online parallel group discussions.

In this work, we design and evaluate an interface to overview online parallel group discussions. The scope of this work focuses on the instructor's experience while overviewing a medium-sized class, where multiple groups of two to three students have discussions in parallel. To investigate this, we conducted a participatory design study with five instructors or teaching assistants (TAs) with various online teaching experiences, to understand existing obstacles in managing online parallel group discussions in their teaching. We performed a participatory design process and iteratively created sketches and low-fidelity prototypes to identify important features and design considerations. Our resultant interface, *Groupnamics*, includes four visualizations based on the findings from our participatory design study. *Groupnamics* offers an overview of up to 10 groups in a one-page view with visualizations of recent vocal activities and statuses of each group. In this manner, our interface ambiently displays the atmosphere and dynamics of on-going discussions by each group, and allows instructors to identify groups that may need intervention. Our user study confirmed the positive effects of *Groupnamics*, in particular offering the ability to identify which student groups to join for further support.

This paper presents our exploration of an interface to support instructors to overview online parallel group discussions and its validation through a user study with 16 instructors. We focus on the following research questions in this work: RQ1. *What information should an interface present instructors to overview online parallel group discussion and how?* RQ2. *How can such visualizations support instructors to identify which groups to intervene for providing help?* RQ3. *How do classroom visualizations affect the level of confidence intervening with students during on-going discussions?* This paper expands the research landscape of interfaces for online teaching by offering the following three contributions:

- Derivation of interface design considerations for supporting instructors to overview and manage online parallel group discussions through a participatory design study,
- Development of *Groupnamics*, an interface that visualizes the activities and statuses of multiple groups in a one-page view, and
- Evaluation of *Groupnamics* with 16 online class instructors, confirming its benefits to overview online parallel group discussions and uncovering future research directions in the domain of online teaching and its interfaces.

2 RELATED WORK

2.1 Presenting Student Interaction to Instructors in In-Person and Online Classrooms

Instructors often have to balance teaching with managing a large number of students [38, 60]. In particular, instructors face challenges, such as finding appropriate ways to keep students engaged [76], and distributing their time across as many students as possible [79]. To support single instructors teaching groups of students (one-to-many interaction), researchers have investigated tools for both in-person [2, 4, 5, 9, 32, 73, 83] and online classrooms [15, 18, 19, 35, 53].

Support systems for in-person classrooms, such as Sync Class [32] and EduSense [2], use computer vision to leverage information from students' activities and statuses, such as their facial or body gestures, to provide substantial new analytics to instructors. To approximate the history of where the instructor's attention has been focused, ClassBeacons [4] uses ambient displays placed on students' desks. These studies suggest that providing instructors with rich data about their students' statuses can reveal key insights regarding level of student engagement, and help them better manage the challenges of large class sizes.

Online classes, however, add unique challenges due to their format, such as the need for instructors to spend more time per student [79], and the lack of information on student reactions while teaching [19, 61]. Researchers have explored different support systems tailored to online classrooms, for instance by presenting aggregated views of students' activity and history [35], level of student engagement [15, 53], or a representative of viewer reactions [61]. These systems allow instructors to see the progress of not only individual students but also the entire class as a whole, which standard videoconferencing software does not typically offer. However, they focus on unidirectional, lecture-style classes, which represent only one of many teaching formats.

Beyond traditional lectures, instructors often employ different teaching formats, such as group discussions [21, 66] and flipped classrooms [3, 13], to make classes more engaging. Group discussions can be a powerful method to manage large classes [58, 66]. However, the online setting presents unique challenges for group discussions because instructors lack ambient information about groups' statuses that they would otherwise have in an in-person classroom. This suggests an important new research area: investigating how to provide the awareness of students to support instructors during online parallel group discussions.

2.2 Visualizations in Group Discussions

Instructors often employ group discussions in classes to provide students with an opportunity to converse and increase engagement in conversation [66]. However, during in-person classrooms, instructors are not always able to observe all details about the group and its members, nor always be present to facilitate conversations during group discussions. Thus, it is necessary to look into various techniques to visualize details of the group discussions to aid group conversations.

Previous work has explored visualizations of participants during in-person group discussions to present participation individually [50, 62, 73, 74] or as a group [1, 45, 46, 74], visualize conversation content [6, 12, 16, 42, 55, 68], encourage self-regulation of participation [11, 23, 24, 75], and present conversation statuses [33, 84]. These projects found that visualizing participants' actions and utterances in various ways can help them monitor their own contribution to a discussion while maintaining attention on the group overall. However, the research above has focused on a single group of people in person, and its findings are not directly applicable to a scenario where instructors oversee multiple online parallel group discussions.

Previous work also investigated visualizations to support online group discussions for similar reasons, such as encouraging self-reflection for more balanced conversation [27, 29, 48, 80], and reflecting content of discussions [25, 26, 56, 64, 69, 72, 77]. However, it primarily focuses on online forums or chat-based group discussions, which are different from the online parallel discussions typically seen during synchronous online classes. While other prior work has examined support for discussions in video chats or videoconferencing to facilitate balanced conversations[28, 39–41, 51, 57, 63, 71], its scope is still constrained to a single group. Further investigation on support for managing multiple simultaneous group discussions would broaden the research domain of visualizations for group meetings and discussions.

Commercial communication tools, such as Discord, provide features to simultaneously visualize the dialogue in multiple rooms of members, identifying each member. When a user joins a channel with an audio conversation feature enabled, all members of the conversation are listed in a column. An active speaker is highlighted in a green circle around that user's avatar. However, the understanding of what information should be included and at what level of granularity is necessary for instructors to overview parallel group discussions in an educational setting has not yet been fully established. Uncovering interface design considerations is, therefore, critical to tailor videoconferencing tools toward educational contexts.

3 PARTICIPATORY DESIGN STUDY

To uncover design considerations and derive interface designs for *Groupnamics*, we employed a participatory design approach [59, 70] with instructors and teaching assistants who had experience teaching online. Specifically, this part of the study aimed to answer the first research question (RQ1. *What information should an interface present instructors to overview online parallel group discussion and how?*). The following study protocol was approved by the Institutional Review Board of the authors' university.

3.1 Participants

We recruited five participants with experience teaching groups of students in online classes. We stopped recruiting participants as we observed a convergence in ideation suggestions. We chose to prioritize participants based on their experience overviewing groups of students online regardless of their teaching position. All participants were recruited through the authors' network using a snowball sampling approach. All participants attended all sessions, except PA4, who was unable to attend one session due to a schedule conflict. Each participant was compensated approximately $25 USD per session. Table 2 in Appendix A details their demographics and relevant online teaching experience.

3.2 Procedure

We conducted four sessions to discuss design considerations and possible interface designs with the five participants. The participatory design sessions were conducted on an individual basis. In the first session, we asked participants about their teaching experience, in particular managing online parallel group discussions. We then showed each participant a series of sketches of interfaces for overviewing online parallel group discussions (Fig. 2 (a)). We were inspired for the first set of sketches by commercially available products, such as activity trackers for health (e.g., nurse monitors) and group exercises (e.g., SelfLoops), productivity-related applications (e.g, Trello), and bar and pie charts that break down individual contribution in teams. We further created designs that would allow the participants to compare varying levels of granularity, such as group- vs. individual-level visualizations to identify their preferences. We chose to initiate the participatory design with sketches to facilitate the ideation process with our participants. We did not observe any priming effects as the final prototype, *Groupnamics*, varied greatly from the sketches presented in our first design session.

We introduced each sketch with a brief explanation of the design and provided example scenarios to suggest possible use cases of the visualizations.

After completing the first session, we developed low-fidelity prototypes that included detailed illustrations of interface functionalities (Fig.2 (b) and (c)). We then iteratively performed revisions of the design prototypes and discussions with participants until we observed clear convergences after the fourth session. All sessions were screen and audio-recorded via Zoom, and transcribed for later analysis. Sessions were conducted in English or Thai depending on participants' preferences. All the sketches and prototypes developed through this participatory design process are available in the supplementary material.

We extracted 232 quotations associated with practices and challenges of managing online parallel group discussions. We conducted a thematic analysis on the transcripts and notes taken by the first author during the discussions. We took a deductive (question-driven) approach with RQ1 in mind, and identified eight design considerations in terms of what information should be presented and how for supporting the overview of online parallel group discussions.

3.3 Design Considerations on What Information Should be Presented

3.3.1 ***Vocal data.*** All participants expressed a desire to see student vocal activity during online parallel group discussions. The participants shared that seeing vocal data could support them by helping to "confirm that everyone's interacting" (PA1) and identify "who is the leader in a team, and who is [quiet]" (PA4). PA4 explained how speech visualization can be similar to in-person classes:

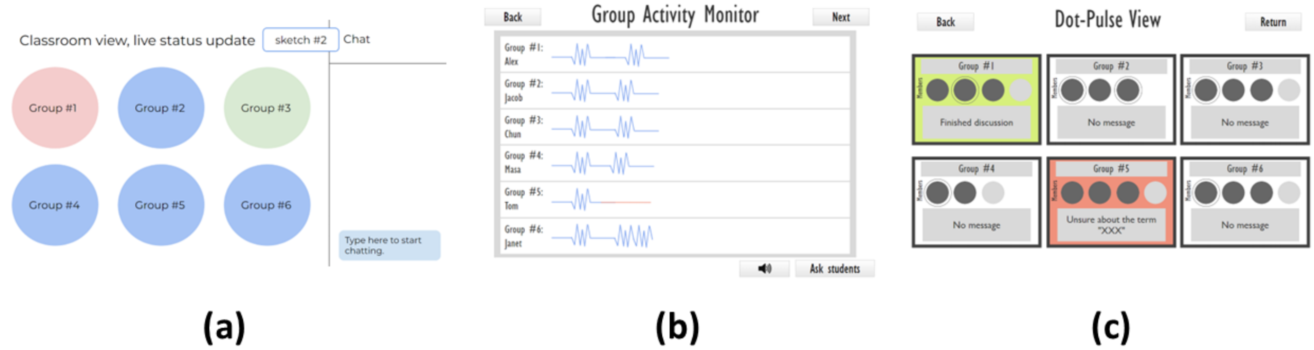

Figure 2: Examples of sketches (a) and low-fidelity prototypes (b and c) used during the participatory design sessions to prompt and facilitate conversation. The full collection of the sketches and low-fidelity prototypes is available in our supplementary document.

> *I can see who's talking... [I] can go out [of the breakout room] and see who is talking more, who is talking less... [I] can monitor just like [what I'm] doing [in a] real classroom.* [PA4]

3.3.2 ***Direct Messages***. All participants shared an interest in having direct message communication with their students during online parallel group discussions. The primary purpose of this communication channel is to quickly address students' questions as they arise. However, two participants (PA3, PA5) explicitly shared their observations that students are often reluctant to ask questions in the presence of their peers:

> *"When some group wants to ask for help but is embarrassed or scared that the group [won't] look good... only the instructor [should] see if they have an issue... They don't need to have [their message] appear in front of everyone."* [PA5]

3.3.3 ***Status Indicators***. All participants expressed their desire for features that allow students to convey their current progress and need for assistance. They expressed the benefits of "efficiency" (PA1) and "glanceability" (PA2) of interfaces that used color to indicate statuses while working with many groups. Three participants (PA1, PA2, PA5) explicitly suggested that an indicator for completion can also serve as a method to gauge the level of appropriateness of the task and the time allotted. PA4 shared his suggestion on indicating status using colors:

> *[Highlighting] the entire [group] with [a] different color is very useful for the instructor because [they] can immediately see their progress. And even the color itself... You can have a color scale from maybe red to green, and [depending] on [the] color, you can tell the progress.* [PA4]

3.4 Design Considerations on How Information Should be Presented

3.4.1 ***Providing an Aggregated View of all Groups in One Interface***. All participants agreed that seeing all student groups at once can keep them informed of the general atmosphere and fluency of a discussion. However, three participants (PA2, PA3 and PA4) expressed concerns for screen space while overviewing all groups and balancing other tasks at the same time. This suggests that, for instructors, it is important to see all groups to understand the overall atmosphere, but that this should be presented in a compact interface.

> *[With the aggregated view]... the instructor does not have to go into one [group] and cut connection with all other [groups]. And this is very important because [without the aggregated view]... once I [join a group]... I [would] miss information connected [to] all others.* [PA4]

3.4.2 ***Visualizing Individual-level Participation within a Group***. Our prototypes included variations of group-level and individual-level visualizations. Group-level visualizations treat the group as one entity while individual-level visualizations show each student within a group separately. While participants saw merits in both, all positively shared their interest in individual-level visualizations to see the contribution of each student.

On the contrary, four participants (PA1, PA2, PA4, PA5) expressed some concerns that clearly quantifying individual participation (e.g., how long a person has talked for) may not accurately represent the student's contribution:

> *The quantity [students speak] doesn't equate to [the] quality. Someone may [say] something that is very critical but doesn't spend a lot of time [to say it]. And other people may speak for a long time, and then the other person may seem to have talked for a lot smaller of a portion. Compared to those who talk a lot, it may make the instructor misunderstand the student [who doesn't].* [PA5]

These results suggest that visualizing individual-level participation in a group allows the instructor to see the balance of the conversation between group members. However, visualizing its quantity may risk misleading the instructor about students' contributions.

3.4.3 ***Visualizing Recent Vocal Activity Within Groups***. All participants shared that while they are in discussion with one group, they are concerned about how other group discussions are progressing.

> *When I stop by each break out room, I realize there are only certain people that talk and the other people remain silent. So I'm not sure if that person remained silent the whole time or is it just when I'm there.* [PA1]

To identify how group discussions are progressing, four participants (PA1, PA2, PA4, PA5) suggested identifying "when there are stops in communication, and when [the students] start [talking] again" (PA5).

3.4.4 ***Avoiding Overly Detailed Visualization about Individual Students.*** While participants agreed that visualization of students' activities would be useful, participants emphasized the importance of an appropriate level of granularity. Two participants (PA3, PA4) emphasized that overly detailed visualization about each student could be overwhelming and distracting to the instructor. Moreover, two participants (PA1, PA2) stated that an overly informative interface may promote a competitive environment between students in a group.

> *I feel like the [detailed view] almost gives the sense that it's like a race between the [students] and I don't want to view it that way. And I don't want one implicit bias to emerge that this [student] is ahead and that [student] is not... So it's fine to see if [groups] are competing with [other groups, but] I don't want to see competition within [a group].* [PA2]

3.4.5 ***Allowing Students to Communicate their Discussions Status.*** When participants were presented designs that categorized students based on their level of participation in the discussion, they agreed that this level of granularity is unnecessary and difficult to act upon in real-time. Instead, all participants responded positively when presented sketches in which student groups indicate their own status, such as "done with the exercise" or "requesting for help." PA2 shared his thoughts on how status indicators may help reduce communication burdens:

> *We had a lot of situations where... [the students say], "We need five more minutes."... But for that, they would also have to chat... So I think [status indicators] could be helpful... like to get some more context of the time in a more global sense... But I think it will reduce some of the burden of communication on [the students'] end.* [PA2]

4 *GROUPNAMICS* INTERFACE DESIGN

Based on the findings from our participatory design process, we developed *Groupnamics*, Figure 1, a visualization system to support instructors to overview online parallel group discussions. In *Groupnamics*, each student discussion group (breakout room) is represented by a white box. Each group's box contains its name, visualization of its activities, a direct message box, and a button to join the group. All groups are presented in a one-page view, as suggested by our design considerations summarized in Section 3.4. Visualizations in *Groupnamics* include: *anonymized individual student speech utterance visualization, a group silence duration visualization, a group status visualization,* and *direct messages* (Figure 3). This section explains the details and design justifications for these features.

4.1 Anonymized Individual Student Utterance Visualization

Based on the results discussed in Section 3.4.2, *Groupnamics* visualizes the current speaker of each group using gray circles corresponding to each student. The dark and light gray circles correspond with an individual that is speaking and that is not, respectively (Figure 3a). This provides instructors with a quick overview of conversation frequency and balance, and shows recent vocal activities within a group (Section 3.4.3). Students' names are omitted so that instructors cannot build potentially-biased impressions of a particular student (Section 3.4.4).

4.2 Group Silence Duration Visualization

To provide the instructor with further information on the current flow of conversation in each group, *Groupnamics* visualizes the duration of silence with the background color of the group name (Figure. 3b). After detecting the end of a speech utterance, *Groupnamics* will gradually change the color intensity of a group's name box from gray to orange, maxing out in intensity at 10 seconds and remaining in that state until a new speech utterance is detected. This provides the instructor with information on silence duration and frequency, and becomes more attention-grabbing as the silence lasts longer. Once a new speech utterance is detected, the color transitions back to gray over a period of 2 seconds. The time to reach the maximum color intensity was experimentally chosen based on our review of the recorded student discussion data (Section 5). Sub-ten second silences were common in our pre-recorded data, and our configuration can avoid overly frequent false alarms. However, future work is encouraged to investigate appropriate thresholds more systematically.

4.3 Group Status Visualization

The group status visualization allows students to inform instructors of their status on the current activity or discussion. When a student group sends a status, the background color of their corresponding box in the instructor's view changes accordingly. Currently, *Groupnamics* features two statuses: asking for assistance from the instructor (HELP), and notifying the instructor when the group has completed the discussion activity (DONE). The HELP and DONE statuses are represented by a red and green background, respectively. With this feature, students have an explicit way to communicate with instructors when they need support or when they complete the given discussion task (Section 3.4.5).

4.4 Direct Messages

Groupnamics supports direct messages from students to the instructor at a per-group level. These messages are unidirectional from students to the instructor, and appear in the message window in the box of the corresponding group (Fig.3 (d)). Only the latest message is visible at any time, and it remains so until a new message is sent.

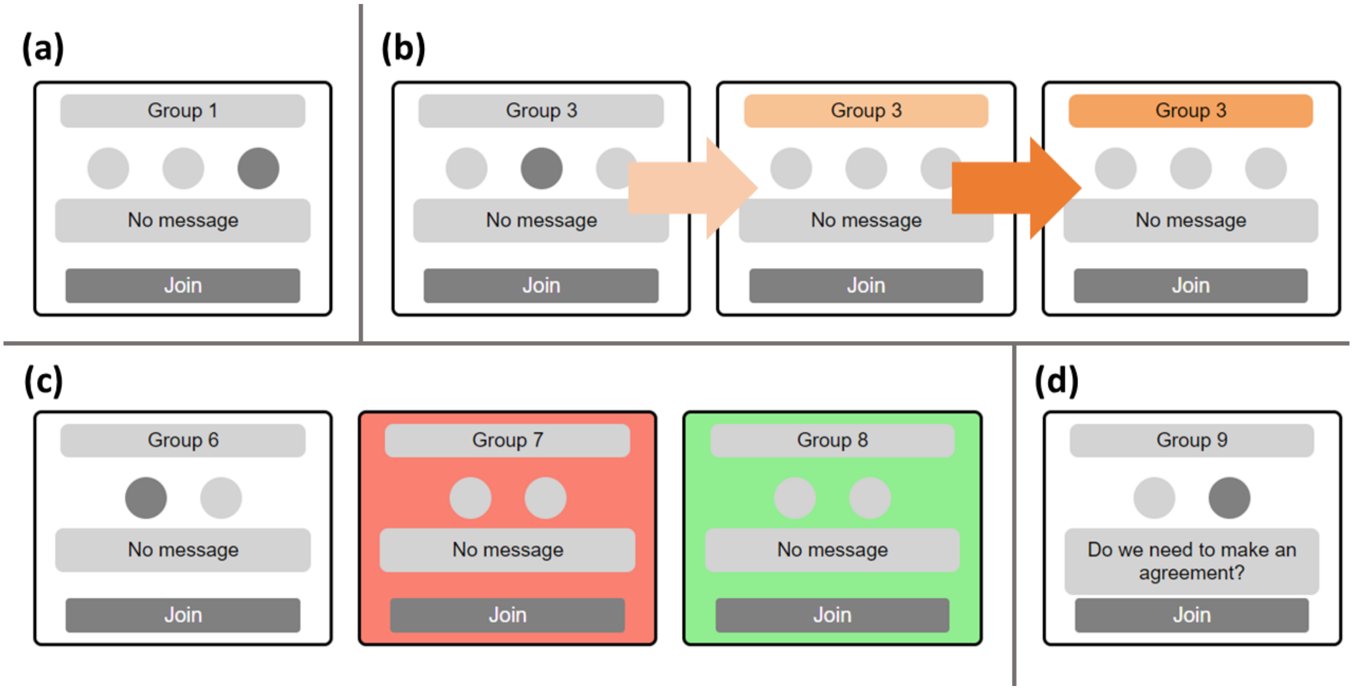

Figure 3: (a) Anonymized Individual Student Speech Visualization: Each student is represented as a circle. A light gray dot corresponds to a student that is not talking; a dark gray dot refers to a student that is talking. (b) Group Silence Duration Visualization: The group label gradually changes colors from gray to orange as no students within a particular group talk. (c) Group Status Visualization: As a group, the students can share a status - white for "no status", red for "help", and green for "done" - which changes the background color of the group box accordingly. (d) Direct Messages: A chat message from the student group only shared with the instructor.

4.5 Implementation

As our main research contributions lie in the design of the visualizations and their evaluations, we designed the current *Groupnamics* system to function with pre-recorded student discussion videos (see Section 5 for more details). In this way, we circumvent technical difficulties that are not associated with our contributions. We use Zoom and its built-in transcription feature to collect the discussion data. Although this method suffers from some limitations, such as only recognizing one speaker at a time and failing to recognize utterances when speakers talk in a low volume, such failure cases occur only occasionally. We extract the following data from the transcripts: speech utterances of each student and corresponding timestamps (used for anonymized individual student utterance visualization). We then store this data in a database for the demonstration and user study of *Groupnamics*.

Based on the information in the dataset, our backend system recognizes silences to achieve the group silence duration visualization. To emulate the group status visualization and direct messages, we asked student participants to type keywords into the Zoom chat. When a group wanted to request for help and they completed discussions, they typed in *##HELP* and *##DONE*, respectively. During the data pre-processing, we extracted group statuses and their corresponding timestamps for emulating the use of group status visualization for our demonstration and user study. A message with *##MESSAGE: [message]* was used to emulate a direct message from the group to the instructor's interface.

The *Groupnamics* interface is developed as a web application using JavaScript, HTML, and CSS. Video streams and corresponding data from the database are used to dynamically change the visualization elements.

5 STUDENT DISCUSSION DATA COLLECTION

We conducted online sessions with 10 groups of two to three university students and recorded their discussions to simulate an online classroom breakout room experience with many simultaneous groups. This method was chosen to fix the conditions of student behavior across participants so that our comparative study would focus on the effect of the presence of the *Groupnamics* visualization. This also allowed us to circumvent some technical limitations and focus on the primary scope of our work.

The following data collection procedure was approved by the Institutional Review Board of the authors' university.

5.1 Participants

We recruited 24 university students (11 female, 12 male, 1 non-binary) to participate in discussion sessions in English. There were no other screening criteria. 23 students reported they were located in Asia, and one in North America. Each participant was compensated the equivalent of approximately $15 USD.

5.2 Procedure

Student groups were formed based on their availability. After introducing the purpose of the discussion session, we allotted time for the participants to introduce themselves. Two of the ten groups reported knowing other student participants prior to joining the discussion session. All discussions were conducted and recorded via Zoom. Additionally, we enabled the transcription function to record the content and time stamps of each participant's speech. All participants were given the option to participate with their cameras enabled or disabled.

We set two discussion tasks to encourage "diverse interactions" [34] between our participants, and these were designed to allow the participants to be able to interact without prior professional knowledge [41, 44]. The tasks were: "determining the course of a self-driving car" (also known as a *trolley problem*) and "planning a road trip". Each discussion task was 15 minutes long, and participants were asked to reach a consensus within the time limit. During the discussion sessions, the participants were informed that there was no instructor present, but were prompted to interact as they would normally in a situation where an instructor could freely join the discussion at will. Furthermore, they were informed that they may use several predefined commands, as described in Section 4.5.

The student discussion data collection took approximately one hour. Participants were allowed to use other tools, such as screen sharing and web browsers, if they wished. Beside providing time reminders and solving technical issues, the experimenter did not interact with groups during the discussion sessions.

This procedure produced the following data: 300 minutes (2 sessions × 15 minutes × 10 groups) of audio and video group discussion recordings; timestamped transcripts of all student speech; timestamped student direct messages; and timestamped group statuses. All data were pre-processed for our user study, as described in Section 4.5. For participants who chose to participate with video, we blurred all individuals' faces during the pre-processing. Additionally, we blurred privacy-sensitive information, such as desktops and bookmark bars, when participants shared their computer screen.

6 USER STUDY

We conducted a comparative user study to understand the effects of *Groupnamics* on overviewing online parallel group discussions. This user study procedure was approved by the authors' Institutional Review Board.

6.1 Participants

We recruited 16 instructors (PB1–16) with experience teaching or facilitating online courses with groups of students. Our power analysis confirmed that the target sample size would be 15 for paired t-tests with the expected effect size, the alpha level, and the pre-specified statistical power being 0.8, 0.05, and 0.8, respectively. To fully counter-balance the presentation order of the conditions, we recruited 16 participants. Relevant details are included in Table 3 in Appendix B. Participants were recruited from the first author's personal network through a snowball sampling approach. PA1 continued from the participatory design study and is referred to as PB9 in the user study. Similar to the participatory design study, we chose to prioritize participants based on their experience overviewing groups of students online. Each participant was compensated the equivalent of approximately $40 USD for their participation.

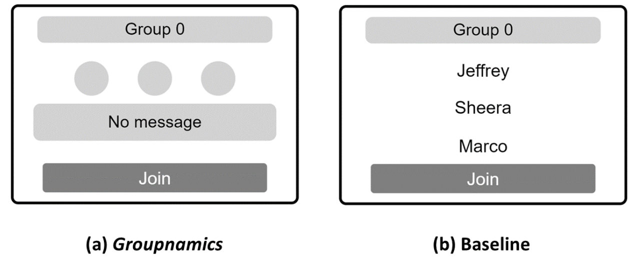

Figure 4: A screenshot of *Groupnamics* and the baseline interface used in our user study.

6.2 Conditions

We designed a within-participant evaluation to compare *Groupnamics* (Fig. 4 (a)) against a baseline interface with all visualizations removed (Fig. 4 (b)), which represents existing online meeting platforms commonly used in online classes. In this interface, each box contains the group's name, names of individual members, and a button to join the group, and no student interaction data were visualized. While a visual highlight for an active speaker is available on commercial communication tools (e.g., Discord), we deliberately designed our baseline without highlighting the active speaker to confirm the effects of individual-level visualizations on instructors while overseeing online parallel group discussions (Section 3.4.2).

6.3 Hypotheses

We developed the following hypotheses to evaluate the effect of *Groupnamics* in terms of overviewing and managing online parallel group discussions:

- H1. *Groupnamics* would be more useful than the baseline interface to overview online parallel group discussions. This is because *Groupnamics* provides information about the students' level of verbal discussion and glanceable group statuses.
- H2. *Groupnamics* would be easier to use than the baseline interface to overview online parallel group discussions. This is because *Groupnamics* provides information in an aggregated manner and it would not overwhelm participants.
- H3. Participants would be able to develop more confidence in which groups to join with *Groupnamics* than with the baseline interface. This is because the *Groupnamics* visualization enables participants to make more informed decisions about which group to join.
- H4. Participants would experience more workload with *Groupnamics* than with the baseline interface. This is because *Groupnamics* presents more information about student groups for participants to process.

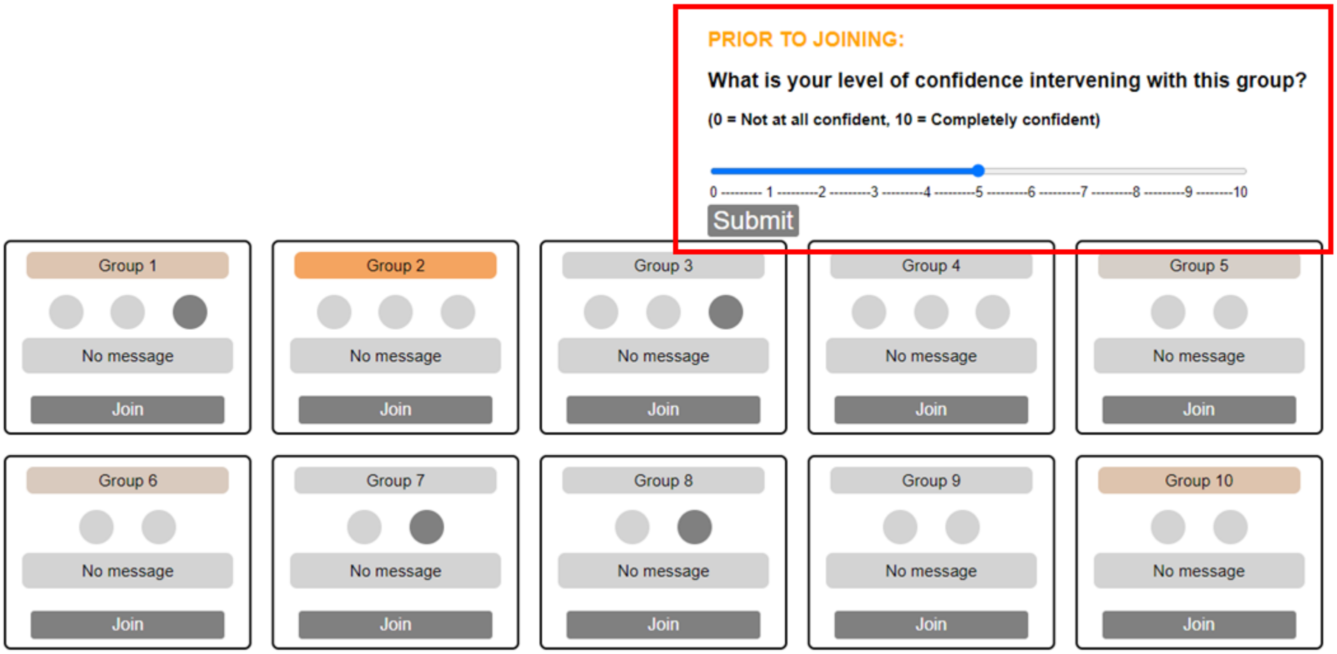

Figure 5: A screenshot of *Groupnamics* with a red box indicating the confidence probe presented to participants before and after joining a group discussion.

6.4 Task and Procedure

After confirming consent from the participant, the experimenter introduced the purpose of the user study and tasks. The experimenter then conducted a first interview to gather and confirm the participant's basic information and relevant teaching experience. The participants were asked to facilitate students' discussion, using the two interfaces. More specifically, they were instructed to "actively engage and overview all discussions", and "facilitate student groups as they felt was necessary".

The experimenter then presented the interface used for the first session, and demonstrated the system using example data separately obtained from the data collection study (Section 5). The participants were given time to familiarize themselves with the task and the first interface. The experimenter then explained the first discussion topic and allotted the participant time to read over the discussion prompt. The participants started the first session when they felt that they were ready. During the session, they were asked to share their thoughts and reasons when they showed intention to join a particular group in a think-aloud manner. This session lasted 15 minutes, and participants were instructed to engage in groups as frequently as they would feel necessary as if they were running an online class. After the first session ended, the experimenter administered two questionnaires (Section 6.5.2). After an optional 5-minute break, the experimenter then conducted a semi-structured post-task interview based on participants' behavior and their questionnaire responses. They were offered another opportunity of a 5-minute break.

The experimenter proceeded to the second session in the same manner to the first session. The experimenter then conducted an end interview, asking the participant about their experience using both interfaces. After both sessions and all interviews were completed, the experimenter debriefed the participants. In total, the user study took approximately 120 to 150 minutes. We fully counterbalanced both the order of the interfaces and the student discussion data (self-driving cars and road trip plans) across the participants to minimize their ordering effects.

6.5 Data Collection

All interviews were conducted online via Zoom, and video and audio recorded for later analysis. During the user study, *Groupnamics* logged each participant's actions (e.g., joining and leaving a group), and confidence levels before and after joining a group.

6.5.1 Confidence Probe. We designed an 11-point Likert scale (0: Not at all confident – 10: Completely confident) in-task question to understand the participant's level of confidence intervening with a group. Upon joining a group (pressing the button to join in the corresponding group's box), the participant is presented a confidence probe as seen in Fig 5.

The participant presses the "Join" button of a group and states aloud the reason for choosing that particular group. The participant is then prompted to rate their level of confidence joining that group. After submitting their level of confidence prior to joining the group, *Groupnamics* shows the on-going discussions of the selected group. The participant then watches the student discussion until they are able to gauge their own level of confidence based on their observation of the discussion. The participant then submits their level of confidence after seeing the group interaction. The interface includes a reminder "What is the main reason you joined this room?"

to prompt the participant in case they do not mention their initial reason for joining the group. Finally, the participant leaves the room and continues to monitor the entire classroom. The participant repeats this process each time they join a group, regardless of whether or not they had joined that group before.

6.5.2 Questionnaires. We employed two questionnaires to quantitatively understand participants' experience of the two interfaces: NASA-TLX [37] and a questionnaire based on the Technology Acceptance Model (TAM) [22] The questionnaire based on the TAM covers perceived usefulness and perceived ease of use. Table 4 in Appendix C presents 12 questions in this questionnaire, and participants were asked to respond in a 7-Likert scale (from (-3) Extremely disagree to (3) Extremely agree).

6.5.3 Interviews. During the user study, the first author conducted four interviews with each participant. In the first interview, we asked participants about their teaching experience, in particular managing online group discussions (5 – 30 minutes). After the first task, we conducted the first post-task interview, asking about their experience using the first interface given to them (10 – 40 minutes). After the second task, we conducted the second post-task and end interview, asking about their experience using the second interface, and their overall experience using both interfaces (15 – 60 minutes). All sessions were screen and audio-recorded via Zoom, and transcribed for later analysis. Sessions were in English or Thai depending on participants' preferences. The post-task and end interview questions are available in Table 5 in Appendix D.

We extracted 297 quotations associated with participants' experience using both *Groupnamics* and the baseline condition. We conducted a thematic analysis on the transcripts and notes taken by the first author during the discussions. Using a deductive (question-driven) approach to answer RQ2 and RQ3, we identified themes about the participant's perceived usefulness, perceived ease of use per feature, and overall perceived confidence and subjective workload.

7 RESULTS

The average number of occurrences of participants joining groups was 10.88 (SD=5.07) and 11.18 (SD=4.26) for the *Groupnamics* and baseline conditions, respectively. Our paired t-test did not find a statistical difference ($t(15)$=-0.25, p=.81, Cohen's d=-0.07 [95%CI: -0.79, 0.66]). We next look into other quantitative metrics we obtained in our user study, and discuss how they support our hypotheses.

7.1 Perceived Usefulness

We investigated the participants' perceived usefulness of *Groupnamics* compared to the baseline condition. Table 1 shows the participants' average level of agreement with statements regarding the perceived usefulness of *Groupnamics* and the baseline condition. Our paired t-tests revealed significant results on all the items with large effect sizes (Cohen's d=1.37 – 1.83)[1]. These results confirm the better perceived usefulness of *Groupnamics* compared to the baseline interface.

[1]0.8, 0.5, and 0.2 are typically considered as large, medium, and small effect sizes in Cohen's d.

During the interviews, participants credited the usefulness of *Groupnamics* to its visualizations: group status visualization (all participants), and direct messages (all participants), group silence duration visualization (PB2, PB3, PB5, PB6, PB8, PB9, PB10, PB11, PB12, PB13, PB14, PB15, PB16), and anonymized individual student utterance visualizations (PB2, PB4, PB5, PB6, PB7, PB8, PB11, PB12).

Group status visualization: All participants shared that group statuses were useful and clearly indicated in a timely manner which groups needed help from the instructor, allowing them to identify the *"next target"* (PB10) group to join. Three participants (PB3, PB5, PB15) inferred that the group status visualizations can be used as a method to evaluate their own teaching material and prompts.

Direct messages: All participants also found the direct messages to be useful to allow students to quickly communicate to the instructor. Three participants (PB1, PB7, PB11) used the direct message along with the group status visualization for help to determine groups to join. Four participants (PB6, PB7, PB9, PB16) suggested potential merits from combining the group status visualization with direct message functionality to address multiple groups at once.

Group silence duration visualization: Eight participants (PB2, PB3, PB5, PB6, PB8, PB9, PB10, PB16) felt that the group silence duration visualization was useful, as it provided suggestions on which group to join next. PB6 described his experience:

> *[The group silence duration visualization] was more of an attention grabber and less of a red alert because, after a while I realized that [10 seconds of silence] is naturally occurring in groups. There are 10 second periods of silence in almost all of [the groups]... So it wasn't an indication of a problematic group, it wasn't an indication of something that's wrong... I just kept an eye [out].* [PB6]

However, six participants (PB1, PB3, PB6, PB8, PB11, PB16) felt that the group silence duration visualization provided premature information to identify groups to join. PB16 explained his experience of hastily joining a *"silent"* group :

> *At first I thought the [group silence visualization]... [was] a sign of "Oh I need to come in, I need to intervene!". But actually I think [the group silence visualizations] are a little bit fast at showing silence, [so] I jumped the gun... By the time [I joined], the students [were] already talking again.* [PB16]

Anonymized individual student utterance visualizations: The anonymized individual student utterance visualizations enabled eight participants (PB2, PB4, PB5, PB6, PB7, PB9, PB10, PB16) to see the individual participation from each student. Participants used these utterance visualizations to determine groups that appeared to initiate conversation quickly, which they deemed to have a casual (PB4, PB9), talkative (PB2, PB5), and *"friendly"* (PB7) atmosphere. Six participants (PB7, PB8, PB9, PB11, PB12, PB16) expressed that the anonymized individual student utterance visualizations provided helpful cues to avoid disturbing the flow of conversation, or identify if a student is *"dominating the conversation"* (PB8). However, six participants (PB3, PB8, PB9, PB12, PB15, PB16) shared that the visualization could be distracting or confusing. Three participants (PB8, PB9, PB12) articulated that the large volume of students, and therefore visualizations, made it difficult to track many groups. PB12 summarized this experience:

Perceived Usefulness (PU) Statement	*Groupnamics*	baseline	$t(15)$	p	Cohen's d [95% CI]
PU-Q1: I would find this classroom interface useful in my job.	2.13 (1.15)	-0.06 (1.65)	5.08	<.001 ***	1.54 [0.72, 2.36]
PU-Q2: Using this classroom interface would make it easier to do my job.	2.13 (1.20)	-0.38 (1.75)	4.13	<.001 ***	1.67 [0.83, 2.50]
PU-Q3: Using this classroom interface would improve my job performance.	1.94 (1.24)	-0.38 (1.36)	4.65	<.001 ***	1.78 [0.93, 2.63]
PU-Q4: Using this classroom interface in my job would increase my productivity.	1.81 (1.56)	-0.38 (1.63)	3.78	<.01 ***	1.37 [0.57, 2.18]
PU-Q5: Using this classroom interface would enhance my effectiveness on the job.	2.06 (1.18)	-0.50 (1.59)	5.13	<.001 ***	1.83 [0.97, 2.69]
PU-Q6: Using this classroom interface in my job would enable me to accomplish tasks more quickly.	1.63 (1.15)	-0.31 (1.58)	3.78	<.01 **	1.40 [0.60, 2.21]
Perceived Ease of Use (PEU) Statement					
PEU-Q1: I would find this classroom interface easy to use.	1.88 (1.09)	1.88 (1.15)	0.00	1.00	0.00 [-0.72, 0.72]
PEU-Q2: It would be easy for me to become skillful at using this classroom interface.	1.63 (1.45)	0.88 (1.63)	1.86	.08	0.49 [-0.25, 1.22]
PEU-Q3: Learning to operate this classroom interface would be easy for me.	2.19 (0.66)	1.63 (1.36)	1.59	.13	0.53 [-0.21, 1.26]
PEU-Q4: I would find it easy to get this classroom interface to do what I want it to do.	1.94 (0.77)	-0.06 (1.53)	6.61	<.001 ***	1.65 [0.82, 2.49]
PEU-Q5: My interaction with this classroom interface would be clear and understandable.	1.88 (0.89)	0.38 (1.93)	3.87	<.01 **	1.00 [0.23, 1.77]
PEU-Q6: I would find this classroom interface to be flexible to interact with.	1.00 (1.26)	-0.25 (1.44)	4.04	<.01 **	0.92 [0.16, 1.68]

Table 1: The means, standard deviations, and statistical results of the agreement scores of Usefulness and Ease of Use statements between *Groupnamics* and the baseline condition. Responses to the statements were in a 7-point Likert scale, from -3 (Extremely disagree) to 3 (Extremely agree).

> *Even though [I, the instructor,] would be able to monitor or... [acknowledge a] group [is having a difficult time]... It also distracts [me] when I want to focus on [a specific group's] activities... I lose focus easily by focusing on another [individual student utterance] or [silence indicator].* [PB12]

In summary, our quantitative and qualitative results generally uncovered positive effects of *Groupnamics*. We thus conclude that H1 is supported.

7.2 Perceived Ease of Use

We investigated the participants' perceived ease of use of *Groupnamics* compared to the baseline condition. Table 1 shows the participants' average level of agreement with statements regarding perceived ease of use. Our paired t-tests found significant differences in 3 of the 6 statements (PEU-Q4 – 6) with large effect sizes (Cohen's d=0.92 – 1.65): control of interface, clearness and understandability, and flexibility. None of the statements showed significant superiority of the baseline condition.

Participants stated that the group status visualization (all participants) and direct messages (all participants) were intuitive and easy to understand, and that the group silence visualization (PB2, PB3, PB5, PB6, PB8, PB9, PB10, PB11, PB12, PB13, PB14, PB15, PB16) clearly suggested which groups to join. However, nine participants (PB1, PB3, PB9, PB10, PB11, PB13, PB14, PB15, PB16) felt that modification to the anonymized individual student utterance visualization is necessary, and nine participants (PB2, PB3, PB7, PB8, PB9, PB10, PB12, PB13, PB14) reported losing track of which groups they were attending to.

Group status visualization: Three participants (PB2, PB10, PB14) attributed the ease of use to the color changes that made the interface more glanceable and allowed them to quickly overview the groups. Eight participants (PB2, PB6, PB4, PB5, PB11, PB13, PB15, PB16) used the group status visualization as a quick and informative method to gauge how the overall discussion was going.

Direct messages: While all participants did not cite major issues with the direct message feature, three participants (PB8, PB6, PB15) expressed that additional modifications would further improve its ease of use. PB6 and PB15 suggested that other feedback designs to indicate incoming messages, such as a sound notification or other colors, would increase their noticeability.

Group silence duration visualization: Participants noted the group silence duration visualization was easy to use because it intuitively conveyed discussion dynamics, such as smoothness of conversation (PB3, PB4, PB5, PB6, PB7, PB8, PB10) and general frequency of silences (PB1, PB6, PB11). Participants suggested possible improvements to the group silence duration visualization for flexibility, including different levels of silence duration (PB6, PB9, PB11, PB12, PB16), an ability to change the threshold of the silence visualization (PB1, PB2, PB9, PB11), or another visualization to indicate the frequency of longer silences (PB8, PB10, PB16).

Anonymized individual student utterance visualization: Five participants (PB2, PB5, PB6, PB10, PB12) felt that the individual student utterances were redundant with the silence duration visualization, and three participants (PB2, PB8, PB12) found that the volume of visualizations was distracting. Five participants (PB2, PB5, PB6, PB10, PB12) thus suggested merging the group silence duration visualization and anonymized individual student utterance visualization to minimize the number of visualizations presented. Additionally, five participants (PB2, PB7, PB13, PB15, PB16) further suggested that for long-term group projects where

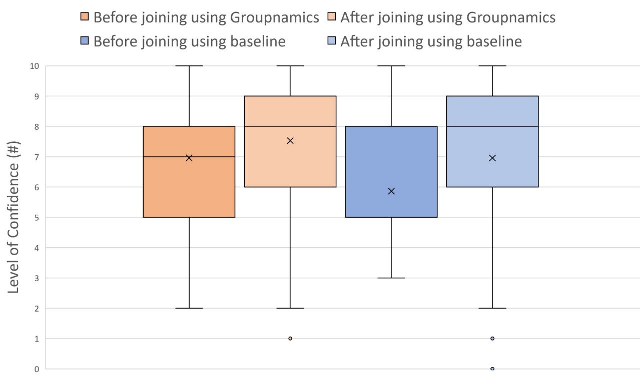

Figure 6: A box-and-whisker plot of the participants' level of confidence before and after joining groups under the two interface conditions. The X mark represents the mean.

the same members would always be grouped together, they would prefer to have an option to see more details about the individual student, such as an icon or name activated by hovering or clicking. PB7 expressed her preference to view the names of students:

> *It's good to have names because, for example... if [a student] is not talking for two classes, I can reach out personally... I can ask him if he's fine or if [he] is feeling good in [his] group or team... Maybe [ask him] if [he wants] to be in a different team... I can see the situation, how it looks and what are the feelings of my students.* [PB7]

In summary, our quantitative results indicate positive results for *Groupnamics*. But the qualitative results uncovered heterogeneous attitudes towards visualizations across participants. We thus conclude that H2 is only partially supported, and future work should investigate what causes such differences in attitudes and how they can be accommodated.

7.3 Perceived Confidence

When comparing levels of confidence prior to joining a group, the participants' average level of confidence using *Groupnamics* was significantly higher ($t(15)$=2.54, p<.05, Cohen's d = 0.67 [95%CI: -0.07, 1.42]) than the baseline condition: 6.67 (SD=1.19) and 5.79 (SD=1.43), respectively (Fig. 6). Participants offered three major reasons related to this positive effect of *Groupnamics*: providing confirmation that the students required help (PB1, PB2, PB3, PB4, PB5, PB6, PB7, PB8, PB9, PB10, PB11, PB12, PB15, PB16); visualizing the fluency of the group discussion (PB2, PB4, PB5, PB8, PB10, PB11, PB12, PB13, PB15, PB16), and providing confirmation that the students finished their discussion (PB3, PB9, PB15).

The average confidence scores after joining groups were 7.33 (SD=1.15) and 6.78 (SD=1.55) in the *Groupnamics* and baseline conditions, respectively. A paired t-test did not find a statistical difference ($t(15)$=1.36, p=.20, Cohen's d=0.41 [95%CI: -0.32, 1.14]).

Six participants (PB1, PB3, PB6, PB8, PB11, PB16) primarily attributed the fluctuation in their confidence to the group silence duration visualization, which they felt occasionally provided premature information on the fluency of the discussion. The participants expressed that they would feel more prepared and confident when joining groups if they knew beforehand how the students were communicating by seeing whether or not the students were screensharing (PB2, PB4, PB6, PB7, PB9, PB15, PB16) or using their cameras (PB3, PB4, PB5, PB7, PB12, PB16) during discussion.

Our results confirm that *Groupnamics* successfully helped participants build more confidence about which groups to join prior to actual engagement. We therefore conclude that H3 is supported.

7.4 Subjective Workload

The average values of the NASA-TLX for *Groupnamics* and the baseline interface were 44.9 (SD=18.8) and 48.6 (SD=22.7), respectively. Our paired t-test found no statistically significant difference ($t(15)$=-0.49, p=.63, Cohen's d=-0.18 [95%CI: -0.90, 0.54]). Seven participants (PB1, PB5, PB6, PB7, PB8, PB12, PB15) rated *Groupnamics* to have a higher workload due to the large amount of information to process at once (PB1, PB8, PB12, PB15), high mental demand due to presentation of many visualizations at once (PB6, PB12, PB15), and high pressure to respond to visualizations in a timely manner (PB7). Conversely, ten participants (PB2, PB3, PB4, PB7, PB9, PB10, PB11, PB13, PB14, PB16) explained that they experienced a lower workload due to the intuitive presentation of visualizations (PB2, PB4, PB11, PB16) and clear indication on which groups to join (PB3, PB7, PB9, PB10, PB11, PB13, PB14, PB16). PB7 captured this dichotomy:

> *I can say [I feel a] bit pressured when I see [these group statuses], but on the other hand, I know which group needs me so in this case it's good, because I know which group I can join.* [PB7]

Our results did not show clear advantages in either of the interface conditions in terms of subjective workload. We thus conclude that H4 is not supported.

7.5 Possible Improvements

Our participants offered different suggestions for possible improvements to *Groupnamics* related to anonymity during online discussions, customization and expansion of notifications, and dedicated space for note-taking.

Anonymity in online discussions: Similar to our participatory design study, our results also confirm participants' unconverged attitudes toward visualization on individual students. Nine participants (PB1, PB3, PB9, PB10, PB11, PB13, PB14, PB15, PB16) suggested in general that they would like to see more details through the anonymized individual student utterance visualization. Nine participants (PB2, PB4, PB6, PB7, PB8, PB10, PB11, PB13, PB15) further shared their preference to see the students' names or initials by a hovering feature. Three participants (PB7, PB8, PB13) suggested viewing names for longer project-based group discussions.

On the contrary, participants felt that identification of individual students was not necessary for varying reasons, such as the names not providing useful data (PB5, PB8, PB9), adding a source of distraction or stress (PB1, PB2, PB11), or being difficult to act upon during a session or in large volumes (PB2). PB2 shared her thoughts regarding the student's level of comfort due to overly-granular information about their activities:

> *Too much information [about the students] in an interface [wouldn't] be a good thing... I don't think that would give*

> *students enough space to think... if the student [knows] that whether [they are] speaking or not will be shown [on an interface]... as a student, I [would] be very stress[ed].* [PB2]

As an alternative to anonymized information, four participants (PB5, PB9, PB11, PB16) suggested providing more details about the on-going discussions other than silence (e.g., the amount of laughter and the balance of utterances between students).

Customization of notifications: Five participants (PB1, PB2, PB6, PB9, PB16) suggested the need for flexibility of customization, for example, adjusting the time threshold for the group silence duration visualization. PB9 shared her experience with the group silence duration visualization indicated by orange:

> *Once I joined this group, the other group [became] orange... I can not be very reactive to these groups' [silences]. So if [the notification]... is more sparse that [would] definitely [be] easier for me to utilize.* [PB9]

Furthermore, two participants (PB15, PB16) suggested providing other feedback modalities, such as using audio to inform the status of a group. PB6 shared his suggestion on how to avoid visually overloading the instructor:

> *I think that visualizing discussion activity in that way... makes it very easy for the instructor to assess and understand in real time what's happening across 10 different breakout rooms... but at the same time, it could have a sensorial overload or cognitive overload on the instructor as well... I would try to probably distribute this information over different sensorial channels. For example, not visualize everything, I know it's predominantly visual because it's zoom, ...but I would try to sonify some of [the information] as well.* [PB6]

Dedicated space for note-taking: While overviewing many groups, six participants (PB1, PB2, PB5, PB8, PB9, PB11) mentioned the mental demand of remembering which groups they visited and descriptions of each group, and suggested adding a space for personal note-taking. PB2 suggested some strategies for note-taking:

> *[I would like] a note section [where] I can record which group - maybe they had some difficulty in discussion before but [the notification] quickly disappear[s]... Maybe... a sticker or a button, that the teacher can click to say [a specific group previously needed] help.* [PB2]

8 DISCUSSION

8.1 Revisiting the Research Questions

The findings from our participatory design (Section 3.3 and Section 3.4) and the resultant *Groupnamics* interface (Section 4) provide rich insights into the information that an interface should present to instructors to overview online parallel group discussions, answering RQ1. We thus discuss the remaining two research questions in this section.

8.1.1 RQ2. How can such visualizations support instructors to identify which groups to intervene for providing help? This research question is associated with both hypothesis H1 and H2, and our quantitative results on perceived usefulness and ease of use generally showed positive results for *Groupnamics* over the baseline interface. The qualitative results also confirm the usefulness and ease of use of *Groupnamics* for overviewing online parallel group discussions. The four features in *Groupnamics* were positively received by our participants because they provided clearer cues for deciding which groups to join. Our participants described the overall experience with *Groupnamics* as enabling instructors to make decisions on which group to join next (PB1, PB2, PB3, PB5, PB6, PB8, PB9, PB10, PB16), allowing them to relax and observe while overviewing (PB2, PB7, PB10, PB11, PB16), providing an efficient overview (PB2, PB6, PB7, PB9, PB11), providing the overall picture of the class as a whole (PB2, PB4, PB6, PB11), and providing timely feedback (PB1, PB7, PB12). The visualizations also gave the participants context on when not to join groups. Three participants (PB8, PB12, PB16) shared they felt they would interrupt the flow of conversation. PB16 shared while initially using *Groupnamics*, he interpreted the group silence duration visualization to be synonymous with the group asking for help. However, upon joining, he found that the group did not need support. Therefore, from his experience, he modified his approach, taking a step back while overviewing:

> *As a manager of a breakout room... of a class, it was really nice to see an overall layout of what's going on with the rooms. In a way, it enabled me to sit back and say"you know what, I'm not going to join any of these rooms to see who actually needs help."* [PB16]

However, our results were not fully in favor of *Groupnamics*. In particular, the qualitative results highlighted heterogeneous attitudes among the participants toward ease of use. Some participants felt information redundancy in the four visualization in *Groupnamics*, and future work should examine how *Groupnamics* can be further simplified while maintaining its positive effect on overviewing online parallel group discussions. Another reason for this is that overviewing and managing online parallel group discussions is an inherently complex task in and of itself. Our NASA-TLX results did not uncover a difference between the two interface conditions, which may imply the demanding nature of the task itself regardless of the interface. PB6 commented:

> *The thing that's making this tiring is the job [of overviewing online group parallel discussions] itself, and not the interface... The interface... is visualizing all this information, so it actually shows you how intense it is.* [PB6]

This observation encourages researchers to further investigate the interface design of support for managing online parallel group discussions, and our work would be a premise for such future work.

8.1.2 RQ3. How do classroom visualizations affect the level of confidence intervening with students during on-going discussions? This research question is directly associated with hypothesis H3, and our study revealed that, prior to joining a group, participants were more confident determining which groups to join when using *Groupnamics*, compared to the baseline interface (Section 7.3). Our qualitative results also support that the visualization in *Groupnamics* offered better identification of groups where intervention would be needed. Seven participants (PB4, PB7, PB9, PB12, PB13, PB14, PB16) explicitly shared that they felt increased confidence when the visualizations identified and confirmed which groups needed their help:

> *I felt much more confident, I felt that I was needed, and I felt much more focused... I wasn't just jumping to groups... here, I was much more serious and much more confident at the same time because I [knew] that they [needed] me.* [PB7]

However, we also observed that six participants (PB3, PB5, PB8, PB9, PB15, PB16) experienced a drop in confidence between before and after joining a group when the discussion dynamics of the groups did not match with their perception from the visualization. Future work should therefore investigate how to narrow the gap between the instructor's expectations about a group and the visualization of group discussion.

8.2 Design Challenges for Future Work

Our results also uncovered unique interface design challenges with regard to overviewing online parallel group discussions.

8.2.1 History of interaction with students. Participants shared that *Groupnamics* provided a large volume of visualization in real-time and that they felt it can be confusing (PB3, PB8, PB15), distracting (PB9, PB12, PB15), and require a high level of attention (PB8). Participants even shared losing track of which group they visited (PB2, PB3, PB7, PB8, PB9, PB10, PB12, PB13, PB14). This indicated that our design not only requires the participants to process lots of information in a short amount of time, but also burdens them because they must remember which groups they joined and how these groups interacted.

One possible solution could be to replay the recorded history of how students are discussing, similar to previous work [35]. However, we anticipate that this could be providing overly-rich data that instructors would be unable to analyze in a short period of time.

Therefore, to balance between an appropriate amount of presented information and amount of time for overviewing groups, we recommend providing note-taking for the instructor, as suggested by the participants, to jot their observations directly within each group visualization, and presenting a history log of what groups the instructor has visited, following the strategy of ClassBeacons [4, 5], to minimize confusion and enable instructors to focus on the next group that requires their attention or groups they have yet to visit.

8.2.2 Student anonymity and surveillance in online classes. Participants were divided on whether or not to keep students anonymous while overviewing online parallel group discussions. They suggested allowing customization of student anonymity depending on how frequent group discussions occur in class. For one-time activities where students are randomly divided into groups, participants found that *Groupnamics* provided an appropriate level of student anonymity. Participants expressed that overly detailed information may make students feel stressed, and that customization of anonymization may be a solution. Supporting this idea, previous work has examined the anonymization of student participation during in-person classes through electronic response systems (e.g., response clickers) [31, 49] and anonymous feedback to lecturers [10, 53], and found students' inclination to participate during classes increased due to the anonymity of responses. Our participants stated that knowing the identity of each student is unnecessary, and would add clutter to an already busy visualization. However, in project-based classes where students are expected to work in teams for more than one session, students should not be anonymized, as the participants expressed the necessity of knowing the members of the groups and building a personal level of connection.

Some participants expressed concern for the students' privacy during online classes. As online classes provide opportunities to access detailed information on each student, it can also present instances for instructors to surveil or monitor the students' progress [54, 78]. Previous literature suggests that students can be sensitive to disclosing personal details and being monitored during online classes and forums [17], and the removal of *"obscurity"* that students are afforded in the absence of surveillance technology in the classroom [7]. Thus, to find appropriate solutions to overview online parallel group discussions, designs should allow for varying levels of customization of anonymity depending on the expected frequency of group discussions and the number of students. Future research should identify and compare design preferences as our findings and related work suggest a divergence in opinion between the instructor and the students.

8.2.3 Social translucence during online parallel group discussions. In line with theories of social translucence [29], the participants shared their desire to clearly convey their own status to other students while they are with a group in order to provide context, particularly when they cannot immediately respond to a request for help. Just as it is important for the instructor to see the students, it is also important for the students to see the instructor to build rapport through open communication [30, 67] during online parallel group discussions. Furthermore, benefits of peer teaching, such as increases in performance and reflection [14, 47] in online classes, suggest potential for designs that encourage social translucence among peers, in this case among groups.

Thus, future work should not only explore the impact of social translucence between students and instructors, but also among groups of students with visualization systems such as *Groupnamics*.

8.3 Limitations

In order to circumvent technical issues extracting student discussion data in real-time, our user study with *Groupnamics* used pre-recorded data, and therefore did not allow participants to interact with students when joining discussion groups. As a result, our findings may not reflect all the nuances of instructor-student interactions during online parallel group discussions. For example, our dataset lacks nuances in speech patterns or behavior of students due to an intervention by an instructor. However, our data still maintains ecological validity for our study as it captures and presents our participants with realistic scenarios that happen while working with many students: natural silences among group discussions, and instances where many groups request help at the same time. These scenarios provide our participants with ample opportunities to prioritize and decide how they will interact with the student groups. We argue that *Groupnamics* was able to capture and present realistic discussion dynamics, and suggest that future work examine the use of visualizations during live sessions to observe and evaluate the influence of the instructor on the student group discussions. We recommend future work to investigate live sessions to focus on the impact of the instructor's intervention on the students' discussion. However, in the case where pre-recorded student discussion data is used, we may investigate how the instructor's personal teaching preference and communication style affect their interpretation of the group visualizations.

Furthermore, although we focused on recruiting participants based on their experience overviewing groups of students online rather than their teaching position, and thus were able to incorporate insights and feedback from various teaching experiences, the position of TA and instructor can invoke different levels of comfort in students [43]. While we argue that the position of the participants does not affect the findings of our study, as we did not investigate *Groupnamics*'s effect on students, we suggest that future work should investigate and uncover how interface designs would vary based on the experience and responsibility of a TA versus an instructor.

Due to the design of our user study, instructors' experience with *Groupnamics* was limited to its short-term use. As a result, our findings reflect initial impressions and effects of *Groupnamics*, rather than the ways that instructors may adopt it over time. A long-term study would allow us to better understand the adoption of *Groupnamics*.

Our evaluation only included 10 student groups (N=24), and thus the scalability of *Groupnamics* to larger class sizes is not fully examined in this work. Our results reflect the dynamics of a medium-sized class [65], and thus may overlook the unique dynamics and challenges in small or large classes. Future work should investigate how class size impacts the usability of *Groupnamics* and its effect on instructors' performance.

This study also focused exclusively on instructors' perspectives on *Groupnamics*, as stated in the introduction. However, in a real classroom, students and instructors influence each other in a dynamic relationship. As a result, students' perceptions of *Groupnamics* and its effect on instructors' performance are also essential for understanding how we can best support online parallel group discussions. While we present the instructors' view on how the students may feel using *Groupnamics*, and related literature that suggests the student's level of comfort with surveillance technology and anonymity during class, future work should explicitly evaluate the performance of online classroom visualizations from the students' perspective.

9 CONCLUSION

Group discussions are an important educational activity, but existing videoconferencing tools commonly used in online classes do not support instructors to manage them. We present *Groupnamics*, a visualization system that aggregates vocal activities and statuses of multiple discussion groups in a one-page view. Our user evaluation confirms the advantages of *Groupnamics* in improving user confidence in determining in which group intervention by instructors is needed. Perceived usefulness and ease of use are also generally improved over the baseline condition representing existing videoconferencing interfaces. Our work thus successfully contributes novel insight into online teaching platform design, in particular, for supporting instructors' management of online parallel group discussions.

Future research should expand our work by examining *Groupnamics* in a broader context. Visualizing interaction among students beyond vocal activity could contribute to improving the practical usefulness and usability of systems like *Groupnamics*. Another important research direction is to evaluate such systems from the perspective of students. This work serves as a foundation for further research on designing and evaluating interfaces to support online parallel group discussions.

ACKNOWLEDGMENTS

We thank Toby Chong, D. Antony Chacon, Zhongyi Zhou, Carla F. Griggio, Eureka Foong, and Chi Lan Yang for their meaningful discussions. We also would like to express our gratitude to our instructor and student participants who shared their time and insight. This project was partially supported by the SPRING GX Project at The University of Tokyo.

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A DETAILS OF THE PARTICIPANTS FOR THE PARTICIPATORY DESIGN SESSIONS

#	Age	Gender	Related online teaching experience
PA1	25	Female	TA for online physics laboratory session including simulations and coding sessions conducted completely online
PA2	26	Male	Primary instructor for HCI course conducted completely online
PA3	26	Female	TA for academic writing course; staff for academic writing services provided by the university
PA4	34	Male	Primary instructor for hardware hands-on course that transitioned to online halfway through the semester
PA5	29	Male	TA for internal lab discussion sessions; instructor for language course

Table 2: Instructor participant demographics. We recruited five participants (PA1–5) with experience teaching online courses.

B DETAILS OF THE PARTICIPANTS FOR OUR COMPARATIVE STUDY

#	Age	Gender	Related online teaching experience
PB1	29	Male	TA for 2 university courses in the School of Policy
PB2	23	Female	High school instructor in training; Instructor for language tutoring; Peer teaching with colleagues
PB3	23	Female	TA and RA for course on sustainable development goals through technology, project-based class
PB4	23	Female	TA for 2 classes focusing on paper reading and presentations
PB5	30	Male	TA for Microeconomics for public policy
PB6	38	Male	Mentor for graduate students; Member of lab that helps conduct workshop and ideation sessions
PB7	28	Female	Instructor for graphic design (e.g., Photograph and Illustrator); Member and organizer for professional development seminars
PB8	23	Male	Lecturer for programming course; Instructor and TA for computer science-related courses
PB9*	26	Female	TA for physics laboratory session
PB10	30	Female	Educational specialist; assistant for video making course
PB11	27	Female	TA for international relation development course
PB12	28	Male	Facilitator for university student organization and admission fair
PB13	31	Male	Professor of engineering and technical courses (e.g., automatic control, advanced control, advanced dynamics, technical drawing) (online/hybrid)
PB14	25	Male	TA for chemistry seminar
PB15	26	Male	TA for application of technology course (online/hybrid)
PB16	28	Male	TA for technical course (hybrid/online); Main instructor for online orientation for campus (online)

Table 3: Instructor participant demographics. We recruited 16 participants all with experience teaching online courses. PB13, PB15, and PB16 have additional experience teaching hybrid courses. PB9* (previously referred to as PA1) continued from the participatory design to the user study.

C QUESTIONNAIRE BASED ON TECHNOLOGY ACCEPTANCE MODEL (TAM)

Q#	Category	Statement
1	PU	Using this classroom interface in my job would enable me to accomplish tasks more quickly.
2	PU	Using this classroom interface would make it easier to do my job.
3	PEU	Learning to operate this classroom interface would be easy for me.
4	PEU	I would find it easy to get this classroom interface to do what I want it to do.
5	PU	Using this classroom interface would improve my job performance.
6	PEU	My interaction with this classroom interface would be clear and understandable.
7	PEU	I would find this classroom interface to be flexible to interact with.
8	PEU	It would be easy for me to become skillful at using this classroom interface.
9	PU	Using this classroom interface in my job would increase my productivity.
10	PU	Using this classroom interface would enhance my effectiveness on the job.
11	PU	I would find this classroom interface useful in my job.
12	PEU	I would find this classroom interface easy to use.

Table 4: Questionnaire based on Technology Acceptance Model (TAM). After each task, we asked participants to fill out this survey about perceived ease of use and perceived usefulness. We randomized the order of the questions to avoid bias.

D INTERVIEW QUESTIONS

Overall experience using interface	How was your experience during the task? What challenges did you encounter during the task? How did the interface support/hinder your ability to overview the students? How did the interface affect your perception of the students or the groups overall?
Joining groups	What expectations did you have when joining this group? Why did you choose to join this group? What contributed to an increase/decrease in your confidence when joining groups? Did your impression change after joining the group?
Features - Overall	Which feature was the most helpful while overviewing? Why? Which feature was the most distracting while overviewing? Why? What features were useful to you? What features were challenging or distracting?
Features - Detailed	How did the anonymized individual student utterance visualization affect your overviewing experience? How did you interpret the anonymized individual student utterance visualization? How did the group silence duration visualizations affect your overviewing experience? How did you interpret the group silence duration visualizations? How did the group status visualization affect your overviewing experience? How did you interpret the group status visualization? How did the direct messages affect your overviewing experience? How did you interpret the direct messages?
Comparing interfaces	Which interface did you prefer to use? Which interface was easier to use? Which interface was more useful? Compare your experience using both interfaces.
Future interface design	What features would you like to see in future implementations? What other information or visualizations do you think would support your overviewing? Do you have any other observations, comments, or suggestions you would like to share?

Table 5: Interview Questions.