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TeamCAST: Visualizing Progress and Contributions in Student Team Projects

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Software Engineering

by

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Thesis Committee:
Professor André van der Hoek, Chair
Professor Sam Malek
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DEDICATION

To my parents, Meena Deshpande and Vilas Deshpande, who made all of this possible,
my brother Aditya Deshpande, who paved the way for me to be able to do this,
and my girlfriend Umang Lahoti, for her unwavering support.

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Finally, I would also like to thank the members of the defense committee, Professor Sam Malek and Professor Jim Jones for being on the defense committee and providing their invaluable insights.

ABSTRACT OF THE THESIS

TeamCAST: Visualizing Progress and Contributions in Student Team Projects

By

Anmol Vilas Deshpande

Master of Science in Software Engineering

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Professor André van der Hoek, Chair

Team-based projects are a cornerstone of contemporary software engineering programs. Although they can be effective in improving learning of the course materials and imparting teamwork skills, teamwork can present challenges for both instructors and students. Well-known problems include teams not following recommended processes (e.g., producing all necessary artifacts at the last minute) and team dynamics interfering with progress (e.g., social loafing, dominating personalities, failing to consider others and their ideas). This thesis introduces TeamCAST, a tool I specifically designed to track both progress and contributions over the course of a team project. TeamCAST is based on the notion of students submitting all intermediate work, which TeamCAST then displays on a dashboard for the instructor to monitor. This thesis reports on the primary design decisions underlying TeamCAST and presents the results of a pilot study in a 179 student software design class.

Chapter 1

Introduction

Teamwork is a fundamental skill for working in the software industry [3]. Many computing (e.g., computer science, software engineering, computer science and engineering) curricula acknowledge this fact by including teamwork as part of their courses. While the primary topic of these courses is typically something different (e.g., machine learning, software engineering, human-computer interaction, operating systems), an implicit goal nonetheless remains for students to practice teamwork in one or more group projects spread out over a number of weeks, or sometimes months. Often culminating in a significant final deliverable (or deliverables) to be submitted at the end, students must work together throughout the project to continue to make progress. While they do so, they usually produce a range of intermediate artifacts on their way to the final deliverable(s).

Practicing teamwork is not the only reason for incorporating teamwork in computing courses: teamwork is also an important pedagogical strategy. A number of research studies have shown that teamwork is beneficial to students' learning of the primary topic being introduced in a course [30, 19, 14]. By working together on, e.g., a networking assignment or project management presentation, students learn from the perspectives of their peers, jointly explore a topic in typically more depth than they can alone, help each other navigate difficulties they encounter, correct each other's mistakes, and more.

Student teamwork is not without its problems, however. One problem that has been informally observed though not systematically studied is that of students not necessarily following prescribed processes or, more informally, a recommended order of steps to take towards project completion. In an Agile oriented software engineering course, for instance, it is important to develop user stories and perform proper design before fully engaging in implementation. While such orderings are sometimes enforced by instructors, in more advanced courses students often are to engage in best practices that they themselves must orchestrate. Regardless, students do not always follow the "right" practices. In the software design course that is taught in my university that involves several three-week design projects, for instance, every session the course is taught, instructors encounter student groups who at the very last minute produce personas "because they are required" rather than producing personas early on to inform their design work.

A second problem concerns interpersonal issues that cause work imbalances. Various behavioral patterns have been well documented, with social loafing [20], freeriding [4], and team members overriding the work of others [25] as a few examples of typical problems that may arise. Peer assessment can help address such cases, but often the information comes at a time that is too late for the instructor to intervene, frequently after a project has already completed [5]. Often, too, if peer assessment is performed mid-way through a project, students feel awkward in reporting team members as being problematic and may well underreport the reality [32]. If the instructors need to intervene, they should know issues of *contribution*.

This paper presents TeamCAST, a novel tool that I have developed to address both issues: being able to monitor student team progress and being able to assess who contributes to what activities while the team is making progress on a project. TeamCAST is based on the insight that, for instructors to be able to do this, it is necessary for them to see the results of intermediate work. TeamCAST follows the principle that teams submit any and all intermediate work shortly after it has completed, meaning that if a team works on a whiteboard, they submit a picture of the whiteboard afterwards, or if they work on a presentation but do not finish it yet, they submit a copy of the presentation when the meeting ends. The goal is not to actually judge the work itself, but to nudge students into the "right" behaviors. Because they know that their progress and their contributions will be visible and inspectable, my hypothesis is that they will therefore adjust their work so they follow suggested practices more closely, and that they will equally contribute more evenly. While it is no guarantee that they will automatically do so, because the work is continuously visible, instructors can intervene much earlier and have a conversation with teams for which their project appears to not be going well. Clearly, a concern is that the tool must be lightweight for both students and instructors: this was a design principle throughout and I discuss more about this issue in Section III.

I implemented TeamCAST and performed a small pilot study in a software design class taught at my institution. Preliminary results from usage of the tool, a small survey, and examination of the data collected indicate that TeamCAST could be a valuable addition in an instructor's toolkit and provide useful insights into team progress and contributions. Students also do not seem to be particularly burdened or upset at having to submit the intermediate artifacts.

Chapter 2

Background

Multiple studies have shown that collaborative learning can generate positive effects on student learning. In addition to direct effects such as learning from the perspectives offered by peers, jointly exploring topics in more depth than possible on one's own, helping each other when someone encounters difficulty with their part of a team assignment, and correcting one another's mistakes, teamwork also increases motivation, helps build persistence, and positively affects creativity in problem solving [7].

Teamwork, however, also comes with complications that must be dealt with. It has been observed that students often are left to their own devices: they are expected to work in a team environment without much, if any, oversight [24], thus putting the onus of learning teamwork skills on them. This in turn can lead to problems, especially if groups are randomly formed rather than deliberately put together, the latter for instance with the input from carefully crafted surveys seeking to understand learning styles, class goals, and expertise, among other items [13]. Even in cases where instructors use a survey, problems in team dynamics can and do still arise. In the most extreme cases, students have been observed to resort to working alone, thereby defeating the purpose of team-based projects altogether [12].

More common, however, are issues of social loafing [1], uneven work distribution [1], freeriding [15], team members dominating conversations and thereby causing others to refrain from contributing [17, 25, 12], team members ignoring the contributions of others outright [12], and last-minute heroes who overwrite some (often significant) portion of the work of their team members. An interesting resource typifies these and even more negative behaviors as named stereotypes [22].

The challenges with team-based learning are well-known and many efforts have been made to address the concerns, with several categories of approaches emerging. One category of approaches focuses on documenting best practices and strategies to structure and conduct team-based projects and classes. The exact best practices vary by paper, with some offering comprehensive guides of design guidelines and management techniques for ensuring students learn well [23] [8], others offering suggestions for group formation, ongoing management, and debriefs at the end of a project [29] [16], and yet others offering considerations regarding team size, team assignment, and task types [31].

Another category of approaches focuses on peer assessment as a strategy to address team progress and contributions, essentially counting on team members holding each other accountable. Peer assessment has become popular among instructors and it has been shown that it can reduce undesirable issues with team dynamics [11] [2]. The effectiveness of peer assessment, though, depends on its implementation, as variations exist in the kinds of questions being asked, the amount of detail being requested, and therefore the amount of effort students have to put into making an assessment. In that context, a particular concern that has emerged is that of accuracy and fairness, especially when the peer review process is heavyweight [33]. Some efforts attempt to ameliorate these concerns by introducing strict protocols by which students are to assess their team members [9]. Other efforts attempt to provide tool support to make it easier for students to perform peer assessment. Examples of peer review systems include SPARK [10] and the Daily Smirk [21].

A third category aims to assess the contribution level of individual team members by leveraging data stored in the tools the students use. Hypothesizing that such data can accurately reflect effort, one example uses GitHub data to automatically create summaries of students' contributions; these summaries are then used by the instructional staff to gauge individual contributions [26]. As another example, Google Docs by default tracks who contributes what and, as such, has also been leveraged to determine respective student contributions (e.g., [27, 28]). A potential pitfall of this kind of approach is that when students discuss work together in person, often one person is capturing the results of the conversation, meaning that their level of contribution as measured by the amount of change in the joint document is disproportionate compared to the other participants who did not take notes but nonetheless helped move the project along.

Introducing team projects creates extra work for instructors, although it is clear that such work is necessary to surface the benefits of collaborative learning [5] and that instructor participation can significantly shape the overall experience [6]. A recent study highlights some of the challenges that prevent instructors from being more meaningfully engaged in this regard, including time constraints, scale in the number of students and teams, and the need for better tools and management techniques [18]. Especially because much teamwork takes place outside the classroom with no possibility of supervision [34], it becomes particularly important to develop ways in which instructors can have insight into what is transpiring in student teams that go beyond student self-reporting or instructors regularly interviewing teams.

This thesis introduces TeamCAST, a novel tool that complements existing efforts by focusing on the problem of gaining visibility into both team *progress* and individual *contributions*. As such, my objective blends the pedagogical goal of student teams working "in the right way", with the goal of reducing intra-team issues stemming from participation and lowering the effort of monitoring while at the same time not unduly burdening the students.

Chapter 3

Design

TeamCAST (Team Collaboration And Sensemaking Tool) is an artifact tracking tool specifically designed for classes that require students to work in teams on a complex project. TeamCAST is based on the observation that, during teamwork projects, students typically produce quite a few intermediary artifacts. Sometimes, those artifacts are prescribed by instructors, who may, for instance, require regular updates or may require a particular sequence of artifacts to be produced toward the final deliverable (e.g., a set of sprints, each sprint starting with user stories followed by mini design docs, test plans, and code, with the completion of the set of sprints culminating in the final delivery of a software system). Other times, students produce intermediate artifacts naturally as part of working together. They may, as examples, get together and draw on a physical whiteboard, work remotely and jot thoughts down in a Google Docs or Miro board, or produce a mock-up of an interface they might implement later.

For most projects, student teams will produce a mix of these prescribed and otherwise more spontaneous artifacts. For most projects, too, outside of the prescribed check-ins that generally happen not too often, these intermediate artifacts are ephemeral. They are not visible to the instructor and many serve a passing role in that they are useful for some time (sometimes just for that one meeting, other times a bit longer), but then lose their value because the lessons learned in producing the intermediate artifacts either stick inside the team's collective memory or become incorporated in other, more permanent artifacts.

These intermediate artifacts, however, provide a crucial opportunity to gain insight into how student teams work. Specifically, *when* they are produced can provide insight into progress; *which* intermediate artifacts are produced can provide insight into whether progress is taking place following the proper steps or in the proper order; *who* produces the artifacts can provide insight into participation of and contributions by different team members.

TeamCAST supports students in submitting their intermediate work each time they produce some sort of artifact, and both students and instructors with an interface through which they can see the project unfold. For students, TeamCAST provides a straightforward calendar-based interface to view their progress. For instructors, that same calendar-based interface is expanded with a set of auxiliary visualizations that help instructors gauge how each team is doing. Below, I first discuss the student interface of TeamCAST and then the instructor interface.

3.1 Student Interface

The student interface of TeamCAST allows students to record and visualize their intermediate work, with relatively low effort. The main component of the student interface is a calendar-like student dashboard. Shown in Figure 3.1, it consists of a calendar along with a navigation bar on the left and an appbar at the top displaying the team name (see Figures 3.2 and 3.3). The content of the calendar consists of working sessions, or sessions for short. Each session represents a cohesive unit of work in which one or more team members engaged

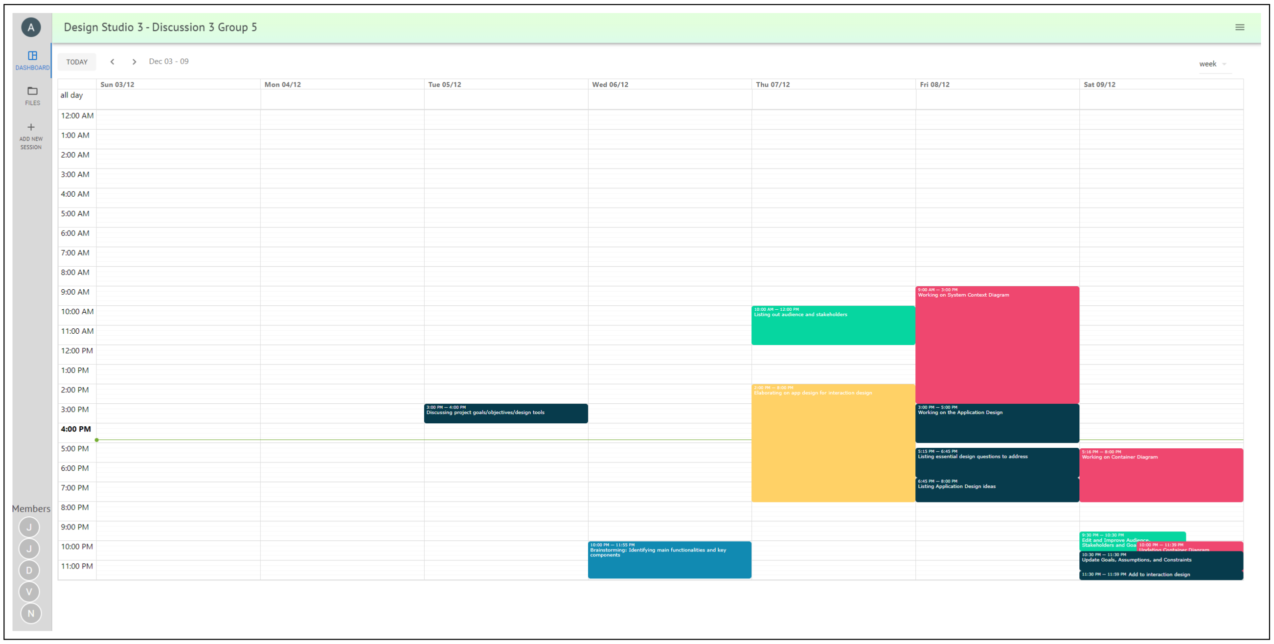

Figure 3.1: Student dashboard showing an actual excerpt of a student team's work during experimental deployment in the course

for the project. In Figure 3.1, for instance, the team worked on five consecutive days, with one session on day one, one on day two, two on day three, four on day four, and four on day five. Note that sessions can take place in parallel (e.g., on day five). In the case of the two parallel activities on day five, as shown in Figure 3.4, three students were working on two different aspects of design. One of the students was working on their own, improving the documentation of the project, while the other two were working together on refining the system's architecture diagram. Note how they kind of jumped the gun on the first day, starting with detailed design work, but then realizing they needed to engage in the other kinds of activities first and doing so in the subsequent days.

Individual sessions can have different colors. Students can assign one of five colors to each session. What the colors represent, however, is not prescribed by TeamCAST and students can choose their own color scheme encoding their sessions. In the case of Figure 3.1, the team used light green when they worked on the documentation shaping the design project (such as listing out audience and stakeholders), light blue for brainstorming, pink for working

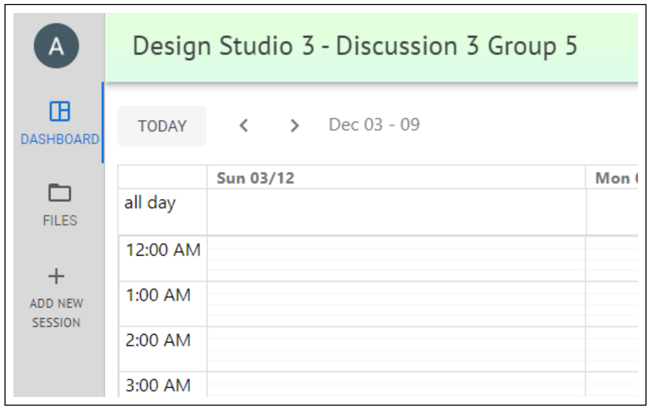

Figure 3.2: A closeup view of the Navigation drawer and title bar

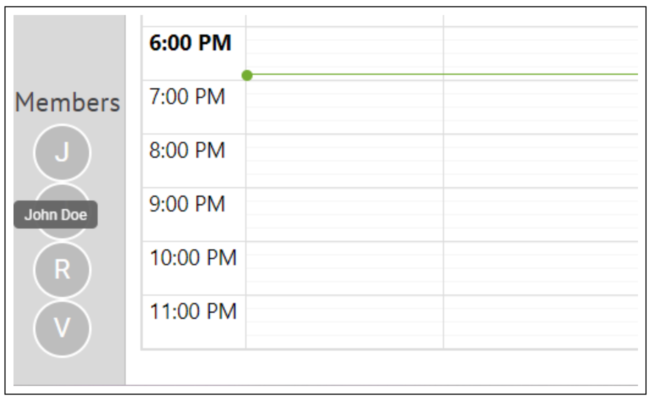

Figure 3.3: A closeup view of the left corner of the dashboard shows chips for the member on the navigation drawer which displays a tool-tip on hovering the mouse

on the system architecture, yellow for discussing overarching design issues to think about, and dark blue for performing detailed design work on the features and architecture of the system.

To add a new working session, students can drag the mouse across the calendar over the desired time period on the desired day, or use the Add New Session button in the navigation pane on the left of the calendar. Upon selection, they are presented with the window shown in Figure 3.5. A student can then assign a title to the working session, assign a color, refine the date and the times of the session, and select the contributors for that session. The data is validated for invalid entries such as an empty title, no contributors, or an invalid time. After clicking Save, the session is added to the calendar. Once a session is added to

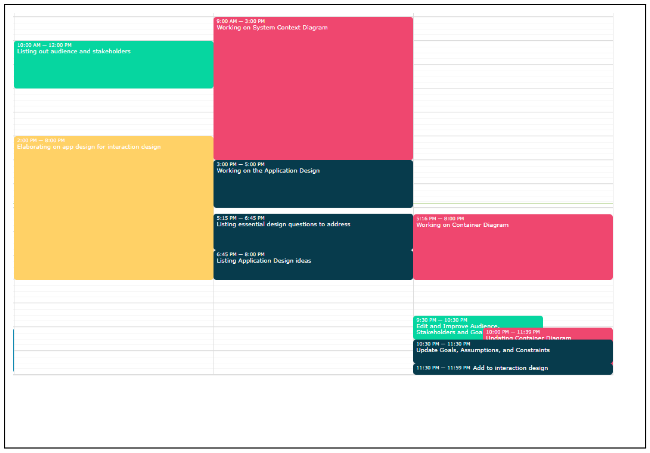

Figure 3.4: A closeup view of the recorded working sessions on the calendar view

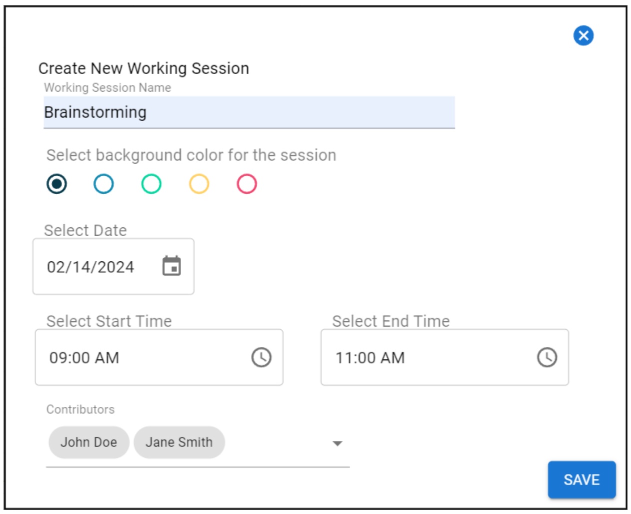

Figure 3.5: Adding a new session

the calendar, others in the team can view it as well. Note that only the person who created a session can edit it afterwards, for instance if they made a mistake in who contributed. While restrictive, it prevents the situation where a non-contributing team member at the last minute adds themselves to some or even all of the prior sessions to pretend they were fully engaged throughout.

Once a session has been added to the calendar, the student who created it can also add any artifacts that were created or modified in the session. TeamCAST is agnostic to the type of file; it can be a photograph of a whiteboard, a PDF download of a Google Docs file, or an

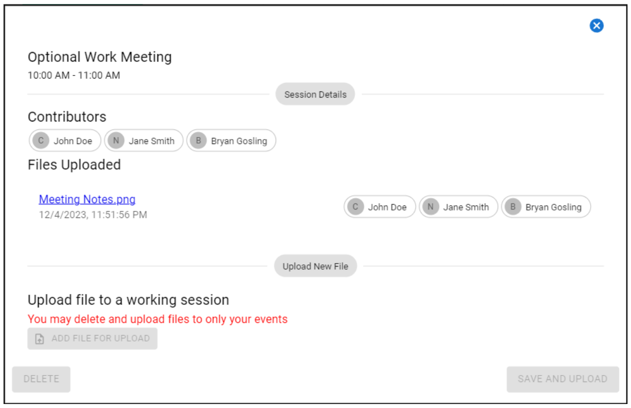

Figure 3.6: Uploading artifacts to a session

image of a mock-up, to name a few. A single session can have multiple artifacts associated with it, since it is well possible that a team works on multiple related parts of a project, for instance on a Figma mock-up with supporting documentation in a Google Docs file. In such cases, all of the artifacts that were newly created or otherwise modified should be uploaded. Note that artifacts do not always have to be new, since team and project work nearly always involves iteration (e.g., refinement of a mock-up, further elaboration of a UML diagram, revision of a design document). I expect students to upload a current copy of the artifact each time they finish working on it.

To support fine-grained attribution, for instance when a whole team comes together to work but it breaks into two subgroups working on different aspects of the project, TeamCAST supports attribution of different team members to different artifacts (see Figure 3.6). By default, the selected contributors are the same as the contributors to a session, but individual team members can be removed and re-added.

The TeamCAST student interface includes one additional view: the artifacts view (invoked by choosing Artifacts in the left navigation pane). This view, shown in Figure 3.7, consists of a paginated table with fields such as name of the file, the name of the person who uploaded the file, contributors to the file, the session to which it belongs, the date and time it was uploaded, the size of the file, and an option to download the file. This page can be used

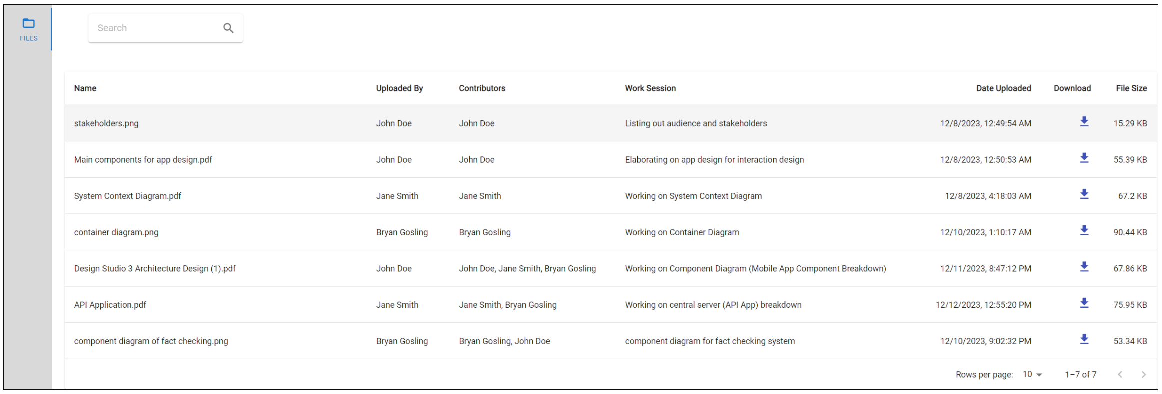

Figure 3.7: Viewing the set of artifacts that has been produced thus far

by students to obtain a quick overview of how their project has progressed in terms of the artifacts, and can also be used to share artifacts among teammates (and even as a backup). To facilitate finding artifacts quickly, the view includes a search bar which can search by file name, contributors, and session title.

Finally, the student interface contains a help section (Figure 3.8) that can be accessed by using the hamburger menu at the top right of the interface. The help section consists of a number of frequently asked questions about the usage of TeamCAST. The section also includes a number of videos that students can view to learn how to use TeamCAST. Students can also submit their issues or suggestions using the form on the page.

The student interface is largely passive, other than allowing students to add new sessions or view specific sessions by clicking on them. That said, as teamwork progresses, the calendar view and artifacts view provide teams with a comprehensive view of their work that they can use to reflect on how they are doing, particularly if they have received guidelines from the instructor regarding how they might want to space out work or which activities should come early and which later. It can also help them to reflect on times that they are not productive (e.g., many activities with few artifacts) or spending effort they might not want to be spending it (e.g., repeatedly working on the same artifact without making progress on others).

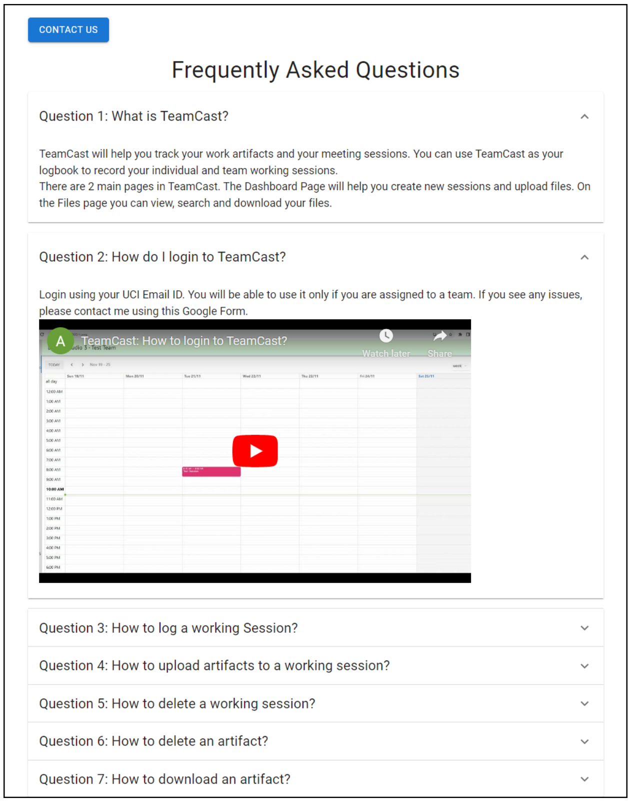

Figure 3.8: Help Page

3.2 Instructor Interface

The instructor interface is designed for instructors to track team progress and contributions. The interface displays the progress and contributions for one team at a time. Instructors can view the progress of a team by choosing its team name from a drop-down menu. Once instructors select a team, they are presented with an interface that consists of two parts (see Figure 3.9): an analytical dashboard that provides a series of cards that summarize a team's behavior, displayed at the top, and a calendar-based timeline similar to the student calendar-based timeline, displayed at the bottom.

The analytical dashboard consists of six separate cards, laid out in two rows of three:

- *Total number of working sessions.* The first card (see Figure 3.10) displays the total number of sessions in which a team engaged thus far. The total is calculated simply by

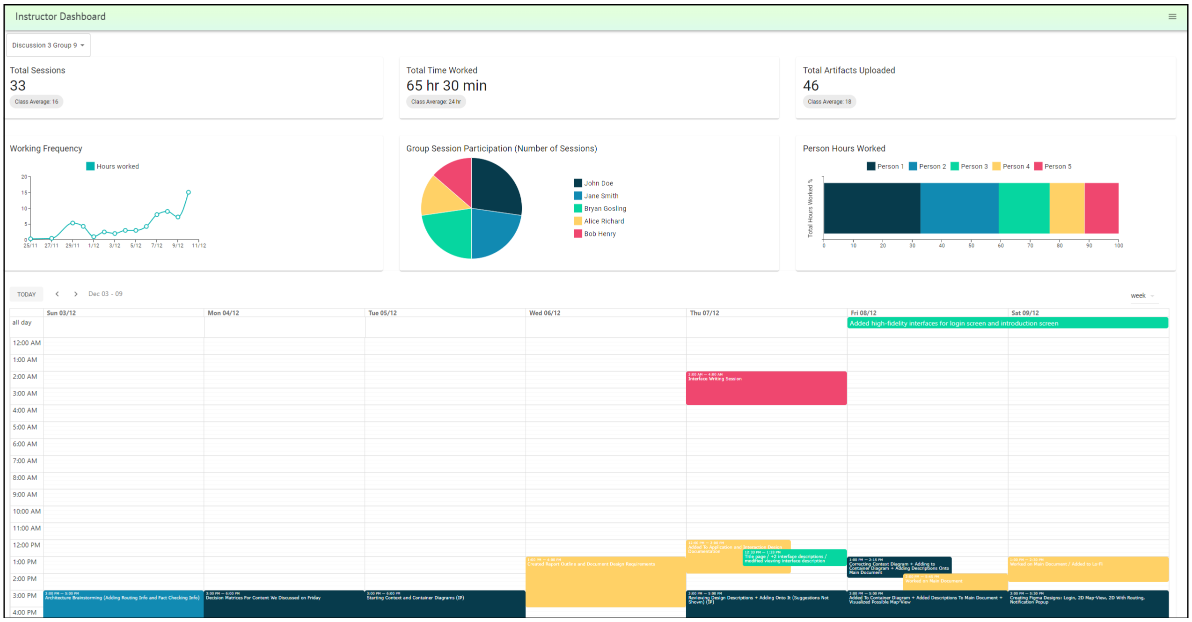

Figure 3.9: Instructor dashboard showing an actual excerpt of a student team's work during experimental deployment in the course

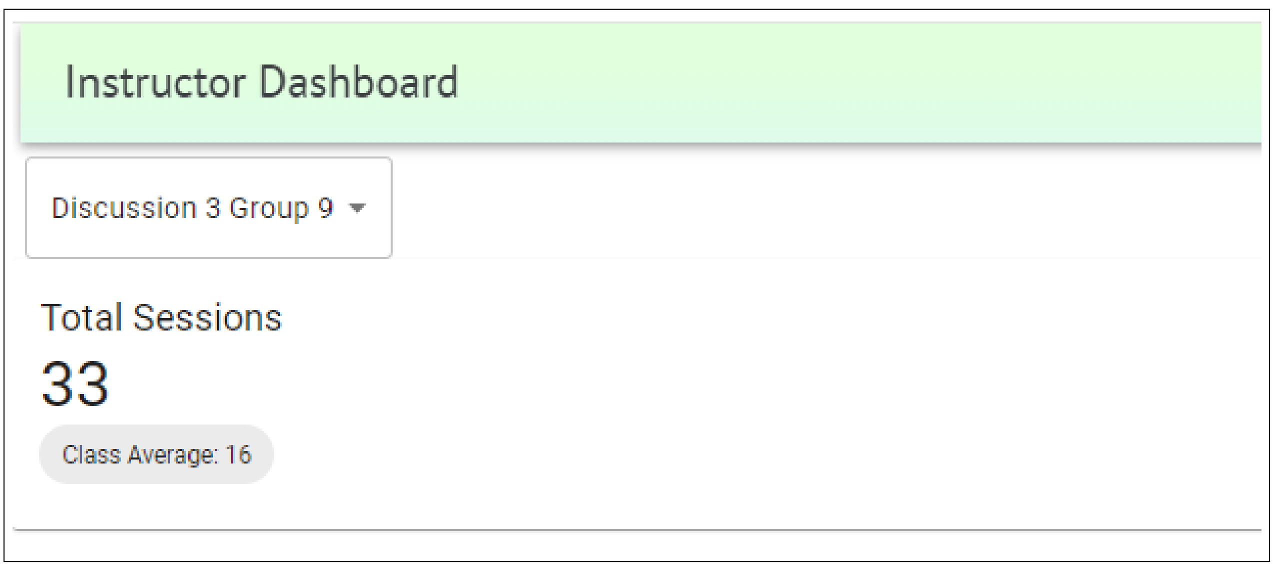

Figure 3.10: Card 1 - Total sessions

counting the sessions logged in TeamCAST, regardless of whether a session consisted of a single student working alone or the entire team working together. To understand how this number compares to other teams, the card includes a chip label that indicates the class average. Note that a comparatively low number does not necessarily mean that a team is performing badly. It can also mean that a team prefers fewer, but longer sessions, or that a team does most of its work actually together rather than individuals working apart and on their own with occasional group check-ins. This card, thus, should be used in conjunction with other cards before drawing any conclusions.

Figure 3.11: Card 2 - Total working hours

- *Total working hours.* The second card (see Figure 3.11) is complementary to the first card and displays the total number of reported working session hours by the team. It is calculated as the sum of the duration of each session logged by the students, with the time spent in sessions with multiple contributors counted only once. Similar to the Total number of working sessions card, this card also displays a chip label indicating the average amount of hours put in by the class for this project. Again, lower numbers should not necessarily be interpreted as bad compared to other teams, since working together more lowers the number automatically.

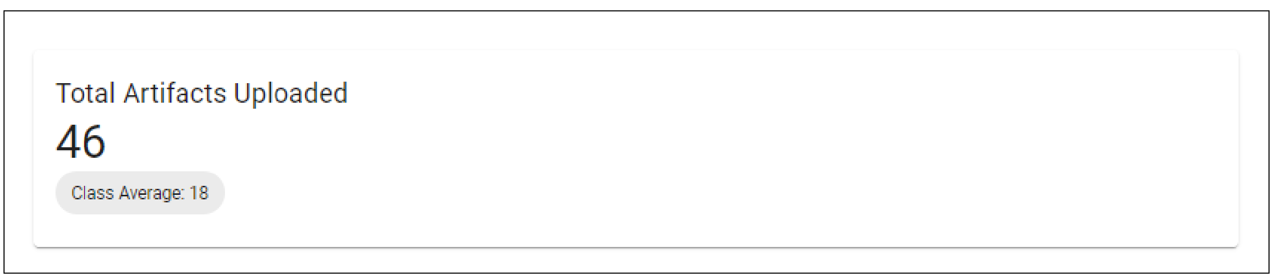

Figure 3.12: Card 3 - Total number of artifacts uploaded

- *Total number of artifacts uploaded.* This card (see Figure 3.12) displays the total number of intermediate artifacts uploaded, with a chip that displays the average across all teams. Again, a low number is not necessarily an indication of poor performance;

where some teams might choose to work in a long Google Docs with integrated images, other teams may want to create different artifacts in more specialized tools. Nonetheless, low levels that are outliers can be an indication for an instructor to examine the progress of the team further, as with the prior two cards.

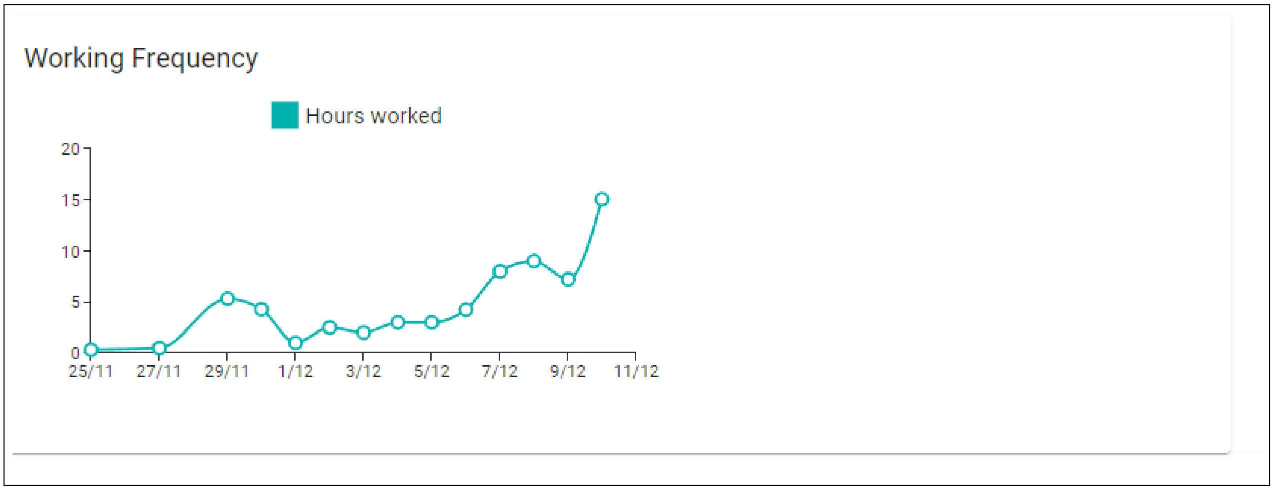

Figure 3.13: Card 4 - Working frequency

- *Working frequency.* The working frequency card (see Figure 3.13) displays a line graph indicating when a team works, organized per day of the project. The X-axis displays the dates of the project while the Y-axis displays the number of hours the team worked each day, as calculated by summing the length of the various sessions on that day. This is an important graph that can be utilized by instructors to understand how frequently the students work on the project, which can be particularly useful in assessing how a team is progressing. Teams that do not start sufficiently early, for instance, will show absence of activity. Sometimes teams, too, start vigorously but trail in the middle, which is typically also not a good pattern. What ultimately are and are not good patterns of engagement will be dependent on the course and the instructor, but this graph can give the instructor a first indication of when things might not be going as planned or prescribed.

- *Group session participation.* This card (see Figure 3.14) consists of a pie chart which

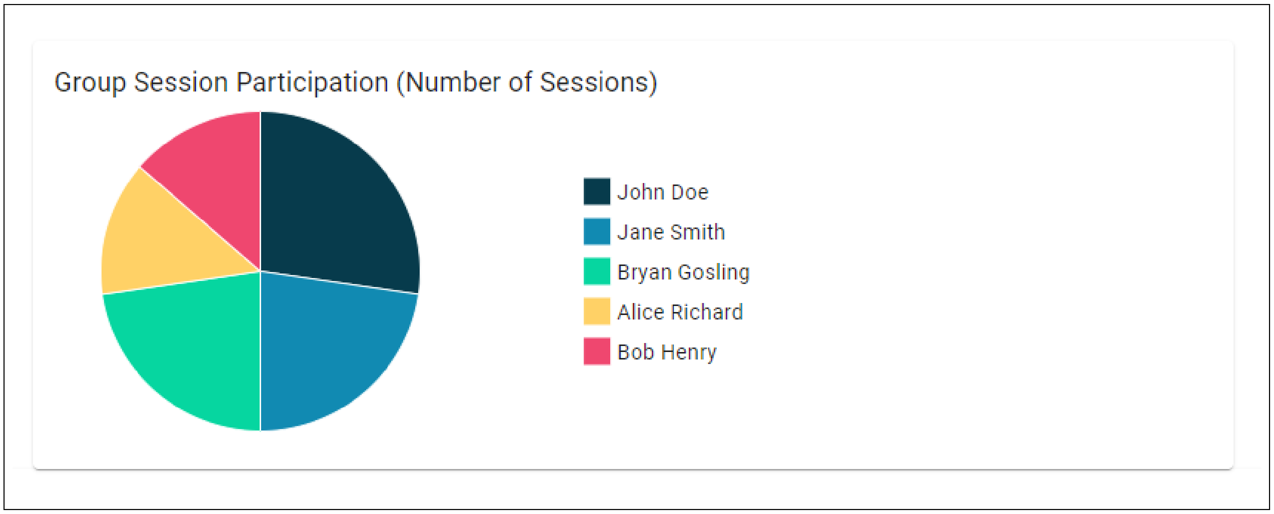

Figure 3.14: Card 5 - Group session participation

indicates the participation of each student in the joint activities of the team. The pie chart is constructed by adding, for each student, the number of collaborative working sessions in which they engage and dividing that by the total number of collaborative sessions. I only consider collaborative working session and I do not consider sessions where individuals worked alone the project, as I want to be able to understand not just whether students contribute individually, but also whether they engage with the group, so to avoid "lone wolfs". The smaller a piece of the pie a student occupies, the less they engaged with the team directly. They still may have been contributing to the project, though, so the card is once again to be interpreted as a potential warning to be investigated further.

- *Person hours worked.* The sixth and final card (see Figure 3.15) indicates the distribution in the person hours spent on the team project using a stacked bar chart. The time duration used to calculate the distribution is different from the TOTAL WORKING HOURS card, because the PERSON HOURS WORKED card calculates the total number of hours a team member worked relative to the total number of hours everyone worked, meaning it also takes into account hours worked individually. For example, if a five person team works in a two hour collaborative session with every member

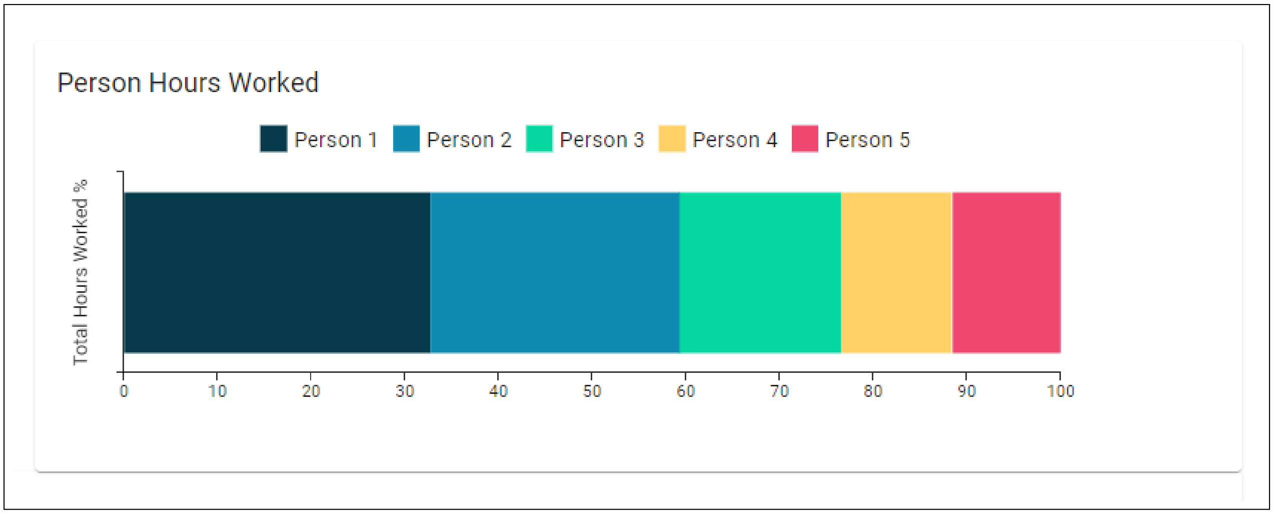

Figure 3.15: Card 6 - Person hours worked

participating in the session, then the total number of person hours worked would be ten hours and each person participated exactly one fifth. If one person then spends another ten hours on their own, their percentage would grow significantly compared to the others. Together with the prior card, this graph can be useful to signify potential issues with contributions by individual members, as well as overall team cohesiveness. Again, however, it is merely a potential indicator, because it is possible that someone tries to game the system with long hours for tiny changes, or that the quality of work delivered by one team member in a short time might well be much greater than that of the remainder of the team. A deeper investigation is thus needed, but at least the need for such a closer look is indicated.

Assuming the information on the cards signals to an instructor that they should take a deeper look, or when the instructor wants to do so out of their own curiosity, they have two options of doing so. First, below the six cards, the instructor interface presents a similar calendar-like timeline that displays all of the working sessions of the team being examined. The instructor can scroll through the timeline to take a deeper look at the sessions of a team, participation in the sessions, and the artifacts created during each session. This can be used to assess whether students teams are making progress and whether the various team

TODAY < > 11/08/2023 — 12/08/2023

Date	Time	Event
Tue Nov 28	8:30 pm — 9:15 pm	Creating Personas
	9:30 pm — 10:30 pm	Primary audiences and stakeholders
	10:45 pm — 11:10 pm	Updated primary audiences and stakeholders
Wed Nov 29	10:00 pm — 10:50 pm	Design Matrices
Thu Nov 30	10:00 pm — 11:40 pm	Primary Audience & Stakeholders
Fri Dec 01	12:00 pm — 12:30 pm	Rough diagram - architecture design
	12:30 pm — 1:00 pm	Mockups for the interaction design
Sat Dec 02	7:30 pm — 8:35 pm	Hand drew Mock-ups and explanation
Tue Dec 05	10:00 pm — 11:00 pm	Figma screens design
	11:00 pm — 11:30 pm	Figma Design - Mockup (Home/Profile Page)
Wed Dec 06	5:00 am — 5:45 am	Figma Session
	10:00 pm »	Finalize Mockup - Figma Design
	10:00 pm — 11:00 pm	uml diagram
	10:00 pm — 11:15 pm	official doc
Thu Dec 07	« 12:30 am	Finalize Mockup - Figma Design
Fri Dec 08	12:00 pm — 12:45 pm	final meeting for the format of the doc

Figure 3.16: Viewing the summary of all the sessions of a team

members are appropriately contributing to this progress. Second, in addition to the timeline view, the instructor can display the working sessions in list form (see Figure 3.16, which is easier to scan from the perspective of assessing the activities in which a team engages (assuming the sessions are properly named). In the case of the team shown in the figure, the team creates personas before designing the UI mockups, which is the proper order.

3.3 Implementation

TeamCAST is implemented as a web application using React for the client side and Firebase for back-end computing, including the database, authentication, and hosting functionality. TeamCAST has a lightweight implementation that can be readily deployed and expanded to support multiple courses. The client is developed using React and uses the Material UI library for React components; the TeamCAST website is accordingly deployed using Firebase hosting. Given the significant demand in terms of storage, I use Cloud Firestore to store data on the server and Firebase APIs to access the data from the client. For authentication, I integrated TeamCAST with my institution's authentication system, so students can log-in using their normal credentials.

Chapter 4

Preliminary Evaluation

TeamCAST is still in the early stages of development, with significant additional functionality still to be added (see next section). That said, I wanted to perform an exploratory assessment to begin to understand how TeamCAST could be integrated into a team-based project, whether students would use it, what kinds of insights could be gained from using the instructor dashboard, and how students felt about having to submit their intermediate artifacts using TeamCAST. Because the deployment was in a course taught by my advisor, the results below should be interpreted as an experience report, not as a formal evaluation. My primary goal was to gather information with which I could assess the potential promise of TeamCAST as well as understand where my subsequent development efforts should focus.

4.1 Deployment Setting

I deployed TeamCAST for the final design studio in a software design class taught by my advisor Dr. André van der Hoek at University of California Irvine. The course is an upper-division undergraduate course that aims to teach the basics of software design through three design studio group projects spread throughout the term. Each design studio is three weeks long and consists of a problem statement resembling a real-life design scenario. The first two design studios introduce a variety of techniques, which students have to bring together in the third and final software design studio in which they are responsible for designing the features of a new software system, its basic user interface, and the anticipated system architecture. There were a total of 179 students in the class who were randomly assigned to a group, leading to a total of 36 groups, each consisting of four or five students.

TeamCAST was introduced to the students before the start of the final design studio. Students were instructed to record all their intermediate artifacts as well as the final deliverable through TeamCAST. This was not a major deviation from prior sections of the course, in which the third design studio always required students to include intermediate artifacts in the final deliverable, with part of the grade depending on teams following good design processes and using select design methods.

4.2 Usage

In total, the teams recorded 581 working sessions in the three weeks of the final design studio, which averages to slightly over 16 sessions per team. On average, each session was 93 minutes long, with the shortest session just four minutes (a quick ChatGPT conversation; ChatGPT usage was allowed in the course) and the longest a little over eight hours (preparation of the final deliverable on the last day, which involved a lot of design work that still needed to take place). In total, the teams spent 862 hours on the 36 design studios, meaning that each spent an average of 24 hours on their project. The most time spent by a team on their group project was 65.5 hours and the least amount of time spent by a team was 5.5 hours. The highest number of sessions recorded by a team was 33 and the least number of sessions recorded was only five. Out of all 581 sessions, 67% (389) were individual sessions and the remaining 33% (192) were collaborative group sessions. The collaborative group sessions involved 3.6 team members on average (70%). The most collaborative team had 2.75 times more group sessions (11) than individual sessions (four) and the least collaborative team had 16 individual working sessions but zero collaborative work sessions.

In terms of artifacts, the teams created 643 artifacts and each group on average created 18 artifacts. This amounts to an average of 1.1 artifacts per session. The team that worked for the most time produced the highest amount of artifacts (46). In comparison, the team with the least number of artifacts only produced six artifacts. The top five extensions of the artifacts submitted are shown in Table 4.1. The kinds of artifacts submitted included lists of essential design questions to address, Figma mockups, whiteboard pictures, documents detailing the features to be designed, architecture diagrams, mindmaps, container diagrams, ChatGPT log histories, sketches, interaction design diagrams, and personas.

Outside of the main document to be delivered, iteration was not that frequent. On occasion I witnessed teams iterating over the architecture diagram or interaction diagrams, but most other artifacts were single use.

File type	Number of Uploads
pdf	308
png	278
jpg/jpeg	38
drawio	4

Table 4.1: Top five extensions of the artifacts submitted

4.3 Examples of Team Behavior

To illustrate how an instructor might use the instructor dashboard, I present a few examples of situations that stood out to us during the trial (not an exhaustive list due to space reasons and this still being a preliminary examination).

My first example concerns a team with an extremely unbalanced work distribution. Shown in Figure 4.1, this team is the anti-thesis of how teamwork should be performed. In a team of four members, one student contributed 90% of the person hours recorded on TeamCAST and they had zero collaborative working sessions with the other team members. While other cards on the dashboard (not shown) contained relatively normal data compared to other teams (e.g., 16 sessions which is the class average, and 28 artifacts) and thus make the team look like a non-descript team, this specific card revealed the truth of a dysfunctional team. Note that the obvious interpretation (and in this case correct interpretation after the instructor talked with the team) is one of freeloading by no fewer than three members who did not care to contribute. An alternative explanation could have been that one person completely overpowered the other team members to the point of them becoming disillusioned and withdrawing from the collaboration. Interacting with a team to get to the bottom of a possible issue is always necessary.

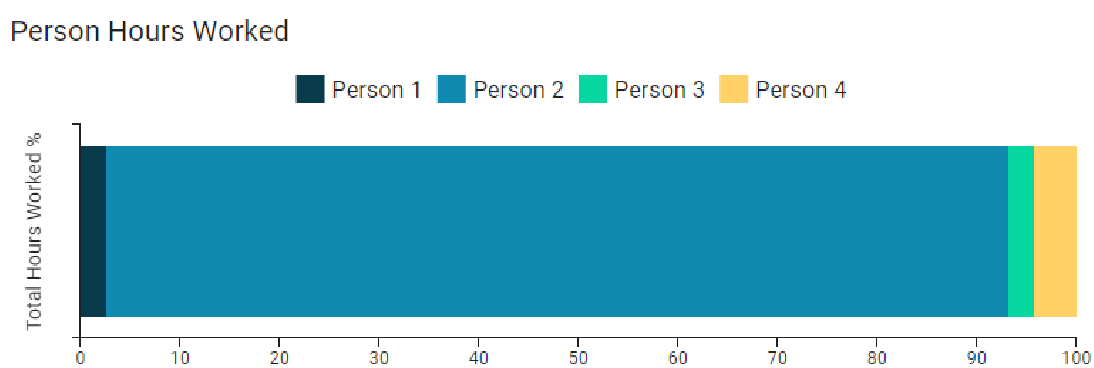

Figure 4.1: Person hours of a group where one person completed most of the work (Names anonymized)

A second example is illustrated by Figure 4.2. On the right hand side is the same diagram as in Figure 4.1, but now for a different team. At first blush, with the exception of the yellow team member, this looks like a balanced team with time investments that are within the normal variations of teamwork. The card on the left hand side, however, tells a different story. It is for the same team, but shows that exactly two people took care of the collaborative work.

Figure 4.2: Session participation (left) and person hours (right) for a team with two members participating in the collaborative work, but all others engaging asycnhronously (Names anonymized)

No other team member attended the meetings. While the team succeeded in asynchronously collaborating, with the two team members directing the other team members by giving them compartmentalized tasks to work on, this also is not an ideal situation from the perspective of a design course. One would want all team members, for instance, to engage in brainstorming and discussing alternatives.

As another example I compare the team that produced the most artifacts (46) with the team that produced the least artifacts (6). At first glance, there is a clear difference in the amount of hours put in by both teams: while the team that produced the most artifacts worked for 65.5 hours across 33 sessions, the team that produced the least number of artifacts worked for 13 hours across 12 sessions. The first team produced an average of 1.39 artifacts for each working session, while the second team only produced 0.5 artifacts per working session. However, a higher number of artifacts does not always mean a better outcome, since the amount of artifacts produced is not necessarily indicative of their design quality. To understand the quality of the designs and processes of both the teams, I examined their working sessions in details. Figures 4.3 and 4.4 show the list of sessions created by each team respectively. Note that, although both teams generally work on the same kinds of design artifacts such as personas, essential design questions, prototypes, mockups, and architecture diagrams, the second team only works on each of these design artifacts once throughout the project. On the other hand, in the first team's timeline, observe that they incrementally

TODAY < > 11/26/2023 — 12/26/2023

Date	Time	Event
Sun Nov 26	4:30 pm — 5:00 pm	Generating a List of Essential Questions Using ChatGPT
Tue Nov 28	8:00 pm — 10:50 pm	Worked on mind-map and added to Essential Questions
Wed Nov 29	2:00 pm — 4:30 pm	Adjusted Essential Questions
	5:10 pm — 7:12 pm	Personas (IP) / Mind Map (IP) / Essential Questions
Thu Nov 30	3:00 pm — 4:00 pm	Continued User Personas
	3:15 pm — 4:30 pm	Created Personas Outline and Invented the Personas
Fri Dec 01	11:00 am — 11:50 am	Discussing Decision Decisions (Friday Discussion)
	11:30 am — 11:40 am	Uploading Information To The Software Sketch
Sat Dec 02	1:00 pm — 3:30 pm	Sketching Architecture
Sun Dec 03	1:00 pm — 3:00 pm	Architecture Brainstorming (Adding Routing Info and Fact Checking Info)
Mon Dec 04	1:00 pm — 4:00 pm	Decision Matrices For Content We Discussed on Friday
Tue Dec 05	1:00 pm — 4:00 pm	Starting Context and Container Diagrams (IP)
	8:00 pm — 9:00 pm	Finalizing Decisions For Matrices
Wed Dec 06	11:00 am — 2:00 pm	Created Report Outline and Document Design Requirements
	3:30 pm — 3:45 pm	Adding HTTPS/JSON/JDBC To Container Diagram (IP)
Thu Dec 07	12:00 am — 2:00 am	Interface Writing Session
	10:00 am — 12:00 pm	Added To Application and Interaction Design Documentation
	10:33 am — 11:33 am	Title page / +2 interface descriptions / modified viewing interface description
	1:00 pm — 3:00 pm	Reviewing Design Descriptions + Adding Onto It (Suggestions Not Shown) (IP)
	3:00 pm — 4:00 pm	Adjust Context + Container Diagrams and Begin Component (IP)
	7:00 pm — 8:00 pm	Added Google Embed API and Continued Component Diagram (IP)
	8:00 pm — 9:00 pm	Added to Lo-Fi Documentation
Fri Dec 08	11:00 am — 12:15 pm	Correcting Context Diagram + Adding to Container Diagram + Adding Descriptions Onto Main Document
	12:00 pm — 3:45 pm	Worked on Main Document
	1:00 pm — 3:00 pm	Added To Container Diagram + Added Descriptions To Main Document + Visualized Possible Map-View
	8:45 pm — 11:59 pm	Added high-fidelity interfaces for login screen and introduction screen
Sat Dec 09	11:00 am — 12:30 pm	Worked on Main Document / Added to Lo-Fi
	1:00 pm — 3:30 pm	Creating Figma Designs: Login, 2D Map-View, 2D With Routing, Notification Popup
	4:15 pm — 8:35 pm	Hi-fi interfaces
	7:00 pm — 9:30 pm	Report a Problem Interface, Fact Checking Interface and Writing
Sun Dec 10	11:00 am — 6:30 pm	Final Edits and Submission
	2:30 pm — 3:15 pm	Added To Architecture Design Image and Added Leaderboard Interface

Figure 4.3: List view of working sessions of the team with least number of artifacts

added to their design artifacts as well as revisit them. For instance, consider the artifact 'Essential design questions'. Both teams produced this artifact, but the second team only devoted one session to it and did not make any changes to it after that. For the first team, the sessions such as 'Adjusted Essential Questions' and 'Worked on mind-map and added to Essential Questions' indicate that the team updated the artifact they already created after their understanding improved. This pattern is also visible through other sessions such as 'Continued User Personas', 'Finalizing Decisions For Matrices', and 'Correcting Context

Diagram'. This indicates that the team undertook an iterative approach in their design work. In this way, the process timeline can be used by instructors to evaluate the quality of the design process.

TODAY < > 11/26/2023 — 12/26/2023

Date	Time	Event
Wed Dec 06	10:30 pm — 11:15 pm	Essential Design Questions to Address
Thu Dec 07	2:00 pm — 3:15 pm	Primary Audience + Stakeholders
Sat Dec 09	12:00 pm — 2:00 pm	Roles & Decisions (Integration Design) + Chat GPT Conversations
Mon Dec 11	7:00 am — 8:00 am	Creating Personas
	6:45 pm — 7:15 pm	Level 3 Component Diagram
	7:30 pm — 8:00 pm	Finishing Personas
	8:30 pm — 11:30 pm	Wireframe and Mockups
	9:20 pm — 10:20 pm	Architecture Design
	11:00 pm — 11:59 pm	Architecture Design - Component Diagram
Tue Dec 12	12:00 am — 12:30 am	Architecture Design - Component Diagram (cont)
	1:00 am — 1:45 am	Component Diagram
	2:00 am — 2:45 am	Revising Overall Project

Figure 4.4: List view of working sessions of the team with least number of artifacts

As a final example, Figure 4.5 compares the WORKING FREQUENCY cards for the team that spent the most hours in working sessions (65.5, left) and the team that spent the least in working sessions (g, 5.5, right). Note that the scales for both teams differ, both in the X-axis (dates that they worked) and the Y-axis (hours worked). While it is tempting to immediately conclude the team with the most hours might have performed better, a majority of their hours were spent working alone whereas all hours in the other team were spent together with the entire team (which the other cards clearly show on the dashboard), so the concern is somewhat ameliorated. That said, regularly spreading out work is important for design projects to create time to reflect, iterate, and refine. The team on the left clearly had more opportunities to do so than the team on the right. Using this card would allow the instructor to intervene with the team on the right to nudge them into getting together more frequently

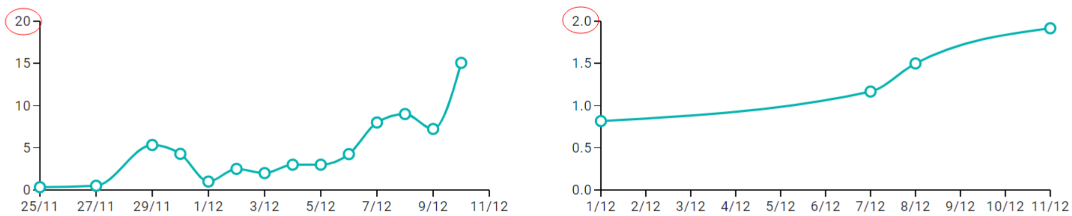

Figure 4.5: Working frequency comparison between group with maximum hours and group with minimum hours worked

and sequence their work appropriately.

4.4 Survey

At the end of the course I conducted a preliminary optional survey to understand how students felt about using TeamCAST. I only received a very small number of responses, likely because the survey was optional, landed during finals week, and was due right before the Winter break. Nonetheless, I received some useful feedback upon which I report here.

4.4.1 Overhead

I was especially interested in how students felt about the extra work of having to upload intermediary artifacts. Students largely did not object (e.g., *"Was not much of the work"* and *"No pressure, it was just copy paste"*, though a couple of students termed uploading to TeamCAST as *"Tedious"*). Eight students uploaded their work to TeamCAST generally right after the work session, while three chose to upload a short while later.

Overall, students felt positive about their experience. One student points out *"It was very easy to demonstrate who did what"* and another shared that *"...graders would be able to see our design process more clearly"*. Also, submitting intermediate artifacts helped as *"It also decluttered the final document, because progress work is able to be stored and viewed by the* *graders separately."*

4.4.2 Effect on the design process

I asked students to reflect on the impact that TeamCAST had on their process, especially in the context of the prior design studios that were without TeamCAST.

Nine students felt that TeamCAST helped them follow a more organized design process, sharing, for instance, that *"[TeamCAST] made us think more incrementally about creating artifacts in design process"*, *"It pushes the progression"*, *"[It] made our group space out our work across the full design studio"*, and *"[It] made us think more about the order we do things in."* TeamCAST motivated some students to reflect on their design process. One student commented, *"It helped track our progress I guess allowed us to look back at previous artifacts."* TeamCAST also encouraged students to space out their work as opposed to doing their work at the last minute. One of the responses mentioned that *"TeamCAST made our group space out our work across the full design studio."*

Students had mixed responses on whether it increased the quality of their work. Out of the 11 student, five believed using TeamCAST led to a better design outcome, while three said it had no effect on the outcome, and three believed it probably did not have any effect on the outcome. Students who gave a negative response viewed TeamCAST as *"more of people submitting artifacts whenever it is completed"*, rather than as a tool that helps them track their progress.

4.4.3 Accountability

Despite some of the examples of poor behavior I shared earlier, students felt that using TeamCAST improved accountability and encouraged them to complete their work on time.

Students understood that using TeamCAST instructors would be able to see their process, so they felt that *"People were more aware of them having to do something to prove that they weren't slacking off."* One student mentions that *"It gave me more confidence that my group members were contributing to the project meaningfully."* Another student mentioned *"When looking through the artifacts, you can identify who put in the work and who didn't"*, with another one mentioning that TeamCAST impacted them positively by allowing them to *"identify and reach out to a member falling behind and help them out".* Eight out of 11 students felt that TeamCAST helped them gain insight into their team members' contributions as compared to previous design studios. They mentioned *"we could visually see when things were completed and how to space out work"* and *"we were able to see who did what and the updates."* Nine out of 11 students felt that TeamCAST represents their work fairly, which indicates that students perceived TeamCAST as a trustworthy tool to faithfully capture their efforts.

4.4.4 Suggestions for improvements

Students were also asked their likes and dislikes about TeamCAST as well as suggestions for improvements. The user interface and the layout of the dashboard received positive responses from the students. One student mentioned, *"I loved the layout, it looked very nice and easy to use. It made me feel more accomplished seeing everything that I had done when it was uploaded on TeamCast".* Students also liked the ability to represent contributions visually using different colors.

Students disliked the strict rules for editing sessions and uploading files. TeamCAST is designed such that, once students record sessions, they cannot edit them, which can lead to some extra work if they make any mistakes. For instance, a student mentioned that *"Sometimes I titled things wrong or forgot to add a contributor and I would have to start* *over."* Students also disliked that TeamCAST does not allow multiple students to upload files to a session. One student commented that *"I disliked the fact that only the person who created the session could upload files."* Although this is an intentional design decision to prevent unauthorized changes from other team members, students would like a more flexible approach that allows all team members to upload files to a session.

Suggestions for improvements also touched upon the need for flexibility. For instance, one student commented that *"I think that if the person who creates the session states who participated in the session, those people should also be able to upload files that they may have on their own device."* Other suggestions had ideas for new features such as *"An all-in-one 'upload work for today' button that will automatically route to files"* and *"I wish I was able to see the artifact that was published on TeamCast than a simple title. It would allow me to see the state and may even revert back to it if needed."*

4.4.5 Recommend

Overall, when asked whether they would recommend TeamCAST for other group projects, five students responded they would highly recommend it, one would recommend it, three were neutral, and only one recommended against. I take this as a positive for future development of TeamCAST, particularly because I believe we can further reduce the burden on the students (see next section).

4.5 Discussion

Through the pilot study and the survey, I was able to collect contribution data of 179 students and a survey about the experience of 11 students using TeamCAST. I analyzed their contribution data using the instructor dashboard and I was able to identify notable team behaviours. By using TeamCAST, it is possible to detect these common patterns that often transpire in such team-based projects.

The preliminary evaluation provides initial indication that, in its current form, TeamCAST can function as a tool to track student progress and contributions. It informs instructors of their working process and allows students to reflect on it as well. By using the instructor dashboard, I was able to identify common issues that are present in these teams.

I highlighted four examples throughout the preliminary evaluation in section 4.3. The first two examples depicted flawed social dynamics. The first example is an example of social loafing and the second one represents lack of team collaboration. Both these behaviours negatively affect the learning outcomes of group based courses. It is possible that instructors would not be aware of such avoidable scenarios unless students explicitly report it, which is rare as students are hesitant to do so. It is also possible that students are not aware that these practices are not ideal.

The next two examples provide a lens into how student teams can adopt different working styles to accomplish the same task. These examples highlighted some good practices adopted by students such as reiterating their design artifacts frequently and producing high quality artifacts as well as some negative team processes such as last minute work and subpar design practices. In such cases, instructors can nudge students in the right direction if they are going off tracks. This has the potential to positively affect students to collaborate more and follow the right practices in the design process which is an important part of their learning experience.

The identification of these examples implies that issues of process and contribution exist and can remain undetected (since the analysis was performed after the course completed). These issues will remain undetected unless we as researchers put effort into solving them by, for instance, designing and using tools like TeamCAST. To comprehensively assess the process we need to evaluate not only the final deliverable but also the intermediate artifacts. Instructors also need to address contribution issues to ensure students learn good teamwork practices.

The survey responses revealed the experiences of 11 students using TeamCAST. Overall, although a low number of students responded, their experience was largely positive. There were two main aspects of students' feelings towards TeamCAST. One was the effort of uploading to TeamCAST, which they felt was not excessive. Another was their feeling about representing their work to instructors through TeamCAST. Of those who responded, students largely felt that their efforts were fairly portrayed by TeamCAST. These responses were in line with my expectations. The effect of TeamCAST on the way students collaborate and how they feel about their own work is not conclusive from the responses. I received some positive responses about effect on accountability and improvements in the process but more responses are required to infer decisive benefits. Students also recommended for TeamCAST to be used again in the future which is a positive sign.

From the students' perspective, TeamCAST in its current form is mainly a tool to record their work and although some students do benefit in terms of self-reflection and accountability, the student interface needs additional features to fully function as a tool to aid student learning (see chapter 5).

Overall, through this pilot study I have shown feasibility of using TeamCAST in such group based courses and collected preliminary data that I presented from various perspectives to highlight the potential of TeamCAST to be used in a larger study.

Chapter 5

Future Work

Future work will consist of four directions of research. First, I intend to develop tool bridges to make it easier for students to submit intermediate work. I want to make the process of uploading work to TeamCAST even more easier for students. Even though, in its current state, uploading to TeamCAST is not considered a burden by the students, I understand that this process can be automated. I, for instance, envision plug-ins for Google Docs and Figma that would automatically populate some of the needed information and especially upload the artifact automatically.

Second, I intend to further refine the instructor interface. More information can be displayed, ranging from simple minimum and maximum values to entirely different cards that, for instance, better illustrate iteration over artifacts. For example, I plan to add a feature that will allow instructors to filter the session timeline for each student and display their work one at a time. This will help instructors to view the contributions of individual students to the project. By looking at the student's individual timeline, instructors would be able to identify if they are actually contributing to the project of if they are, for instance, merely showing up in group meetings without putting in individual effort. It is also possible to show greater details to the instructors about the work of the team through more cards such as the ratio of individual to group session and the working frequency of each individual.

Third, I intend to explore developing instructional units that focus on explicit reflection with students over emerging dashboards, so students can learn from discussion about different approaches why certain approaches may be beneficial. With multiple future deployments, a rich basis of past experiences will exist that can be shared and collectively analyzed.

Finally, I plan to leverage data collected using TeamCAST to begin to understand the correlations between processes followed, participation patterns, and eventual project and course grades. With future deployments, I will be able to collect a large dataset that can reveal generalized insights about student behaviour in group-based projects. Such data could potentially be used to identify shortcomings in the student collaboration process. I also want to link the data collected from TeamCAST with peer evaluation data as it has potential to reveal correlations between student contributions and the perception of their teammates towards those contributions.

Chapter 6

Conclusion

In this thesis, I have presented TeamCAST, a novel tool that I developed to monitor student team progress and track student contributions. I introduced the design and implementation of TeamCAST, while highlighting its potential utility to instructors through a preliminary deployment in a course at my institution. At the relatively small cost of students having to submit intermediary artifacts, which was somewhat ameliorated by awarding them some credit for the assignment, students are pressed into more proactively organizing how they want to pursue the project and instructors are provided with the tools necessary to spot potentially problematic teams. Although both TeamCAST and the evaluation are highly preliminary, I believe the approach of collecting intermediary artifacts shows promise and is worthy of further exploration.

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