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Implementing a Tool for Structured Roles in Hybrid Collaborative Learning Environments

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Implementing a Tool for Structured Roles in Hybrid Collaborative Learning Environments

Abstract

Collaboration in group-based learning often suffers from inequitable effort distribution and role stereotyping. To address these challenges, we developed a structured role enforcement tool within PrairieLearn, an open-source learning platform. This tool allows instructors to assign roles with specific permissions, facilitating the equitable distribution and management of tasks. In its initial deployment, the tool was implemented in a computer science course with both in-person and online sections. Analysis of collaboration metrics – such as role adherence, role rotation, and team consistency – revealed positive outcomes across both formats. These findings demonstrate the tool's potential to foster effective and equitable collaboration in diverse learning environments. Future work will examine its impact on students' sense of belonging and collaborative learning outcomes.

1 Introduction

Collaborative learning has been shown to improve students' sense of belonging [1], learning outcomes [2], and retention by increasing engagement and working memory resources [3]. However, the benefits of collaboration can diminish when effort distribution is inequitable or when team members are stereotyped into specific roles (e.g., women expected to take notes). Structured roles –predefined responsibilities assigned to team members – can mitigate these issues by providing clear expectations and fostering equitable participation [4, 5, 6, 7]. Structured roles are commonly used in collaborative learning in computer science through pedagogies like pair programming [8] or Process Oriented Guided Inquiry Learning (POGIL) [9, 10].

Despite their benefits, structured roles have been underutilized in computer-supported collaborative learning (CSCL) environments, as most platforms lack the ability to enforce these roles [11]. CSCL focuses on using digital tools to enhance collaboration, offering features like automated feedback and group awareness tools [12]. While some instructors have encouraged the use of structured roles in CSCL, these roles are rarely enforced systematically, leaving students free to deviate from their assigned responsibilities [7].

To address this gap, we developed and deployed a tool to enforce structured roles within PrairieLearn, an open-source learning platform [13]. This paper presents an experience report on the first implementation of the tool in a junior-level computer science course offered in both online and in-person formats. Our primary goal was to assess how the tool performed in fostering

collaboration across both sections.

In the remainder of this paper, we provide a detailed description of the structured role enforcement tool, including its design, functionality, and integration into the PrairieLearn platform. We then describe its first implementation in a computer science course, highlighting the hybrid course format with both online and in-person sections. Next, we examine key collaboration metrics: adherence to assigned roles, frequency of role rotation, and team consistency, comparing these outcomes between the two sections. By analyzing these metrics, we aim to assess whether the tool supports positive collaborative practices across different learning environments and holds potential for fostering effective teamwork in both online and in-person settings.

2 Overview of the structured role tool

The design of our tool was inspired by pair programming and POGIL, both of which divide learning tasks among specific roles. In pair programming, the Driver types the code while the Navigator reads the instructions and provides feedback to the Driver. POGIL typically assumes groups larger than two and incorporates a variety of roles. For our tool, we focused on three roles that could most be directly implemented in code: the Recorder, responsible for typing in answers; the Manager, tasked with keeping the group on track; and the Reflector, who guides the group in reflecting on their learning and process. Both approaches share the goals of 1) preventing the student who is typing from dominating the collaboration, and 2) discouraging students from dividing the work and recording answers separately.

We translated these goals into the implementation of the role enforcement tool within the open-source code of PrairieLearn. The tool enables instructors to define roles and specify permission levels for each role. The names, number of roles, and their associated permissions are fully customizable, allowing instructors to tailor the tool to their specific needs. In its initial implementation, the tool included three key permissions: View, Submit, and Assign. The View permission allows students to access and read questions, the Submit permission enables them to input answers and submit them to the PrairieLearn autograder, and the Assign permission grants a team member the ability to assign or edit roles within the group. This functionality ensures that students' actions align with their designated roles, fostering structured collaboration during group activities.

Figure 1 illustrates an example in which the instructor defined the roles of Recorder, Manager, and Reflector. A more detailed description of these roles, along with their associated permissions within the system, is provided in the next section.

3 Course Context

In the Spring 2024 semester, we deployed the structured roles tool in an upper-division required computer science course at the University of Illinois Urbana-Champaign. Students could choose between an online or in-person section, both taught by the same instructor, offered at the same time, using identical materials.

The course followed a flipped format, requiring students to complete weekly pre-lecture

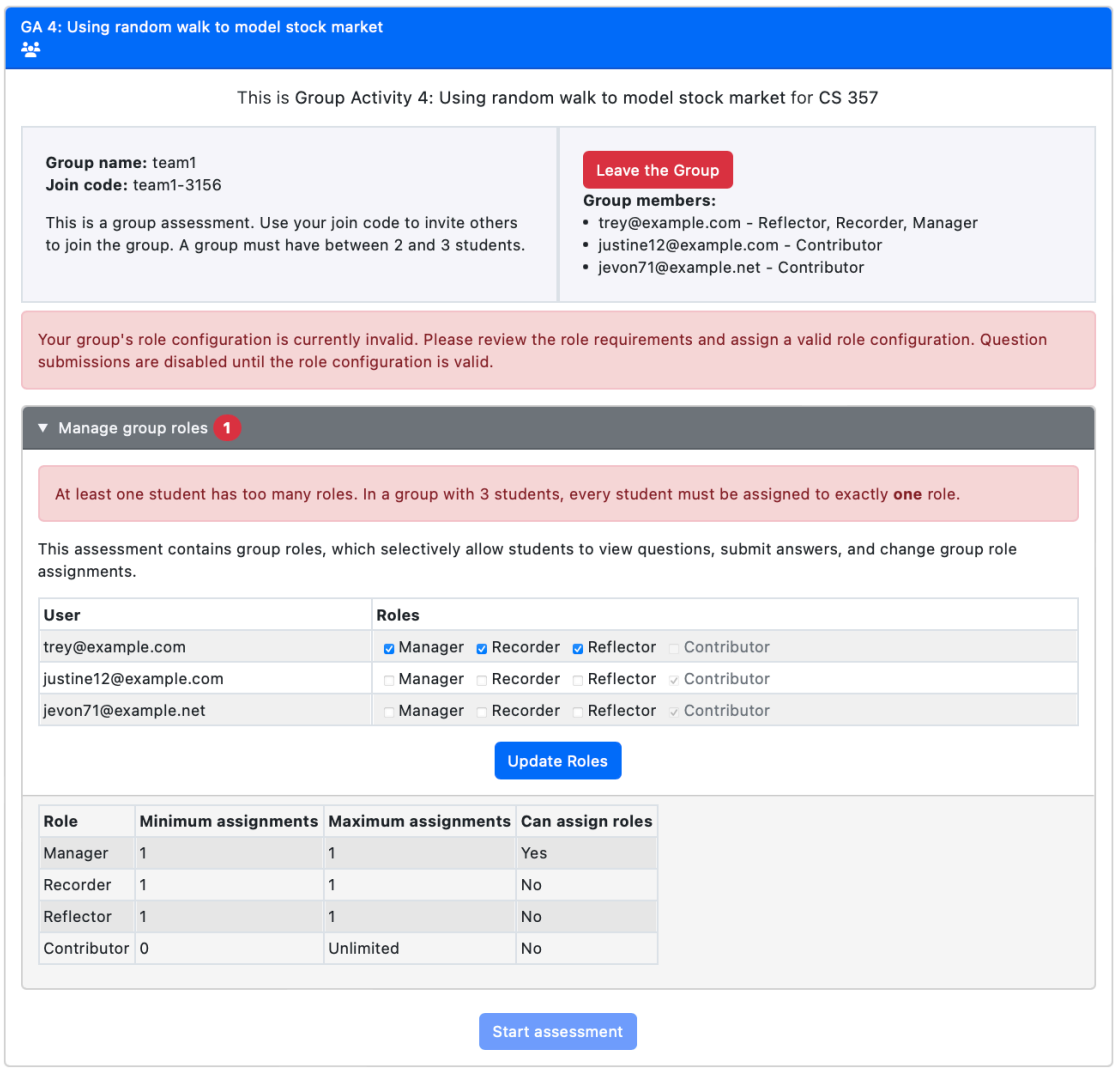

Figure 1: Assessment overview page for the Manager, who has the ability to assign roles to team members. The assessment becomes available once all roles are assigned.

assignments and corresponding homework sets. The primary difference between the sections was how students completed the "in-class" activities. In the in-person section, students were required to attend class during lecture time to work in teams on computer-based activities. In the online section, students could complete the same activities asynchronously (but on same day as the in-person students), still in groups, with no attendance requirement.

During lecture time, students in the in-person section received support from course staff (a combination of the instructor, graduate teaching assistants, and undergraduate course assistants) circulating in the classroom, while students in the online section could join a Zoom meeting during lecture hours, with breakout rooms available for team collaboration and staff assistance. In both sections the the student-to-staff ratio was 20:1.

Students were allowed to switch sections during the first two weeks of the semester to choose the format that best suited their learning style or personal preferences. Of the 402 students enrolled in

the course, 187 registered for the in-person section, and 215 registered for the online section.

The “in-class” assignments consisted of group activities (GAs) delivered through the PrairieLearn platform. Students worked in teams of 2–3 to complete the GAs, receiving instant feedback on the correctness of their answers from PrairieLearn autograders, along with support from course staff. During the first two weeks of the semester, students were encouraged to work with random peers to explore potential group dynamics. After this period, students could either choose their own groups or be pseudo-randomly assigned based on group formation practices informed by prior research [1].

For this course, the instructor defined three structured roles – Manager, Recorder, and Reflector – with specific permissions configured in the PrairieLearn system:

The **Manager** coordinated the team’s efforts, ensuring progress and organization. This role was automatically assigned to the first group member who opened the GA, granting them the Assign permission, which allowed them to assign roles to other team members.

The **Recorder** was responsible for documenting the team’s work, primarily entering answers into PrairieLearn. They were the only team member with Submit permissions for coding questions, though all group members could build the solution code collaboratively.

The **Reflector** ensured all team members were engaged and on track. At the end of each activity, they completed a survey reflecting on the group’s interactions and how the activity supported learning. The Reflector was the only team member with View and Submit permissions for the reflection survey, which were not accessible to the Manager or Recorder.

Figure 1 illustrates the assessment overview page for the Manager. The assessment could not begin until all roles were assigned to team members, as indicated by the disabled “Start Assessment” button. If the group size was smaller than the number of required roles, individual members could take on multiple roles. The system performed all necessary validations to ensure prerequisites were met before allowing the team to start the assessment.

The GAs primarily involved solving real-world coding problems that applied concepts covered in the previous week’s pre-recorded videos. These activities were delivered via Jupyter notebooks with real-time synchronization. Figure 2 shows the assessment overview page, which includes four questions. The first three questions progressively increase in difficulty and rely on the understanding of the preceding solution. This scaffolding approach is characteristic of POGIL activities. To unlock the second question, students must achieve completeness on the first question, defined here as a score of 100%. This locking mechanism prevents students from dividing tasks in a “divide-and-conquer” manner and instead encourages genuine collaboration. The locking feature can be enabled or disabled at the instructor’s discretion.

In this assessment, the instructor granted "Edit" permissions for the first three questions exclusively to the Recorder, while all other team members have "View" permissions. This setup allows students to collaborate on discussing and constructing solutions for each question, but only the Recorder can submit the answers to the auto-grader (Figure 3). For the final question (the activity debrief), the instructor assigned both "View" and "Edit" permissions solely to the Reflector (Figure 2).

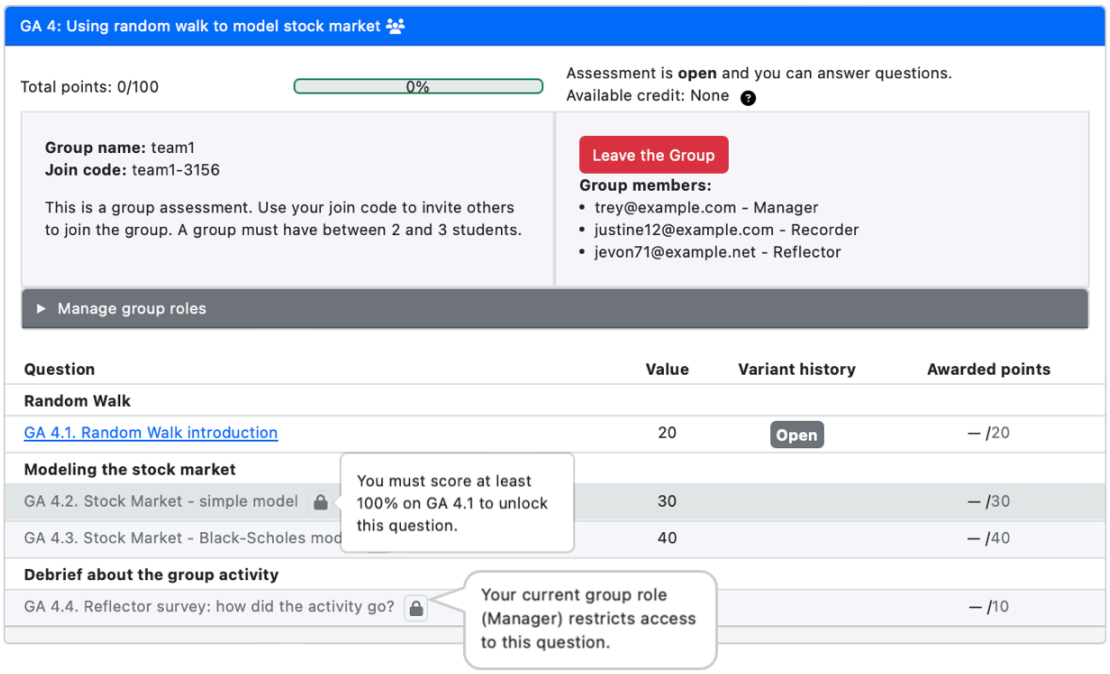

Figure 2: Assessment page showing how questions (parts of the assessment) are locked until completion of preceding questions. Additionally, it highlights that the debrief question is restricted and can only be viewed and edited by the Reflector.

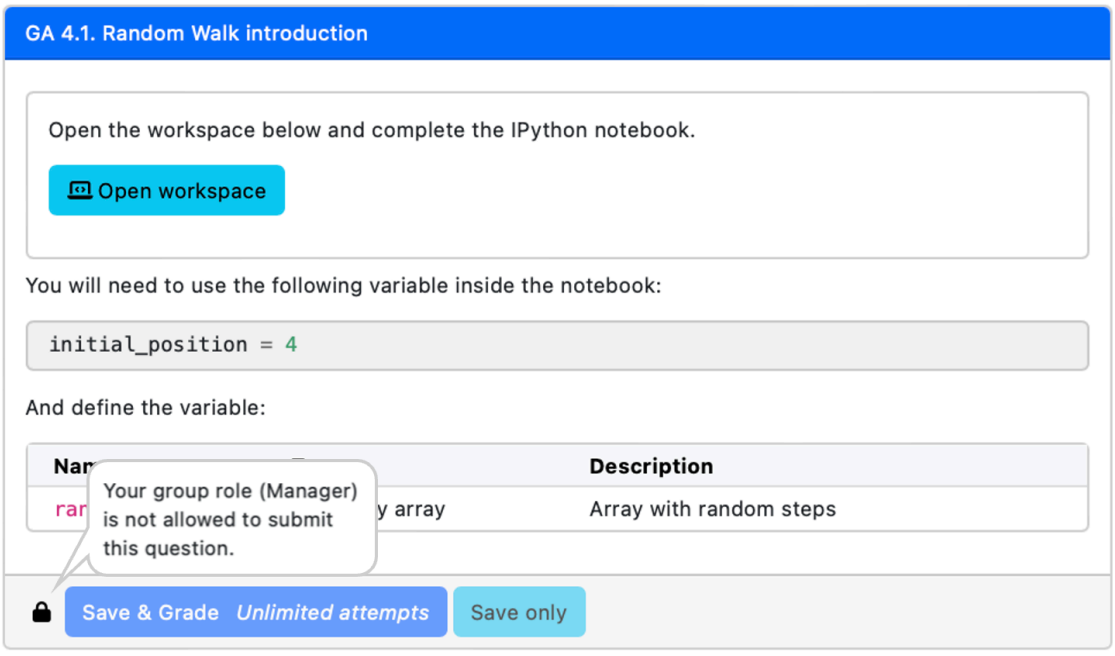

Figure 3: Example of a question in which the Manager has "View" permissions, but not "Edit". The Recorder is the one with both "View" and "Edit" permissions.

4 Collaboration metrics

In the following, we define a set of collaboration metrics based on log data from the PrairieLearn platform, such as role adherence, role rotation, and team consistency.

4.1 Group Role Adherence

At the start of each GA, students self-assigned their roles, which were then recorded in the PrairieLearn platform by the team Manager. While students were encouraged to maintain the same role throughout the activity, the Manager had the ability to reassign roles at any time. This flexibility is necessary to accommodate unexpected situations, such as a student arriving late or leaving early. However, this limitation in role consistency also introduced the potential for misuse, as students could exploit the system by allowing one member to complete tasks intended for another role.

To measure whether students adhered to their self-assigned roles, we analyzed the action logs recorded by PrairieLearn during each group activity (GA). These logs provide detailed information on the assessment pages each student viewed, the submissions they made, and any updates to the structured roles.

For each student in each GA, we defined their assigned role as the final role logged in the system for that activity. We then reviewed the student's log to identify any actions that did not align with their assigned role. For instance, if a student was assigned the role of Reflector but submitted answers to a coding question, it indicated that the student had previously held the Recorder role before switching to Reflector. Such cases were categorized as instances of non-adherence to their assigned role for that GA.

To quantify adherence, we assigned a score of 1 for a GA if a student adhered to their role throughout the activity and a score of 0 if they did not. These scores were then averaged across all group activities to calculate an overall role adherence score for each student. Finally, we averaged the individual adherence scores of all students within a group to determine the group's role adherence score.

4.2 Group Role Rotation

To measure how evenly the roles were rotated among group members, we again defined their assigned role as the last role logged in the system for that GA. We then summed up the role counts across all GAs to determine the number of times each student was assigned to each role. This data was stored for each student in an array x with three entries, each entry representing the number of times the student was assigned to each role. Each entry could range from 0 to 12, and their sum would be equal to 12, as there were 12 GAs during the semester. For example, $x = [2, 4, 6]$ indicates that a student participated 2 times as a Manager, 4 times as a Recorder, and 6 times as a Reflector. To normalize the count array, we divided each entry by 6 for students in a group of 2, or by 4 for students in a group of 3. We denote the normalized array as $\hat{x}$. For the example above, if the student was in a group of 3 students, the normalized array would be $\hat{x} = [0.5, 1, 1.5]$.

An even work distribution would be the vector $1 = \begin{bmatrix}1.0 & 1.0 & 1.0\end{bmatrix}$. After normalizing and taking

the complement to associate a higher score with a more even distribution of work, we defined the role rotation score for each student as

$$\text{score} = 1 - \frac{\|\hat{x} - 1\|_2^2}{12}. \tag{1}$$

We averaged the role rotation score for each student within a group to obtain the group role rotation score.

4.3 Team consistency

All students were expected to complete the GAs with their preassigned groups, but these assigned groups were not enforced in the PrairieLearn platform. Therefore, students could still complete GAs with a different group rather than the assigned one.

Students in the online section received a small credit towards their final grade (up to 0.75%) for completing the GA with their assigned group. This incentive was not given to students in the in-person section.

For each student in each GA, we defined that a student worked with their preassigned group if at least 50% of the preassigned group completed the GA together. To compute the student team consistency score for a GA, we assigned a value of 1 if they completed the GA with their assigned group, and 0 otherwise. We took the average of these scores across all group activities to get the team consistency score for each student. Finally, we averaged the individual team consistency scores for all students in a group to obtain the team consistency score.

5 Our first observations in a real classroom setting

5.1 Collaboration metrics

The instructor encouraged all students to work with the same team throughout the course and to rotate equally among the different roles within their teams. To further incentivize participation, students in the online section were awarded small amounts of credit toward their final grade: up to 0.75% for participating in each role at least twice and another 0.75% for completing the GAs with their pre-assigned group. In contrast, this requirement was not applied to the in-person section. Instead, students in the in-person section earned the same 1.5% credit through class attendance.

The rationale behind this difference was that in-person students, by being required to attend class and complete the GAs synchronously, were naturally more likely to work with their assigned teams and rotate roles. Fig. 4 illustrates the distribution of all collaborative metrics for both the online and in-person sections.

The mean group **role adherence** score for the in-person section was 0.818, while the mean score for the online section was 0.778. This difference was statistically significant ($p = 0.022$). Groups may achieve lower role adherence scores when a student arrives late or leaves early, requiring role adjustments mid-activity. We hypothesize that such disruptions are more likely in asynchronous settings, like the online section, compared to the synchronous format of the in-person section,

which may explain the slightly lower scores for the online section. Nonetheless, nearly 80% of students in the online section adhered to their assigned roles, indicating strong alignment with structured collaboration practices across both settings.

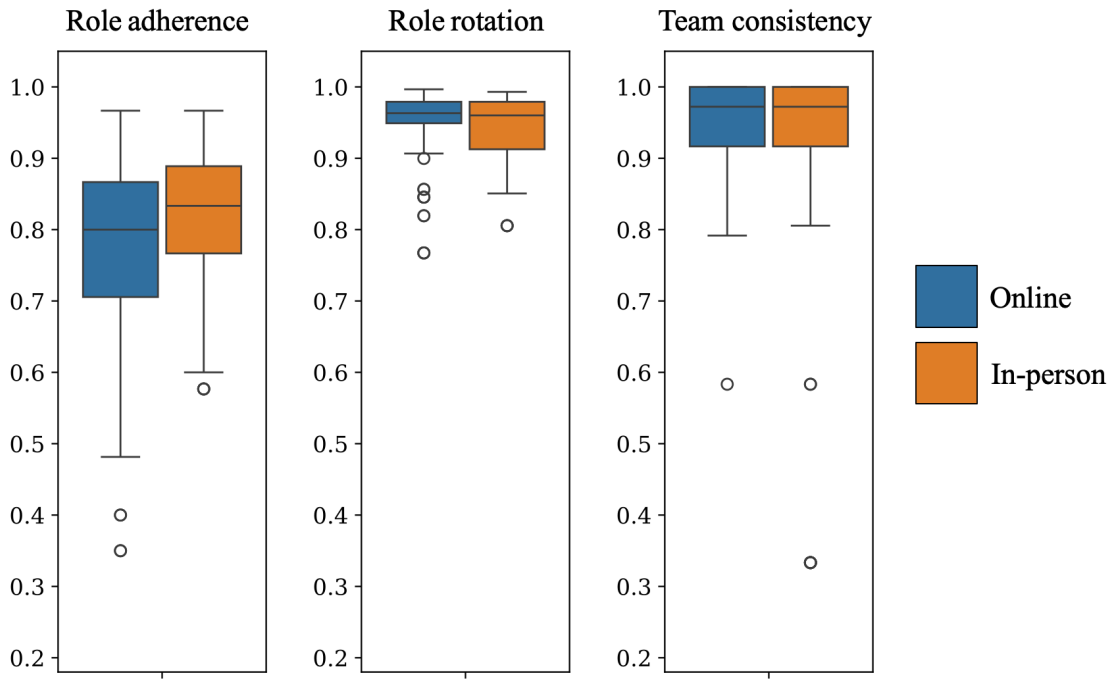

Figure 4: Distribution for the collaboration metrics role adherence, role rotation and team consistency for both the online and in-person sections.

The mean group **role rotation** score for the in-person section was 0.944, while the mean score for the online section was 0.955. This difference was not statistically significant ($p = 0.078$). Overall, groups in both sections demonstrated consistent role rotation among team members, even without grade incentives for the in-person section. While it is possible that groups in the online section might have achieved lower rotation scores without the credit incentive, the high scores observed in the in-person section highlight the tool's potential to promote equitable collaboration during group activities.

The mean **team consistency** score for the in-person section was 0.939, while the mean score for the online section was 0.951. This difference was not statistically significant ($p = 0.452$). Overall, teams in both sections demonstrated high consistency throughout the semester, despite the absence of system-enforced team requirements for both sections or grade incentives for the in-person section.

5.2 Where and when students in the online section meet

The reflection survey included a question asking when and where the group completed the GA. Based on these responses, we determined whether the group completed the GA during class time or outside of class time, and whether it was completed in person or remotely using online communication tools, such as Zoom or Discord. This analysis focused exclusively on students in

the online section, as those in the in-person section were required to complete the GAs during class time in the classroom.

To analyze meeting times for the online section, we calculated the proportion of group activities completed during class time for each student. On average, 61% of students in the online section completed their GAs during scheduled class hours. This suggests that while a majority utilized class time for their group work, a significant portion opted to collaborate outside of scheduled hours, highlighting the flexibility of the online section.

For the meeting location, we analyzed whether groups in the online section completed their GAs in person or remotely using online communication tools. On average, 22% of students in the online section reported meeting in person with their peers to complete their GAs, while the remaining majority collaborated remotely. This finding highlights that, despite the online format, a subset of students still opted for in-person collaboration when possible, indicating varied approaches to teamwork within the online section.

Fig.5 shows the percent of the groups in the online section that met in each of the 4 possible categories: in-person during class (14%), in-person outside class (8%), remotely during class (47%) and remotely outside class (31%).

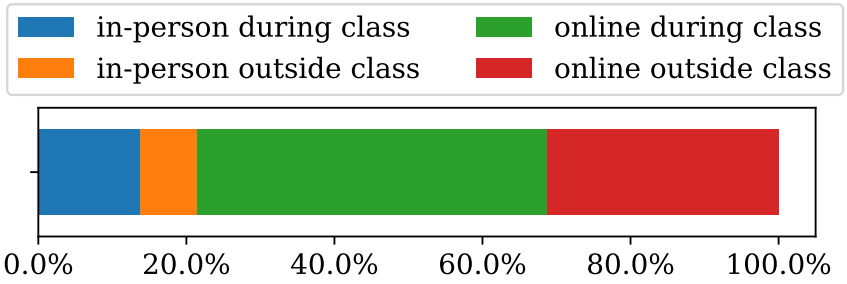

Figure 5: Distribution for meeting time and place for the asynchronous section. The students are distributed across all combinations of meeting time and place.

These findings highlight the diverse ways in which students in the online section approached collaborative work, utilizing both the flexibility and accessibility of the online format. While the majority of students completed their GAs remotely and during scheduled class hours, a notable subset leveraged the opportunity to meet in person or outside of class time, showing adaptability in their teamwork practices. This variation highlights the importance of providing flexible options in hybrid learning environments, as it allows students to choose collaboration methods that best align with their personal preferences and circumstances. Such flexibility can enhance participation and engagement, ultimately supporting positive collaborative outcomes.

6 Discussions

The deployment of the structured role enforcement tool revealed that students were largely consistent in the groups they worked with to complete the GAs, and roles were evenly distributed among group members. This experience report highlights the potential of computer-based tools to

support structured roles and foster positive collaborative interactions in both online and in-person settings.

To build on this work, we plan to investigate the impact of the structured role enforcement tool on students' sense of belonging, expanding on prior research [14, 15]. Specifically, we will conduct quasi-experimental studies comparing semesters when the tool was implemented (Spring and Fall 2024) to those when roles were encouraged but not systematically enforced (Spring and Fall 2023). This analysis aims to identify significant differences in students' sense of belonging associated with the tool's adoption.

Additionally, we will conduct a controlled experiment in a Spring 2025 class to gain deeper insights into the tool's effects. Students will be divided into two groups: one with access to the role enforcement tool and one without. This experiment will measure the tool's direct impact on collaborative learning outcomes and its ability to promote equitable and effective team dynamics.

7 Acknowledgment

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