Understanding SSRL Strategies and Its Impact on Group Performance in a CSCL Environment: A Case Study from a Project-Based Learning Course in India

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Abstract: In the current knowledge-driven society, teams are expected to work on open-ended and ill-structured challenges collaboratively. In this study, we investigate different SSRL strategies learners used to apply in open-ended and ill-structured tasks and their impact on teams' performance. This study spanned over 12 weeks for a set of open-ended tasks in a project-based Human-Computer interaction course. We have coded SSRL strategies under four major categories for two types of teams - high and low scoring. While investigating the difference in the application of SSRL strategies between high and low-scoring teams, we have found a considerable differences. Those differences were represented by using quantitative and thematic representations.

Introduction

Computer-supported collaborative learning environments (CSCL) facilitate interactions among learners to acquire knowledge, skills, and attitudes (Dillenbourg, 1999; Kaye, 1992; Koschman, 1996). As different learners are coming from diverse socio-cultural backgrounds, they bring with them diverse goals, approaches, attitudes, and experiences which become an important and dynamic element in collaborative learning environments. Handling the dynamic nature of the team and simultaneously achieving progress in a given task needs many socially shared regulation strategies amongst the collaborating members (Järvelä et al., 2018). While collaborative learning looks attractive for facilitating collective knowledge construction, it's not easy to orchestrate (Lobczowski et al., 2021). While working collaboratively on the set of tasks, some cognitive and metacognitive issues may arise due to differences in task and content understanding or different interpretations of the task by different learners (Jarvela & Jarvenoja, 2011). Studies investigating the relation between socially shared regulation of learning (SSRL) and group performance are limited and indicate that effective SSRL produces high group-level performance (Panadero & Järvelä, 2015). Furthermore, shared regulation is socio-historically and contextually situated in both individual and collective beliefs and experiences that together inform joint task engagement and are modified due to collaboration (Järvelä et al., 2018). Learners use different cognitive and metacognitive SSRL strategies while working on a shared task and those strategies are related to monitoring, controlling, planning, or reflecting (Lobczowski et al., 2021). SSRL occurs as a group-level phenomenon where students collectively negotiate and align common perceptions regarding the collaborative learning process and take control of the task through shared and negotiated, iterative fine-tuning of cognitive, behavioral, motivational, and emotional conditions (Hadwin, Järvelä, & Miller, 2016; Järvelä & Hadwin, 2013; Winne, Hadwin, & Perry, 2013). Learners apply different SSRL strategies while working on a set of open-ended and challenging tasks.

In the interconnected and interdisciplinary knowledge-driven professional environment, the ability to work collaboratively on ill-structured long-term project goals (e.g., Global Goals - https://www.globalgoals.org/) and engaging in socially shared regulated learning throughout the process have become vital skills nowadays. In this context, we explore the project-based learning for fostering such socially shared regulation of learning (SSRL). Project-based learning pedagogy has six features - (a) learning goals, (b) collaboration, (c) focus question, (d) engagement in scientific practice, (e) scaffolding with learning technology, and (f) creation of tangible solutions useful for addressing real-world problems (Krajcik & Shin, 2014). In project-based learning, learners engage with the problem, learn by doing, discussing, applying ideas and try to solve the problem given to them, which increases learners' engagement and helps them to develop a deeper understanding of important ideas by facilitating them opportunities for problem-solving, decision-making, and explaining their ideas (Krajcik & Shin, 2014). To investigate how teams apply SSRL strategies in a project-based learning environment and how these strategies may affect team performance, our research question is - How do high and low-scoring teams differ in terms of the application of SSRL strategies while solving an ill-structured challenge in a project-based learning course?

Method

This study was conducted as part of 12 week graduate-level online Human-Computer Interaction course using Microsoft Teams in Fall 2021. The course had to be conducted online due to the Covid-19 pandemic. The course had one instructor and two teaching assistants (TAs) - the authors of this paper. A total of fifteen first-year learners consisting of nine Ph.D. and six Master's learners (Mean (age) =25 years, SD=1.77; 50% Male, 50% Female) participated in this study. None of the participants knew each other before the course. The participants were divided into four teams consisting of 3-4 members each; each team consisted of Master's and Ph.D. level learners. The course followed a project-based learning approach in which the following ill-structured design challenge was given to all the teams - "Design an online inclusive library for learners". All teams worked towards designing a solution for the given open-ended problem statement throughout the duration of the semester-long course.

After basic orientation and introductions, the instructor announced the ill-structured design challenge in class. The semester-long course was divided into a set of five major interrelated tasks (See Table 1). Each task spanned over approximately 2-3 weeks with predefined deliverables contributing toward the final solution. Each week consisted of (a) one hour for instruction by the instructor to explain required concepts, tasks, deliverables, and resolve doubts, and (b) two hours for teamwork in the team's dedicated breakout rooms. In the breakout rooms, learners discussed the design challenge, SSRL strategies and simultaneously worked on a solution using the Miro™ platform - a collaborative whiteboard enabling distributed teams to work together - and shared Google Document. The instructor and TAs visited all teams one by one in their breakout rooms during their teamwork. The course readings corresponding to each week and task were shared with the learners in the week prior to the instruction. Each class session started with an emotion poll to understand the general affective states of the students followed by class instructions and discussions to resolve the doubt. Learners were briefed about the tasks, associated activities, and deliverables each week as per the weekly course plan. Teams were asked to share/present their team progress with the entire class at the end of each task listed in Table 1. Also, after a task, learners had to fill a self-evaluation survey periodically in which individual members reflected on (a) their perception of self and others' performance and (b) behavioral and emotional reflections on the basis of performance in the task. This self-reported data was represented team-wise by using radar charts and shared with the team members as feedback on their past performance during the self-evaluation window.

Table 1:
Task list for project-based Human-Computer Interaction course

Task	Task Name	Duration (in weeks)
Task 1	Understanding problem & user needs using concept mapping	2
Task 2	Data gathering, interviews, problem definition using fishbone diagram	3
Task 3	Analysis and user persona	2
Task 4	Ideation for the design solution and literature review	2
Task 5	Sketch prototyping, solution evaluation & refinement	3

Data Collection

Data sources include the following- 1) Video, audio, and screen-recording of interaction in breakout rooms, 2) solution design using Miro™ board, 3) design details and rationale in design journals, and 4) task-wise project performance. Learners also met outside regular class times in their breakout rooms. These were also recorded and included in our analysis. Miro™ board activity for all teams was mapped to the breakout room interactions during analysis. Note that data from radar charts were not considered for this analysis since these were not relevant to the research question being investigated in this paper.

Data Analysis

We evaluated the deliverables associated with each task using a rubric (see Table 2). All teams were first evaluated task-wise (see Table 3) and then the total score was calculated by summing the task-wise scores. While doing the task-wise evaluations we considered the team's Miro™ boards and shared documents. The total score indicated the quality of the team's work for the task(s) being evaluated. Out of four teams, we then sampled two teams with the highest overall scores (team 1) and the lowest overall scores (team 2) for further analysis. Analyzing these contrasting teams would help us unpack the differences in terms of the application of SSRL strategies by a group of students while solving an ill-structured challenge in a project-based learning course. These two contrasting cases would also enable us to investigate the differences between SSRL strategies and their effect on the team's performance. Team 1 had scoped down the ill-structured challenge to focus on speech and hearing impaired (DHH: Deaf or Hard of Hearing) students to address their need to communicate effectively and access specially designed content to help them learn. Team 2 scoped down the challenge to focus on the problems faced by students

from economically marginalized sections in accessing resources during online classes. We followed the content analysis approach (Mayring, 2000) to analyze the student conversations in these two teams. This method was suitable for this exploratory study since it enabled us to understand the emergent patterns and inter-team differences.

Table 2:
Rubric for evaluating tasks and deliverables for project-based Human-Computer Interaction course (Max. pts. for each criterion = 10)

Criteria	Exemplary	Valuable	Needs Work
Literature review	Existing resources (e.g., publications, policy docs) have been analyzed sufficiently to understand the problem and existing solutions; Gaps have been clearly articulated to justify the need for the project	Some resources have been analyzed but gaps have not been articulated and justified well	Lack of review of relevant resources and gap identification
Data gathering & analysis	Open-ended interviews & in-depth questioning techniques (e.g., 5 Whys) have been used. Data has been organized & analyzed using various means (e.g., fishbone diagram)	Interviews have been conducted but data has not been organized & analyzed well to inform design	Lack of interviews & user data
Identifying users' needs	Empathy and/or affinity map clearly captures users' interview data for all quadrants and users' needs have been identified	Empathy/affinity map has been made but user needs are missing	Lack of empathy /affinity maps and user needs
Persona	Persona(s) clearly captures users' needs, pain points, experiences, behaviors and goals	Persona(s) give partial idea of the target user & their characteristics	Persona(s) are missing
Problem statement	Problem statement has been stated clearly, specifies the target user(s), their primary need and an insight that reflects a nuanced understanding of the user's problem	Problem statement is clearly stated but good insight is missing	Problem statement is missing or generic that does not identify the primary need and insight
Ideation	Multiple distinct ideas have been generated using diverse techniques; the process and rationale for selecting the best solution has been clearly presented	Multiple ideas have been generated but process and rationale not presented	Only one idea has been generated and implemented
Evaluation	Selected idea has been evaluated using appropriate means, the testing criteria/metrics (e.g., heuristics) have been clearly articulated	Evaluation has been done but criteria not specified	Idea/product has not been evaluated
Refinement	All revisions based on evaluation have been suggested or implemented	Some revisions have been suggested/implemented	No revisions have been suggested.
Quality of the solution (proof of concept/ low-fidelity prototype)	The final solution is creative, unique, relevant to the identified problem, and mapped to various theory(-ies) of learning. It adheres to relevant design principles and has been generated in a systematic manner	Solution is creative, unique, and relevant to the problem but lacks mapping to relevant learning theories and design principles	Solution already exists or is not relevant to the design problem
Teamwork & communicat- -ion	Every member owns a specific part of the project that they drive forward. Simultaneously, every member has helped each other and can demonstrate that they have made a significant and valuable contribution towards the progress of all the parts and thus the entire project. Team members have communicated well with each other and have also been able to convey their ideas to the class.	Every member demonstrates ownership of a specific part of the project that they drive forward while helping others with their parts. But there are issues with communications within the team and/or while presenting	A lack of ownership of the project with one or two people have done all the work

The cognitive and metacognitive SSRL strategies enacted and applied by both teams were coded using four broad categories - S1: Monitoring/controlling task understanding, S2: Monitoring/controlling content understanding, S3: Planning task performance, S4: Monitoring/controlling task performance - using a top-down coding approach for each task (Lobczowski et al., 2021). Furthermore, to investigate the nuanced differences between SSRL strategies and their effect on the team's performance, we pursued thematic analysis (Braun & Clarke, 2012).

Table 3:
Task-wise scores for all teams (out of 10)

Task	Team 1	Team 2	Team 3	Team 4
Task 1	9	7	8	8
Task 2	10	7	8	7.5
Task 3	10	7	10	9
Task 4	9	7	8	7.5
Task 5	9	7.3	9	8

The unit of analysis was an episode containing enactment/application of predefined SSRL strategy by two or more members irrespective of the duration of the enactment/application (Isohätälä et al., 2018; Järvenoja et al., 2020). One instance of such a unit is given in Table 4. In this episode, learners demonstrate monitoring/controlling task understanding and planning task performance as SSRL strategies. The overall design journal for each team was also analyzed. Finally, the solutions/prototypes proposed by both high and low-scoring teams were evaluated for the quality of the proposed prototypes.

Table 4
Example of a unit of analysis from the interaction transcription

One SSRL episode of team 1 showing the instances of the S1 & S3 SSRL Strategies
(L1) Member 3: Solution should be user friendly
(L2) Member 2: Yes, I think, to go to solution, it will take weeks (more)..Is there any smartphones that are user-friendly for blind students.. we can search (on web)
(L3) Member 1: Yeah
(L4) Member 3: Yeah, Kindle kind of devices are there...in the audio format
(L5) Member 1: We can do more study on this
(L6) Member 2: (responding to member 3, supporting member 1) I think (after discussing this) we need not go in solution part right now. Now we will focus on problem and then later we can go for solution
(L7) Member 1: Yeah...right.
(L8) Member 4: Yes, I was thinking the same
(L9) Member 1: Eventually, we can come up with multiple problems (use cases to understand user needs)

The above episode was first coded as an instance of S1 SSRL strategy (Monitoring/controlling task understanding) because member 2 first asks an open question to understand the available options (L2). In response, members 1 and 3 share their thoughts promptly (L3-5). Here, member 2 is trying to understand the task properly and trying to use available resources for a better understanding of the task. Member 2 also helps other members refrain from indulging in thinking about task performance directly without properly understanding the task first (L1, L6). Member 2 attempted to keep all team members on track. Gathering new task information and getting/keeping everyone on track comes under the monitoring/controlling task understanding SSRL strategy (Lobczowski et al., 2021). This episode was also coded as S3 SSRL strategy (Planning task performance) because while member 1 wants to begin researching the kinds of devices available for their use (L5), member 2 counters it by saying that they should instead "focus on the problem" (L6). Thus, member 2 is setting the target for the team and other members agree with member 2's stand (L7-8). Member 1's response (L9) shows how other members were aligned with the target set by member 2 since it might help them understand the user needs in a more detailed way (Task 1). Setting the goal targeting groups' cognition and debating the task strategy comes under the planning task performance SSRL strategy (Lobczowski et al., 2021).

Results

We found differences in the application of SSRL strategies between high and low-scoring teams (Figure 2). The high-scoring team (team 1) has applied more SSRL strategies per task than the low-scoring team (team 2). The

SSRL strategies applied by team 1 (M= 79.2, SD=29.03) were 396, whereas SSRL strategies applied by team 2 (M= 51.4, SD=20.61) were 257. Figure 2 shows that team 1 engaged in more SSRL strategies compared to team 2 throughout the entire semester. Figure 2 shows the difference in the task-wise application of SSRL strategies and Figure 2 also shows that the SSRL strategies demonstrated by team 1 for each task were also higher than those of team 2 for each category of task.
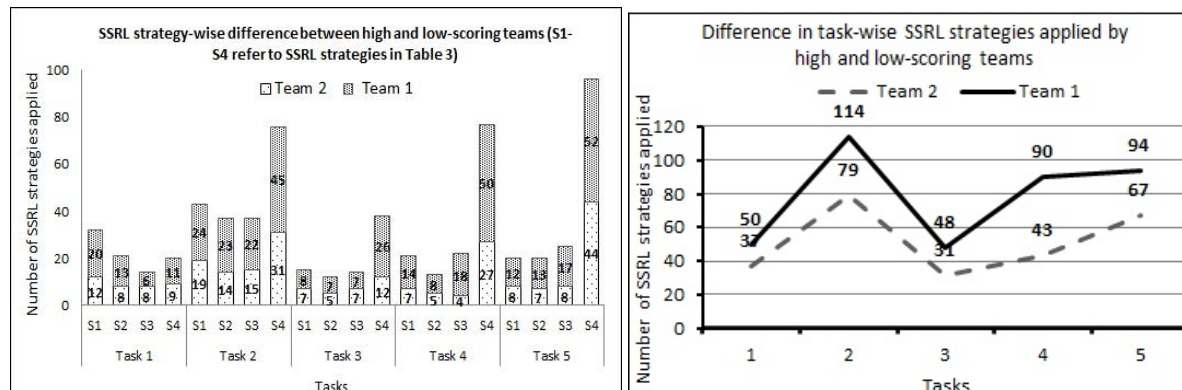

Figure 1:
SSRL strategy-wise difference between high and low-scoring teams (S1-S4 refers to SSRL strategies)

Figure 2:
The difference in task-wise SSRL strategies applied by high and low-scoring teams

We see that these differences form a trend across the entire session. From Figure 2, we see that both the teams' use of SSRL strategies peaks for task 2. This may be because the number of subtasks in task 2 was more than in other tasks and the total duration was also longer than the other tasks. So, both teams worked on more activities for a longer time compared to other tasks. Due to this, both teams may have been able to apply more SSRL strategies for task 2 as compared to other tasks. Findings from the thematic analysis help unpack the relation between the SSRL strategies and team interactions throughout the entire semester. The following two themes emerged.

Theme 1: Task completion time
The low-scoring team (team 2) applied fewer strategies than the high-scoring team (team 1) and on average took more time to complete the tasks listed in Table 1. Team 2 took one extra week to complete most (three out of five) of the tasks. The following excerpt by one member from team 2 provides an illustrative example for this theme - *"Each time we present our work late, we must consider that everything is graded here."*

Theme 2: Active participation and reflection on the SSRL interactions
Not all members from team 2 were participating actively in the SSRL strategy conversation initiated by another member. Instead, we observed that in team 1 if any member started any strategy-related conversation then the other members actively participated by sharing their thoughts on it, thereby refining the strategy. Lack of active participation from team members may have impacted team 2's performance while applying S4 (i.e., monitoring/controlling task performance) and ultimately the performance in the whole task leading to the final low score. Table 5 depicts one illustrative conversation highlighting the difference between the number of thoughts shared by members of both teams while talking about their application of monitoring/controlling task performance (S4) SSRL strategy during task 1.

Table 5:
The difference between active participation of high and low-scoring teams

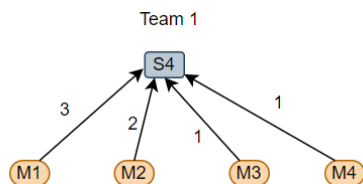| High-scoring team (team 1)	Low-scoring team (team 2)
Member 1: For DHH students we will be adding options, but some additional 1-2 options we can also add for secondary users too. Member 2: Yes Member 3: Right. Member 4: Sorry, I was thinking different, can we include some options for color blinds also like text to speech.	Member 1: This makes sense.. but I would like to ask question (doubt) on implementation part...so I am unable to imagine how implementation part will go.. Member 2: Research (solution designing) begins with personal (past) experiences.. so it will..

| Member 1: Yeah.. that we can include. | (silence for a while and change of topic) |
Member 2: Actually, all suggestions we can include.	
Member 1: Sometime I just mess up in between DHH and other type of students.	
Representation illustrating the participation of members from team 1 (as per the above excerpt).	Representation illustrating the participation of members from team 2 (as per the above excerpt)
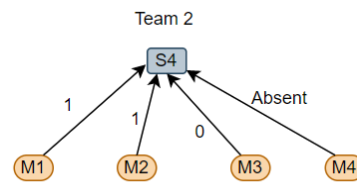
The nodes - M1, M2, M3, M4 shown in diagrams drawn in Table 5, depict team members. S4 corresponds to monitoring/controlling task performance SSRL strategy. Connecting arrows from members to the SSRL strategy show active participation towards the SSRL strategy (S4) and weights (numbers) on connecting lines represent the extent of participation. We see that in team 1, all members participated and contributed sufficiently towards S4 unlike team 2 where only two members participated.

Theme 3: More focus on Monitoring/controlling task performance SSRL strategy
Among the four SSRL strategies, team 2 primarily applied S4 (i.e., Monitoring/controlling task performance) a maximum number of times while doing a given set of tasks (Figure 1). Low application of other SSRL strategies related to task and content understanding and planning task performance is clearly visible for team 2. Lack of focus given to the first three strategies may have resulted in a lack of task and content understanding which can be the reason for low group performance. While team 1 also applied S4 a maximum number of times, members gave sufficient weightage to other SSRL strategies while moving through Tasks 1 to 5. This can be seen in Table 4 where the whole team was working more on monitoring/controlling task understanding and performance planning. When member 3 tried to articulate some thoughts about a solution, member 2 reminded member 3 and others in the team that they needed to focus on problem understanding at the moment and not on the final solution. The important thing is that those four categories of SSRL strategies were interlinked and the previous strategy gives input to the next strategy. Hence, if the due focus is not given to each strategy, then it may derail the regulation process for that particular task or the whole set of tasks.

Theme 4: Team coordination
Team 2 demonstrated a lack of coordination amongst the team members. Group coordination and communication is the key element for effective SSRL (Lobczowski et al., 2021). While team 1 was coordinating effectively by converging about future tasks and the need for improved efforts, team 2 lacked such coordination during tasks 1-4. However, for the last task (Task 5), we observed team 2 using effective coordination and improvement on SSRL strategy application quantitatively as well as qualitatively. This may be because at the start of the last task (i.e., Task 5), some intense and emotional conversations had happened between the members. For example, *"Each time we present our work late, we must consider that everything is graded here... overall compared to other courses, I am struggling with this course and I think we need to step up... our presentation would have been better if we could have met and discussed"*. This may have led the members to seriously think about the task value and the gap in their previous tasks' performances from the other teams. This realization might have ultimately led the team members to rigorously think about the need for improvement. Around this time, one of the TA's had a detailed discussion with team 2 about their users and their understanding of inclusivity. This was necessary since they were going in a loop worrying about the performance without understanding the problem and converging on a shared problem that was scoped appropriately. This intervention helped the team improve its coordination to a certain degree and start making progress. Thus, intervention may have also resulted in the improvement seen in SSRL strategies corresponding to Task 5.

Theme 5: Nature of interaction
Team 2 demonstrated scattered focus during their breakout room interactions (see Table 6). However, for team 1, more focused interactions were visible during the analysis. These kinds of focused discussions may have yielded effective SSRL strategies for team 1. The following example given in Table 6 illustrates how more focused discussion occurred between the members of team 1, whereas how more scattered discussion occurred between

the members of team 2. The center point of discussions for team 2 was very dynamic but in team 1, all team members took care to keep their discussion focused and outcome-oriented.

Table 6:
The difference in nature of interaction between high and low-scoring teams

High-scoring team (team 1)	Low-scoring team (team 2)
Member 1: As per title, what is meant by inclusive? and in which sense? its confusing me.	Member 1: Should we design for entire school then we can add many feature in that.
Member 2: Yeah, I had same doubt, but as per instructions, any general solution wont be useful.. so we have to narrow it (to any use case) in a way	Member 2: Yes, but our main focus will be on class 6-10 and we also have section for other class students
Member 1: Ok.	Member 4: Yes
Member 2: Then what all can be achieved	Member 3: I am still confused, because when it will be accessible and many such things are coming in my mind
Member 3: Yes, we need to read about other use cases before narrowing down to one single use case	Member 2: Isn't this library is supposed as online library? then this problem will not be there
Member 4: Yes.	Member 1: Ohh, Really ! (I forgot)
	Member 4: Then we have to think about making two libraries, (Physical and online)

Discussion and Conclusion

In this study, we investigated differences in terms of the application of SSRL strategies of groups of learners while solving an ill-structured challenge in a project-based learning course. We presented the findings from two teams who demonstrated very different SSRL strategies. These two contrasting cases allow us to capture and understand the team-level SSRL processes in which team members (learners) negotiated, gathered perceptions about working in a team, and took control of the tasks in various ways. The learners enacted different SSRL strategies and tried to iteratively refine those SSRL strategies through discussions (Hadwin, Järvelä, & Miller, 2016; Järvelä & Hadwin, 2013; Winne, Hadwin, & Perry, 2013). The ill-structured tasks posed challenges to both the high and low-scoring teams, and the challenging situation in the tasks likely led the team members towards the enactment and application of several SSRL strategies (Järvelä et al., 2018). Working on the set of tasks for proposing a design for an online inclusive library for learners was also difficult for both teams (Lobczowski et al., 2021) since team members were unknown to each other and were from diverse backgrounds. These may have contributed to differences in their task interpretation and task/content understanding (Jarvela & Jarvenoja, 2011). As stated by Panadero & Järvelä (2015), the application of effective SSRL strategies has an impact on team performance. The comment by member 2 of team 2 while doing Task 1 - "Research (solution designing) begins with personal (past) experiences" shows that the individual and group level socio-historical experiences and beliefs inform the application of SSRL strategies (Järvelä et al., 2018).

In this study, we demonstrated that there are considerable differences in the SSRL strategies applied by high and low-scoring teams. Overall, team 1 applied more SSRL strategies than team 2 (See Figure 2). The need for scaffolding SSRL strongly emerged in the case of team 2. We demonstrated that this team's performance in terms of SSRL strategies improved after intervention by the mentor (TA) as well as team members' sharing intense and emotional conversations about their team's progress. Identifying and supporting these interactions systematically could be beneficial for such low-performing teams.

While both the teams focused heavily on the SSRL strategy S4 (monitoring/controlling task performance), team 2 did this at the expense of other strategies. On the other hand, team 1 used all the strategies adequately throughout the study. The five themes identified above characterize this difference between the two teams' application of SSRL strategies. The themes show the teams differed considerably on all parameters that are likely to affect the final solution to the ill-structured challenge. Team 2 members found it hard to coordinate with each other and converge on a shared understanding of the problem. Their scattered attention to various aspects of the challenge (e.g., online vs physical library, rural vs urban context, etc.,) likely influenced (and in turn was influenced by) the lack of focus on strategies connected to task and content understanding and planning (S1-S3). The project-based learning setting and the ill-structured challenge created opportunities for highlighting and understanding the differences in application of SSRL strategies and their impact on the teams' performance.

Limitation

Our participants in this study belonged to a specific graduate-level course that had to be moved online due to the Covid-19 pandemic. Not all the participants had regular access to technology and the internet and also dedicated

physical space for attending classes and hence participate in this study regularly. While all the teams used the breakout rooms for teamwork, there is a chance that some teams worked outside the breakout rooms based on their convenience. We could not track and analyze these interactions. The number of participants in this study was small. While it enabled us to analyze interactions in-depth, our findings may not apply to different settings (e.g., large classrooms, resourceful learners).

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