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Understanding the Triggers and Dynamics of Socially Shared Metacognitive Regulation in Teams with Divergent Outcomes

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Abstract: Collaborative problem-solving (CPS) offers opportunities for team members to apply their acquired skills and knowledge to shared tasks, particularly when addressing ill-structured problems that require collaboration among individuals with diverse perspectives and competencies. During CPS, learners may encounter various challenging situations referred to as trigger events that serve as markers or catalysts for strategic regulation. Previous studies on socially shared metacognitive regulation (SSMR) have primarily focused on the occurrence of SSMR during collaborative learning, with limited attention to its triggering factors. This study investigates the triggers and dynamics of SSMR in teams with divergent outcomes (i.e. more successful outcome teams (MSOT) and less successful outcome teams (LSOT)). Conducted over 12 weeks, the research focused on ill-structured tasks in a project-based Human-Computer Interaction course. We analyzed 35 hours of video data using thematic analysis, examining teams' verbalized interactions to identify SSMR triggers, followed by coding the identified SSMR episodes to determine their focus and function. Findings revealed differences between MSOT and LSOT in terms of the variety of triggers, focus, function, and the shifts in SSMR strategies. MSOT demonstrated a fundamental focus that enabled teams to grasp essential aspects needed to solve the task, whereas LSOT exhibited surface-level focuses, often involving non-essential components. MSOT applied SSMR strategies optimally and at appropriate times during CPS, while LSOT displayed suboptimal and untimely applications. Moreover, strategy formulation and execution in MSOT were consistent and goal-directed, whereas in LSOT, they were interruptive and momentary.

Keywords: Socially shared metacognitive regulation (SSMR), Collaborative problem-solving (CPS), Project-based learning (PBL), ill-structured problem-solving, Triggers of SSMR, Focus of SSMR, Function of SSMR.

1. Introduction

Collaborative Problem Solving (CPS) in Computer-Supported Collaborative Learning (CSCL) environments provides team members the opportunity to apply their existing skills and knowledge toward accomplishing a shared task. As learners often come from diverse socio-cultural backgrounds, they contribute differing goals, perspectives, attitudes, and experiences; factors that become critical and dynamic during CPS. Managing this diversity effectively while making meaningful progress on a task requires various socially shared regulation strategies (Järvelä and Hadwin, 2024).

Within CPS, team members regulate their cognition, metacognition, motivation, emotions, and behaviors through shared metacognitive monitoring (Järvelä et al., 2013). Yet, cognitive and metacognitive challenges often arise from differing interpretations of the task or content. In such cases, shared metacognition is essential for collaboration, as it enhances awareness of challenges through monitoring and signals the need for regulation. Learners employ various shared regulation strategies, including monitoring, controlling, planning, and reflecting (Lobczowski et al., 2021). Socially Shared Metacognitive Regulation (SSMR)

specifically refers to processes where group members jointly monitor and guide collective cognitive efforts (Iiskala et al., 2015). SSMR is crucial in CPS for aligning group cognition through continuous monitoring and control. These processes include identifying goals and expectations (e.g., what needs to be done), planning (e.g., time allocation), tracking progress, adapting strategies, monitoring understanding (e.g., questioning reasoning), and evaluating the final output (Badhe et al., 2022; Iiskala et al., 2015; Kerrigan et al., 2021).

The selection of more and less successful outcome teams (MSOT and LSOT) in this study is grounded in the theoretical premise that socially shared metacognitive regulation (SSMR) contributes meaningfully to collaborative learning. Preliminary data analysis supports this premise. SSMR includes setting shared learning goals, mutually monitoring comprehension and progress, and reflecting collaboratively on both the process and outcomes (Järvelä et al., 2013). When paired with domain-specific knowledge, these processes positively impact individual learning gains (Chan, 2012). Though theoretical frameworks link SSMR to deep understanding and high-level outcomes (Iiskala et al., 2011, 2015), empirical evidence remains limited. Nonetheless, it is assumed that quality SSMR supports group progress by guiding cognitive control toward shared goals (Iiskala et al., 2021). Thus, this study examines MSOT and LSOT to explore how the dynamics of SSMR correlates with collaborative learning success. SSMR's role is especially critical when learners engage in complex, ill-structured tasks (Iiskala et al., 2021). Research (Iiskala et al., 2004) shows that metacognitive regulation tends to emerge more in such tasks than in well-structured ones. Additionally, task difficulty significantly influences metacognitive activation, as demanding tasks intensify metacognitive experiences (Iiskala et al., 2011; Efklides et al., 1998). However, prior studies mainly focused on how SSMR manifests, not what triggers it (Vauras, Volet, & Iiskala, 2021). To address this gap, this study investigates the triggers of SSMR during a semester-long, ill-structured project and explores its focus and function within CPS.

Trigger events are circumstances that disrupt the learning process, requiring regulatory action (Järvelä & Hadwin, 2024). They act as challenges that prompt learners to apply strategic responses. Studies identify three main SSMR triggers: metacognitive experiences (ME), socio-cognitive conflict (SCC), and error feedback (EF). Metacognitive experiences refer to internal thoughts or feelings that raise awareness about one's thinking or task approach (Efklides, 2006). These include metacognitive feelings (e.g., difficulty, confidence, satisfaction) and judgments or estimates. Both play a key role in monitoring and regulating task performance. For example, feeling that a task is difficult may prompt strategic intervention (Vauras, Volet, & Iiskala, 2021). Cognitive conflict occurs when current understanding is challenged by new or conflicting input. In group settings, this often appears as socio-cognitive conflict—discussions of differing views. Such interactions push learners to reconcile opposing ideas and promote deeper understanding. Lastly, error feedback, which signals incorrect responses, is another common trigger. Feedback prompts learners to reevaluate and adjust their strategies accordingly (Vauras, Volet, & Iiskala, 2021). Overall, trigger events serve as markers for regulation, prompting learners to adjust their motivational, cognitive, emotional, or behavioral strategies to enhance performance (Järvelä & Hadwin, 2024).

Hence, it is important to scrutinize the role of various triggers of SSMR and the corresponding regulatory responses of teams across different contexts. In this study, we investigated the types of triggers that occurred in more and less successful outcome teams, along with the differing responses of these teams to various trigger situations. This longitudinal study was conducted in a semester-long course involving an ill-structured design challenge. The research question (RQ) guiding this investigation is: How do the triggers and responses of SSMR differ between more and less successful outcome teams during ill-structured CPS?

2. Methodology

To investigate the triggers and dynamics of SSMR of teams, we chose an authentic semester-long course in Human-Computer Interaction for educational technology (HCI for ET). The course used a project-based learning pedagogy, which involved four milestones (see table 1) and many CPS tasks. Hence the study was conducted over 12 weeks in a

graduate-level, face-to-face HCI for ET course in a collaborative classroom setting during fall 2022. To achieve heterogeneous grouping, a total of sixteen learners participated in this study. The group consisted of five Ph.D. students, one Master's student, and ten Bachelor's-level students (Mean age = 23.4 years, SD = 4.09; 65% Male, 35% Female). None of the participants knew each other before the course. The learners were divided into four teams, each with four members. All teams included a mix of Ph.D. and Bachelor's-level learners, while the single Master's learner was assigned to Team 3. All sixteen learners were graduates from the engineering, architecture, or science domains, broadly aligning with the STEM field. The course followed a project-based learning approach in which the following ill-structured problem (design challenge) was given to all the teams - “Design an intervention that supports special needs education (formal/informal) for speech and hearing impaired (DHH: Deaf or Hard of Hearing) students”. All teams worked towards designing a solution for the given open-ended problem statement throughout the semester.

Table 1. *Set of Milestones and Subtasks given for Teams in Project-Based Learning HCI Course*

Milestones	Task Name
1	Understanding problem & user needs using concept mapping, literature review
	Data gathering using interviews (on-field task)
	Problem definition using a fishbone diagram
	Analysis of user needs using empathy maps and user persona
2	Ideation for the design solution
	Study of existing systems
	Finalizing one idea using a decision matrix
3	Developing low-fidelity prototype
	Mapping prototype with the problem statement and theories
	Checking adherence to learned design principles with prototype
4	Evaluation of prototype with testing matrix and heuristics
	Refinement of prototype based on evaluation

After basic orientation, the instructor announced the ill-structured design challenge in class. The semester-long course was divided into four major milestones (See table 3) leading to the final solution. Each task spanned approximately 3 weeks with predefined deliverables contributing to the final solution. For each week, learners were having two 1.5-hour-long in-class sessions. Each team was given the opportunity to collaborate and work on ill-structured problems for a total 8.5 hours in 7 weeks. Each session consisted of the following - (a) half an hour of instruction covering required concepts, tasks, deliverables, and resolving doubts, and (b) one hour for teamwork at the team’s dedicated collaborative space (round table). During teamwork, learners discussed the design challenge and task strategies face-to-face and simultaneously documented their progress using the ConceptboardTM platform - a collaborative whiteboard enabling distributed teams to work together - and shared Google Document which contained their design journal. The instructor and TAs visited the teams at their tables for collecting feedback and addressing clarification questions. The course readings corresponding to each week and task were shared with the learners a week prior to the instruction. Learners were briefed about the tasks, associated activities, and deliverables each week as per the weekly course plan.

At the start and end of each milestone, team members were asked to do collective planning and evaluation. This facilitated metacognitive regulation opportunities for the teams while working collaboratively in each milestone. At the end of each milestone, teams were asked to present their team progress to the entire class. They were instructed to log their progress in shared group journals asynchronously (reflecting groups’ status and individual contribution).

2.1 Data Collection

The data was collected for the four teams and prior consent was taken. The verbal interaction of collaborating team members was video recorded, and the milestone-wise deliverable (performance) was evaluated using the rubric. Learners also worked synchronously and asynchronously outside regular class times, but that part was not recorded. ConceptboardTM board activity screenshots and shared group journals for teams were also collected. However, the solution they have developed, their write ups in group journals, written responses in planning, and evaluation should have been factored in the data analysis.

2.2 Data Analysis

We evaluated the team performance associated with each task using a self-evaluation rubric which was shared with teams in the course orientation. All teams were first evaluated task-wise, and then the total score was calculated by summing up the task-wise scores. The tasks were grouped logically into different milestones. While doing the task-wise evaluations using a rubric, we have also considered the team's ConceptboardTM screenshots and their shared group journal to validate the work done. This rubric had been shared with all the teams ahead of time. Out of four teams, two teams were placed in a more successful outcome team (MSOT), and two were placed in a less successful outcome team (LSOT). The MSOT (Team 1 and Team 3) scored 9 and 8.14 out of 10, respectively, whereas the LSOT teams (Team 2 and 4) scored 5 and 5.28 out of 10 respectively. We then sampled video data of the first two milestones (first 7-8 weeks) of all four teams. In the first two milestones, various opportunities were given to all teams to decide problem statements and decide probable solution ideas, which were more challenging and involved substantial amounts of brainstorming and decision-making. The first two milestones allowed learners to put forward their thought processes more openly. To investigate the triggers and dynamics of SSMR, we analyzed the video data (of 35 hours) from a synchronous face-to-face classroom interaction.

Table 2. *Deductive Coding Scheme Followed while Analyzing SSMR and the Degree of Transactivity for Both Teams*

Particular	Subtype	Description
Triggers of SSMR (Vauras et al., 2021)	Metacognitive Experience (ME)	Metacognitive experiences are person's subjective cognitive or affective experiences that monitor and inform a person about a feature of cognitive processing in relation to the task at hand
	(Socio) Cognitive Conflict (SCC)	Based on Piagetian conceptualization of (dis)equilibrium, cognitive conflict refers to a discrepancy between a person's own view of the world and new information that conflicts with the person's existing view.
	Error Feedback (EF)	Students receive feedback from each other during the collaborative learning process. Error feedback may also affect students' metacognitive behavior.
Focus (Grau and Whitebread, 2012)	Fundamental	Refers to essential aspects discussed to solve the task. It is always related to the final goal of the task. it could include or not include discussions about knowledge.
	Surface	Refers to non-essential aspects of the task, such as time management, choice of resources, etc. They are relevant to complete the task; however, the way this is done does

		not have a great influence on the quality of the outcomes.
Function (Iiskala, 2011; De Backer, 2022)	Activate	Activating a new direction for ongoing interaction or a new way of thinking in line with and building upon previous activity
	Confirm	Confirm ongoing interaction, eliciting a continuation of previous activity in the same direction
	Change	Changing the flow of collaborative learning, implying ongoing interaction is challenged and current activities are questioned and rethought to the extent that an alternate direction is taken

All four teams have chosen the problem statements around the proposed themes. The thematic analysis of content analysis approach (Mayring, 2015, p. 95) was followed to analyze students' verbalized interactions during collaborative work (including teams' interactions with instructor or TAs). The verbal interactions during CPS were video recorded and transcribed for data analysis. The triggers of SSMR were coded using the description given in the literature (i.e. ME, SCC, and EF). The start points of conversational segments marked by shared metacognitive experiences were identified as trigger events. The endpoint was marked by the last conversational turn on the topic or the emergence of a new trigger (Iiskala et al., 2011). Segments were considered SSMR episodes if they included verbalizations of monitoring and controlling cognitive processes (De Backer et al., 2022). Each episode contained multiple conversational turns by team members. After identifying SSMR episodes from the video data, we coded the triggers, focus, and function of each SSMR episode using the coding scheme shown in table 2.

SSMR statements were coded by a trained educational technology researcher. The reliability of statement coding was assessed using Cohen's kappa (κ) as a measure of inter-rater reliability. In the first round, two independent educational technology researchers coded 20% of the SSMR statements (210 statements), followed by discussions to resolve disagreements and establish consensus in the second round. Both researchers were well-versed in the metacognition and CPS research area. Inter-rater reliability was assessed using Cohen's kappa (κ). The coding of SSMR skills, focus and function demonstrated a high level of agreement between coders (κ = 0.85). These values indicate reliable coding procedures across constructs, with overall kappa values suggesting substantial inter-rater reliability (Landis & Koch, 1977).

3. Findings

This descriptive statistics and findings for the RQ are presented in this section.

3.1 Descriptive statistics

Table 3 presents descriptive statistics for SSMR episodes across four teams, revealing diverse patterns in metacognitive regulation.

Table 3. *Descriptive Data Showing Information about Team-wise Total Episodes*

	Team 1	Team 2	Team 3	Team 4
Number of Episodes (100)	26	17	31	25
Total Episode Duration	52.43	49.35	77.22	77.28
Min	0.24	0.11	0.17	0.15
Max	8.56	8.7	11.1	10.27

Mean	1.85	2.94	2.30	3.06
SD	2.16	2.5	2.35	2.40

Note: All data is in Minutes (mm.ss format)

The 100 total episodes varied significantly among teams (17 to 31), with notable differences in total duration and average episode length. Episode lengths ranged from 0.11 to 11.1 minutes, with high standard deviations indicating substantial within-team variation. These findings highlight diverse SSMR engagement patterns in terms of frequency, duration, and consistency during collaborative problem-solving.

Table 4 gives team-wise information on triggers of SSMR along with different characteristics of the SSMR episodes (such as focus and function). Further descriptive statistics are shown in the following table 4, which shows the instances of SSMR episodes, triggers, focus, and the function of SSMR episodes. Table 4 groups teams 1 and 3 as more successful outcome teams (MSOT) and teams 2 and 4 as less successful outcome teams (LSOT).

Table 4. *Descriptive Data Analysis for Coding Team-wise Episodes (Showing Triggers, Focus, and Function of SSMR)*

		Team 1	Team 2	Team 3	Team 4	MSOT (Team 1 & 3)	LSOT (Team 2 & 4)
Number of Episodes		26	17	31	25	58	42
Triggers	Metacognitive Experience (ME)	23	14	25	16	NA	NA
	Socio-Cognitive Conflict (SCC)	2	0	4	4	NA	NA
	Error Feedback (EF)	1	3	2	5	NA	NA
Focus	Fundamental	19	8	27	19	46	27
	Surface	7	9	4	6	11	15
Function	Activate	7	6	9	18	18	24
	Confirm	6	8	7	0	13	8
	Change	13	3	15	7	28	11

3.2 Findings from thematic analysis

The triggers and the dynamics of the SSMR (in terms of focus and function) for MSOT and LSOT are presented in Table 4. Furthermore, the thematic analysis helps unpack the differences between the focus and function of SSMR. The following themes emerged from the thematic analysis.

Theme 1: Differentiating focus of SSMR in trigger situation

Differences in SSMR responses were observed between MSOT and LSOT when experiencing SSMR triggers during CPS. The findings highlighted differences in the focus of SSMR among the teams. It was observed that the fundamental focus acquired by MSOT enabled teams to understand the essential aspects required to solve the task, whereas LSOT exhibited surface-level focuses, which are not desirable, as team members engaged in pragmatic or non-essential components of the task. This finding aligns with Iiskala et al. (2011) and Grau & Whitebread (2012). Examples of differentiated SSMR responses and their corresponding focus for similar types of trigger situations are presented in Table 5.

Table 5. *For the SCC Trigger, the Difference in Type of SSMR Response and Focus is given for MSOT & LSOT*

Team 3 (MSOT)	Team 4 (LSOT)
(L1) M4- There is special education for concept learning.. (L2) M1- Special education is for reading, writing and .. (L3) M2- No, Special educators work separately. .. in early years of education ... (Explains that this is how special educators work and for this reason..) (L4) M4 & M1- Ok (Agrees by nodding)	(After looking at the updated problem-statement and realizing that this PS is an updated one and he was not aware about it). (L1) M2- When did we update the problem statement ? (L2) M1- (Smiles).. (L3) M3- What? (L4) M1- M2 is asking when we updated the problem statement. (L5) M3- (Smiles).. Simultaneously.. in the process.
SSMR skill: Monitoring Comprehension Focus: Fundamental Metacognitive strategy: content understanding through Highlighting a discrepancy	SSMR skill: Monitoring Comprehension Focus: Surface Metacognitive strategy: Content understanding through Social Questioning

The episodes presented in Table 5 illustrate how, for a similar type of trigger (i.e., SCC), the SSMR skill, focus, and metacognitive strategy differed between MSOT (team 3) and LSOT (team 4). In response to the SCC trigger, both teams began with monitoring comprehension. However, member M2 (at L3) from team 3 identified a discrepancy in understanding and actively attempted to regulate the content comprehension of other team members. In contrast, in team 4, M2 (at L1) recognized that he had missed the updated content knowledge related to the problem statement and was unaware of the revised version. He externalized his cognitive conflict through social questioning, but other team members did not acknowledge this opportunity to resolve the ambiguity in the shared problem statement or align everyone's understanding. As a result, team 4 ended with a surface-level focus, while team 3 achieved a fundamental focus. This demonstrates the differentiated regulative responses by team 3 and team 4. De Backer (2022) suggests that diverse responses to trigger conditions can lead to varying degrees of facilitation for SSMR, which supports this finding.

Theme 2: Timing and functioning of SSMR in triggering situations

The SSMR responses to the ME trigger also varied between team 1 (MSOT) and team 2 (LSOT). For team 2, the trigger was ME–feeling low satisfaction, whereas for team 1, it was ME–metacognitive judgments/estimates of learning, which stimulated the subsequent SSMR episodes. MSOT exhibited optimal application of SSMR strategies at the appropriate time during CPS, whereas LSOT demonstrated suboptimal application of SSMR strategies.

Table 6. *For the ME Trigger, the Difference in Type of Shared Regulation Response and Focus is given for More and Less Successful Outcome Teams*

Team 1 (MSOT)	Team 2 (LSOT)
(L1) M2- Do we detect and correct errors? (L2) M1- Did we detect something? (L3) M3- and what would be the errors ? (L4) M1- Yeah. (L5) M4- Error means it was just an improvement. (L6) M3- I mean we discuss individual thoughts on what we want to do and	(L1) M3- We also don't meet if we miss the class, and to catch up and update absent person.. (L2) M1- See.. you people (who miss class frequently) have to become more particular, just I have done my part on time, but you people were doing it very late night, I was observing that live on Document.. but you didn't inform.. (L3) M1- Just like, see, M2 have also not done respective parts.. now I can't fill their columns in this

based on discussion we decide. (L7) M2- In our group even if we had contradiction still (after making consensus) we build upon idea so we just don't just reject anyones' idea, (L8) M1- But what to mark here. Neutral..! we are not sure. (L8) All- Yeah. Neutral	sheet right.. (Unpleasant Feeling of (low) satisfaction). and I have prepared a whole structured sheet for us, and just thought let me take up that responsibility and do it. but you people have to at least put your ideas in it... (L4) M3 - Hmm (Yes) (L5) M1- If you want to meet then just schedule and fix the meeting, lets work. just don't say that we don't meet.. this doesn't work..
Major MRS: Process Evaluation Focus: Fundamental Metacognitive strategy: Evaluating Task performance Function: Facilitate- Confirm	Major MRS: - Monitoring Progress - Strategic planning Focus: Fundamental Metacognitive strategy: Planning Task Performance Function: Facilitate- Activate

The difference in the shared regulation responses is evident in the two episodes from both teams (Table 6). In team 1, at L6, the response from M3 indicates that all members contributed to the discussion, and individual thoughts were discussed collectively. The following response at L7 by M2 shows that the team had a shared understanding of how to handle contradictions or conflicts in opinions and how to align perspectives to achieve a common goal. Members of team 1 evaluated their collaboration effectively and confirmed their overall strategy for managing contradictions during teamwork. In contrast, in team 2, at L1, M3 expressed difficulty with group coordination, particularly when members missed class and did not meet outside of class. In response, M1 at L2 suggested that if everyone became more task-oriented, group coordination would improve. Members of team 2 monitored the team's overall progress and proposed a remedial strategy to address coordination issues after recognizing a shortfall in their performance. Here, we can observe that team 1 regulated task-related challenges by achieving shared understanding at the desired time during CPS, whereas team 2 addressed group coordination challenges by proposing remedial actions at an undesired time (i.e., at the end of Milestone 2). Although both teams ultimately achieved a fundamental focus, the distinction lies in the timing and optimal application of SSMR strategies during CPS. These findings align with De Backer (2022) and Vauras, Volet, & Iiskala (2021).

Theme 3: Nature of SSMR strategy

Differences in formulating and adapting task strategies were observed between MSOT and LSOT. In MSOT, strategy formulation and execution were consistent and goal-directed, whereas in LSOT, they were interruptive and momentary. In team 1 (MSOT), while discussing and refining the final goal, the conversation triggered an SSMR episode through a metacognitive judgment about the final goal. In one such episode, M2 identified a discrepancy in the team's goal, saying, *"M2 – I think in sign language the sentence is.. semantics.. but the challenge here would be contextualizing, no matter what the language is.."* This prompted M3 to experience cognitive conflict and regulate M2's interpretation of the perceived goal by responding, *"M3 – So, here we are saying that it's possible to match, but would it be better to say, given the understanding of sign language sentence construction, we need to teach them English language's sentence construction?.."* This exchange was seen as a goal-directed approach, after which the team began working toward the finalized goal. This indicates that team 1 (MSOT) adopted consistent and goal-directed SSMR during CPS. In contrast, team 2 (LSOT), while evaluating the task using the evaluation sheet, saw M1 state, *"M1 – I have updated everything in the task evaluation sheet (without discussing with all team members). If you want to update, then you can..."* The other members accepted this without objection, even though they were aware that the evaluation sheet was intended to help teams identify gaps in their task strategy and address them collaboratively. This indicates that team 2 (LSOT) adopted a momentary and unfocused SSMR approach during CPS. These results indicate that MSOT and LSOT exhibited diverse regulation responses to trigger conditions.

4. Discussion

The present study aimed at investigating various triggers conditions experienced by teams and their corresponding SSMR response for MSOT and LSOT. The limited research on the triggers of SSMR presents practical challenges, as it hinders the ability to effectively support activities that could foster SSMR during collaborative learning (Vauras, Volet, & Iiskala, 2021). The findings have highlighted occurrences of three types of triggers of SSMR (i.e. metacognitive experience (ME), socio-cognitive conflict (SCC), and error feedback (EF)) for MSOT and LSOT. The SSMR response in terms of focus and function showed the highlighting differences in those teams. Difference in the focus was observed in the data such as varied focus while creating understanding, performing operations, and producing outcomes. It is important to note that the level of cognitive effort and level (surface vs. fundamental) on which the group works and discusses during CPS may determine the magnitude of the effect of SSMR but it remains within the scope of learners' competence. The findings highlight meaningful differences in focus between MSOT and LSOT, and suggest the need for targeted support for teams in challenging situations.

Further, the evidence on function of SSMR indicates that MSOT and LSOT differ in terms of timing and adequacy of the SSMR during CPS. If the functions of SSMR are ill-timed or inadequate during regulation, they may significantly impact the effectiveness of SSMR, regardless of how frequently regulatory processes occur (Badhe et al., 2022; Vauras, Volet, & Iiskala, 2021). The differences with respect to the nature of the SSMR shows that in MSOT, strategy formulation and execution was consistent and goal-directed, whereas in LSOT, it was interruptive and momentary. The interruptions and abrupt shifts in the SSMR strategies may hamper collective discussions and outcomes. This study adds value to SSMR research by revealing different types of trigger situations experienced by teams with divergent outcomes, and by highlighting the nature of their varied SSMR responses during CPS. The findings are aligned with the prior but limited literature on triggers of SSMR. This study provides empirical evidence of occurrences of trigger situations for MSOT and LSOT and differences in their corresponding SSMR response. These findings have implications for developing targeted scaffolds for teams during CPS.

5. Limitation & Future Work

Although this study provides insights into shared metacognition in CPS, it has limitations. Some teams may have worked outside the classroom, with those interactions not captured. Future research should include asynchronous data and broader sources for comprehensive analysis. The small sample size and factors like motivation or task interest may have influenced SSMR. Larger, more diverse samples and replication across educational contexts would enhance generalizability and validate findings.

6. Conclusion

This study explored triggers and SSMR behavior during ill-structured CPS tasks among four teams with divergent outcomes in semester-long project-based learning HCI course, categorized as MSOT and LSOT based on their performance. We have investigated triggers of SSMR (i.e. ME, SCC, EF). The contrast between these types of teams enabled a deeper examination of the focus and function of their SSMR. It also revealed the dynamics of their SSMR, showing how team members negotiated, shared perceptions about collaboration, and exercised control over the tasks in different ways. The findings indicated notable differences between MSOT and LSOT in terms of the triggers, the focus, and function of SSMR, and how SSMR strategies evolved over time. MSOT maintained a fundamental focus, allowing teams to identify and engage with the core elements necessary for solving the task. In contrast, LSOT tended to operate with surface-level focuses, often concentrating on non-essential aspects. MSOT implemented SSMR strategies effectively and at timely moments during CPS, whereas LSOT's application of these strategies was less effective and poorly timed.

Additionally, while MSOT's approach to strategy formulation and execution was consistent and aligned with their goals, LSOT's efforts appeared sporadic and lacked continuity. These insights contribute to a more refined understanding of the triggers of SSMR along with the defining differences among MSOT and LSOT. By identifying triggers, focus, and functions of SSMR, the findings provide a foundation for designing targeted scaffold mechanisms to strengthen SSMR in CPS contexts.

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Ethics approval

This research study was conducted in strict accordance with the guidelines of the Institutional Review Board (IRB) and Ethics Committee at the Indian Institute of Technology Bombay, India.

References

Badhe, V., Priyadarshini, R., & Dasgupta, C. (2022). Understanding SSRL strategies and its impact on group performance in a CSCL environment: a case study from a project-based learning course in India. In Proceedings of the 15th ICLS-CSCL 2022, pp. 187-194.

Chan, C. K. (2012). Co-regulation of learning in computer-supported collaborative learning environments:A discussion. Metacognition and Learning, 7, 63–73.

De Backer, L., Van Keer, H., & Valcke, M. (2022). The functions of shared metacognitive regulation and their differential relation with collaborative learners' understanding of the learning content. Learning and Instruction, 77, 101527.

Efklides, A. (2006). Metacognition and affect: What can metacognitive experiences tell us about the learning process? Educational Research Review, 1, 3–14.

Efklides, A., Papadaki, M., Papantoniou, G., & Kiosseoglou, G. (1998). Individual differences in feelings of difficulty: the case of school mathematics. European Journal of Psychology of Education

Grau, V., & Whitebread, D. (2012). Self and social regulation of learning during collaborative activities in the classroom: The interplay of individual and group cognition. Learning and Instruction, 22(6), 401-412.

Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning. Hellenic Journal of Psychology, 1, 147–178. https://psycnet.apa.org/record/2005-14171-003

Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. Learning and Instruction

Iiskala, T., Volet, S., Jones, C., Koretsky, M., & Vauras, M. (2021). Significance of forms and foci of metacognitive regulation in collaborative science learning of less and more successful outcome groups in diverse contexts. *Instructional Science*

Iiskala, T., Volet, S., Lehtinen, E., & Vauras, M. (2015). Socially shared metacognitive regulation in asynchronous CSCL in science: Functions, evolution and participation. Frontline Learning Research, 3(1), 78-111.

Järvelä, S., Järvenoja, H., Malmberg, J., & Hadwin, A. F. (2013). Exploring socially shared regulation in the context of collaboration. Journal of Cognitive Education and Psychology, 12(3), 267-286.

Järvelä, S., & Hadwin, A. (2024). Triggers for self-regulated learning: A conceptual framework for advancing multimodal research about SRL. Learning and Individual Differences, 115, 102526.

Kerrigan, S., Feng, S., Vuthaluru, R., Ifenthaler, D., Gibson, D. (2021). Network Analytics of Collaborative Problem-Solving. In: Ifenthaler, D., Sampson, D.G., Isaías, P. (eds) Balancing the Tension between Digital Technologies and Learning Sciences. Cognition and Exploratory Learning in the Digital Age. Springer, Cham.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. Biometrics, 33, 159–174. https://doi.org/10.2307/2529310

Lobczowski, N. G., Lyons, K., Greene, J. A., & McLaughlin, J. E. (2021). Socially shared metacognition in a project-based learning environment: A comparative case study. *Learning, Culture and Social Interaction,* 30, 100543. https://doi.org/10.1016/j.lcsi.2021.100543

Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. Approaches to qualitative research in mathematics education: Examples of methodology and methods, 365-380

Vauras, M., Volet, S., & Iiskala, T. (2021). Socially-shared metacognitive regulation in collaborative science learning. Trends and prospects in metacognition research across the life span: A tribute to Anastasia Efklides, 83-102.