A Software Engineering Capstone Infrastructure that Encourages Spreading Work Over Time and Team

***Abstract*—How can instructors facilitate spreading out the work in a software engineering or computer science capstone course across time and between team members? Currently teams often compromise the quality of their learning experience by frantically working before each deliverable. Some team members further compromise their own learning, and that of their colleagues, by not contributing their fair share to the team effort. To mitigate these problems, we propose using a GitHub template that contains all the initial infrastructure a team needs, including the folder structure, text-based template documents and template issues. In addition, we propose each team begins the year by identifying specific quantifiable individual productivity metrics for monitoring, such as the count of meetings attended, issues closed and number of commits. Initial data suggests that these steps have an impact. In 2022/23 we observed 50% of commits happening within 3 days of due dates. After partially introducing the above ideas in 2023/24, this number improved to 37%. To measure the fairness we introduce a fairness measure based on the disparity between number of commits between all pairs of teammates. Going forward we propose an experiment where commit data and interview data is compared between teams that use the proposed interventions and those that do not.**

***Index Terms*—software engineering; capstone; template repository; productivity measures; fairness metric**

I. Introduction

The workload for a software engineering or computer science capstone team project is often unevenly distributed over time and between team members. Teams typically work in frantic bursts of activity right before a deadline and then cease almost all activity until their next deadline. These work habits compromise the learning objectives of the course because the students do not have time to properly plan their activities or reflect on their work. The uneven distribution of effort between team mates is also problematic. Some students take on an unfair share of the work, causing them stress and possibly hurting their experience in other courses, while those investing less effort miss important learning opportunities. How can instructors mitigate these problems?

To address the uneven distribution of work, we need to first think about why the problems exist. A student project is not the same environment as the workplace. Students are often learning the content just before applying their knowledge. Since they are doing a capstone project for the first time, students might struggle with determining the expectations; they might not know where to start. In industry team members usually have full-time dedication to a project, unlike the academic environment where students are juggling many courses [1]. Moreover, team members cannot be fired or moved to another project for poor performance. Peer pressure and the prospect of uncomfortable social interactions can make it challenging for someone to take charge of their group, or to criticize other group members.

For saving the student's time and clearly showing expectations, we suggest requiring all capstone teams to start from the same GitHub template repository. The template repository is populated with folders, text-based template documents and template issues. Citations on this topic. Too much freedom in decision making can be paralyzing for a new team. They don't know where to begin. By making the infrastructure decisions for them, they can focus on their project.

An even workload between teammates can be improved by becoming aware of potential problems as early as possible. Decide before things get ugly. Citations.

In Section II we describe the baseline structure of the capstone course. We propose two interventions to the baseline: 1) using a template repository; and, 2) explicit quantifiable team contribution measurement. We follow this with some encouraging preliminary data from when we partially introduced the two interventions into the course (Section III). We then describe our proposed approach for collecting more detailed data to judge the effectiveness of the proposed interventions (Section IV). The presentation of the proposed experiment includes discussion of threats to validity.

II. Baseline and Proposed Infrastructure

The infrastructure described here matches the final year SE capstone course at [Redacted]. The course follows the ACM guidelines of spanning a full year, being a group project, has an implementation as its end deliverable, has a customer for each project and includes student reflection [2]. This course is currently delivered to 150 students divided into 29 groups of 4–5 members (the typical size for capstone courses [3]). Teams are provided with a list of curated software development projects from academia and industry. Teams can also propose their own projects. Most projects have a supervisor/client that the team can meet with to discuss their project. In cases where there is no supervisor, the team still needs to explicitly identify the stakeholders for the project.

A. Structure and Timeline

Figure 1 show the V-model [4] structure of the capstone course. The documents created include the Software Re-

quirements Specification (SRS) and various Verification and Validation (VnV) plans and reports. Due to time constraints not all artifacts of the V-model are produced. Those that are created are circled with red ellipses, along with an annotation showing the week number where the artifact is due for a full year (26 week) course. The week is when the Revision 0 draft of the document is due. Almost all documents also have a second revision (Rev1 Doc) that is due at the end of the course (Week 26). The iteration allows students to take the formative assessment for Rev 0 to produce a higher quality document for their summative review. An iterative process for software capstone course is recommended by VanHanen and Lehtinen [5] to improve the learning outcomes.

In recognition of the value for teams of "getting their hands dirty", a Proof of Concept (POC) Demo is scheduled for week 10. During this demo the teams demonstrate the aspect of their project that is of most concern for feasibility of the project, providing an opportunity to revise the project scope if necessary. The Rev0 demo is expected to show off the final and complete product. The teams rarely achieve this, but the push for Rev0, together with the feedback they received, allows them to improve their software for the final demo (Rev 1 demo). The structure of the course is stable, having been offered in this form for four years. The interventions described in the next sections are in the context of this structure.

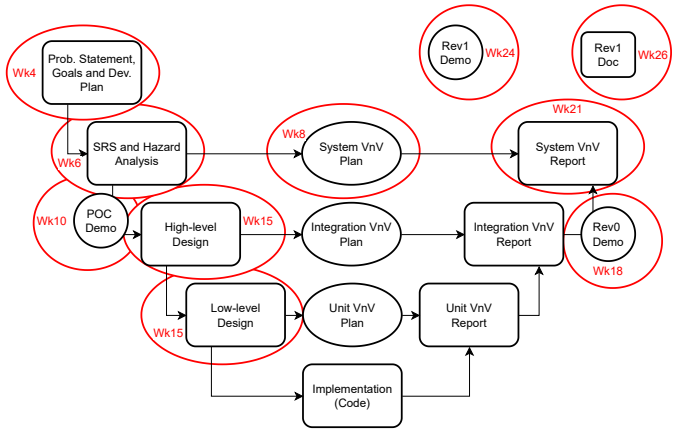

Fig. 1: V Model Used for Capstone Deliverables

assistants and instructor. When students have a clear idea of the expectations, they should find it easier to dive into their project.

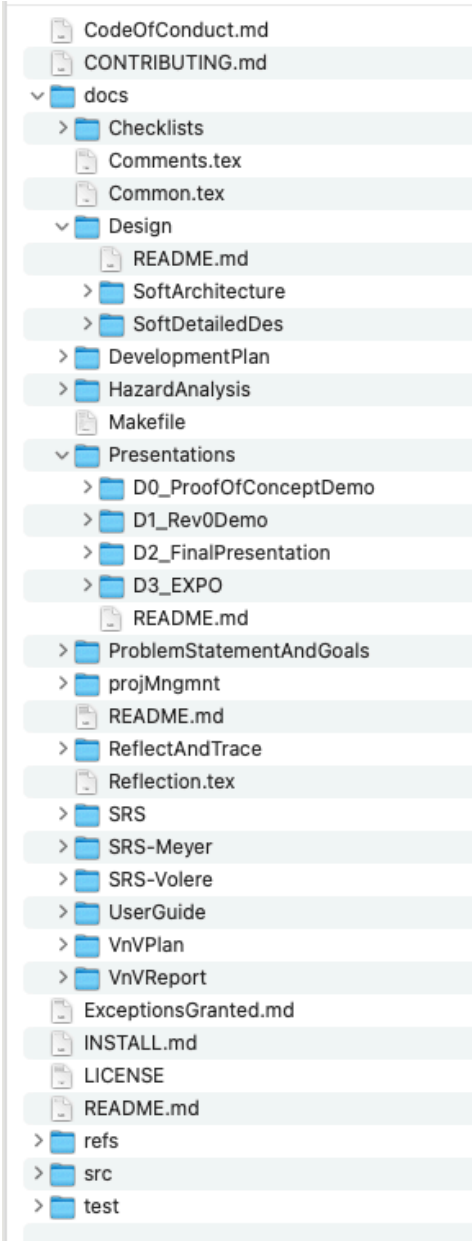

Fig. 2: GitHub Capstone Template

B. Template Repository

All teams start their project by using the same GitHub template repository. The template repo, summarized in Figure 2, contains all the initial infrastructure each team needs, including the folder structure, text-based template documents and template issues. The goals of the template are to remove the time team's spend building their project's infrastructure, and to standardize all the arbitrary decisions, like folder and document names, between all the teams. The standardization helps teams when doing peer reviews of each other's work and it improves communication between the teams, teaching

The template documents are written in LaTeX, although teams are allowed to redo the template in another text-based format, like markdown, if they wish. Besides the advantage of separating document appearance from document content, the text-based format facilitates tracking the productivity of the team members through git commits, as discussed in Section II-C. The documents correspond to the deliverables in Figure 1. The students can use any standard SRS template, including selecting one of the three options given: SRS (a template for scientific computing software [6]), SRS-Meyer (a

template by Bertrand Meyer [**?**]) and SRS-Voler (the Volere template [7]).

For further standardization, the template repo includes four issue templates for: 1) team meeting agendas; 2) TA-team meeting agendas; 3) supervisor-team meeting agendas; and, 4) lecture attendance. In addition to encouraging good organizational habits, the issues are also used to partly measure the commitment of students to their teams, as discussed in the next section.

C. Team Contribution Measurement

To improve the distribution of the workload to all team members, we can take advantage of the quantifiable productivity measures available from git and GitHub. The value of a metrics-based software engineering process is emphasized by Conn [1], although they do not list the recommended metrics. In the current work the suggested metrics for each team member are counting team meeting attendance and using GitHub insights to count the commits to the main branch. Each team produces a summary table as part of their performance report before the three demonstrations: POC demo, Rev0 demo and Rev1 demo (see Figure 1 for the timing). In the performance report the team can also record reasons for a team member to appear to perform poorly on any of the metrics. The hope for explicitly capturing these numbers will reveal any problems with team collaboration. Ideally the problems will be revealed early and improved, but if the problem cannot be dealt with, at least there will be enough data to assign a fair individual grade to all team members.

- co-author commits

Measures used by team. Team charter. - also survey

III. Preliminary Data

Look at commits over time, and possibly lines (removing outliers) of code over time

A. Timeline Comparison

Timeline comparison

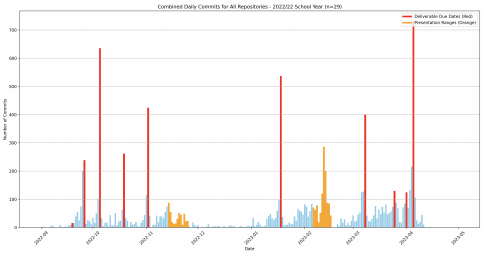

Fig. 3: Timeline of Commits for 2022–2023

B. Measuring Fairness

In order to measure the fairness of work distribution among teammates, we sought to compute a metric where values range from 0 to 1, and where values in between contain meaningful information. Thus, we devised the following *unfairness* metric where C:

$$\text{unfairness}(C) = \frac{\sum\limits_{c,x \in C, c>x} (c - x)}{(|C| - 1) \cdot \sum\limits_{c \in C} c}$$

where C is the multiset of teammates' numbers of commits to the repository.

The metric computes the sum of the difference between each teammate's commits and those who committed less than them, normalized by the number of teammates (excluding themselves) and the total number of commits. This yields a value from 0 to 1, called the *unfairness* metric, where:

- 0 indicates that teammates did an equal amount of work
- 1 indicates that all the work was done by one teammate
- A value between 0 and 1 indicates the proportion of work per person which could have been given to someone who did less work

Fairness is defined as $\text{fairness}(C) = 1 - \text{unfairness}(C)$.

For example, if a team with Persons A, B, and C did 10, 5 and 5 commits respectively, then $\text{unfairness}(\{10, 5, 5\}) = 0.25$. This is because on average Person A did 5 more commits than their teammates and thus these 5 commits (out of 20) are considered *unfair work*. The fairness value is thus 0.75.

Figs. 5 and 6 show the fairness values for teams in 2022/23 and 2023/24 respectively.

In the future, we will experiment with applying this metric to things other than commits (e.g. lines of code written, issues created/closed, etc.), as well as investigating a correlation between lower fairness values and perceived unfairness according to the teammates themselves. Another research question would be if having live access to this fairness metric encourages teams to share work more evenly or simply encourages them to "game the system" to increase the value.

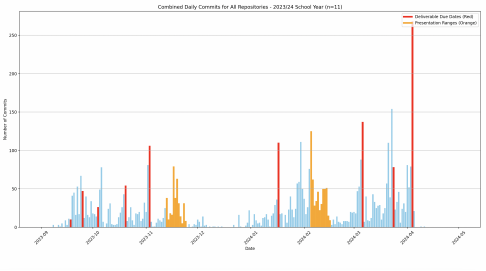

Fig. 4: Timeline of Commits for 2023–2024

IV. Proposed Experiment

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A. Experiment

Start with research questions.

Collect the same data as in Section III and conduct focus groups in all three CAS capstone courses (SE, CS and TRON).

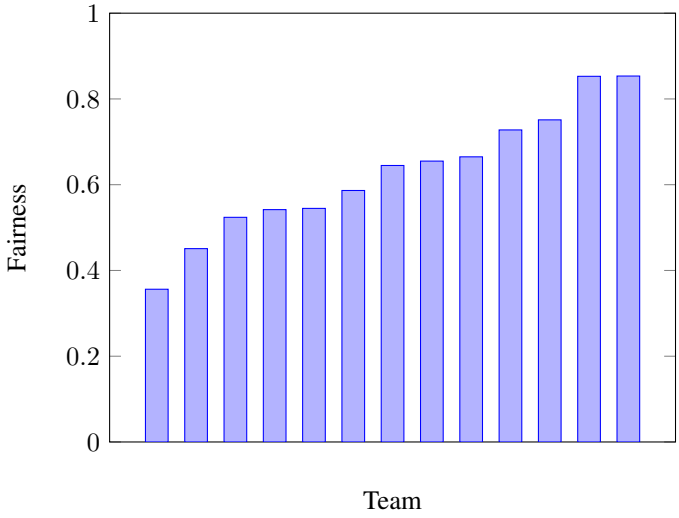

Fig. 5: Fairness of Commits Per Team 2022/23 [n=13] (Mean: 0.63, Stddev: 0.15)

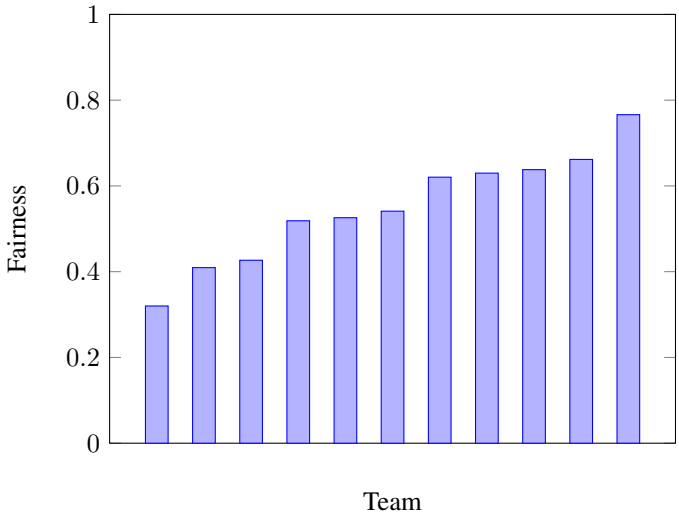

Fig. 6: Fairness of Commits Per Team 2023/24 [n=11] (Mean: 0.55, Stddev: 0.13)

B. Threats to validity

- Multiple changes are made to the course, so it is difficult to determine which change influences the student behaviour. The focus group should hopefully tease that out.
- Comparing different courses with different instructors, different backgrounds for students, etc.
- Not a controlled experiment - introducing more than one change into the course. The changes are related because the productivity metrics would not be possible without a version control system.
- The interventions proposed here might behave differently for a capstone course that follows a different structure (Section II-A).

V. Concluding Remarks

The template presented here is for the capstone course under discussion; the template could be forked and modified to match the needs of a different capstone course.

Acknowledgements

If any.

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