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How Do Students Deliberate for Socially Shared Regulation in Collaborative Learning? A Process-Oriented Approach

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Abstract: Socially shared regulation (SSRL) has been recognized as a contributing factor to successful collaborative learning. In this paper, we adopted a process-oriented approach to examine how students deliberate for SSRL through different regulatory triggers in a collaborative learning context. More specifically, this study examines the relationship between different types of regulatory and deliberative characteristics of interactions and then explores their sequential patterns through cognitive and emotional triggers. The study involved ten triads of secondary students (N=30) working on a collaborative learning task. The process mining results showed that following regulatory triggers, groups switched to more metacognitive and socio-emotional interactions as they adopted control strategies, such as defining problems, establishing strategies, and providing social support. This study not only contributes to a better understanding of SSRL by exploring learners' deliberative negotiation but also presents a novel fine-grain video analysis approach to examine SSRL in collaborative learning.

Introduction

Driven by the needs of the 21st century, collaboration and self-regulated learning are increasingly important skills for academic success, career progression, and life-long development (Järvelä et al., 2019). Increasing evidence suggests that regulation in learning is critical for achieving collaborative success at both the individual and group levels (Bakhtiar & Hadwin, 2020). This has, thus, offset an evolution of growing bodies of research in self-regulated learning (SRL) and its social forms namely co-regulated learning (CoRL) and socially shared regulated learning (SSRL) (Hadwin et al., 2018) in collaborative contexts such as computer-supported collaborative learning or collaborative problem-solving (Michalsky & Cohen, 2021; Zheng et al., 2019). However, the main challenge faced by many researchers in the field is that it is difficult to capture and study (S)SRL in authentic learning contexts (Järvelä et al., 2019). (S)SRL rarely occurs in normal learning situations and the dynamic cyclical, multidimensional, and intertwined nature makes it difficult to identify, complex to examine and little is known about its emerging mechanism. In collaborative contexts, all three types of regulation exist, interact dynamically, and influence each other (Bakhtiar & Hadwin, 2020; Järvelä et al., 2019). Through constant reflection and negotiation with the self, context, and other(s), learners take control of the learning process and overcome challenges through constant iterative adaptation at different levels of cognitive, behavioral, motivational, and emotional conditions. Collaboration is often inhibited by multiple levels of challenges such as task difficulties, lack of shared understanding, or emotional conflicts (Järvenoja et al., 2019). However, research has reported a relationship between these challenging situations and regulatory activities. Researchers have argued that negative incidents and obstacles can also trigger discussions and negotiation among group members, suggesting its potential for locating situated interactions for regulation in response to them (Järvelä et al., 2019).

In line with this call, our study aims to provide empirical evidence regarding the potential of using regulatory triggers as treating conditions to stimulate and locate regulatory interactions. A regulatory trigger refers to a motivational, cognitive, emotional, or behavioral event that inhibits task progress and requires adaptation of current regulatory practices or strategies (Järvelä et al., 2023). In this study, we particularly examine the cognitive and emotional triggers that target the adaptive process of cognition and emotion correspondingly. We attempt to examine SSRL from a deliberation process-oriented approach, as theories of SSRL have suggested negotiation is one of the core mechanisms for the cyclical adaptation of regulated learning (Hadwin et al., 2018). The focus on deliberative negotiation, i.e., the term "deliberation", is chosen for its distinctive emphasis on convergent interests and a shared nature (Ihnen, 2014). We examined the types and patterns of interactions throughout regulatory triggers from both regulation and deliberation perspectives. Specifically, our research questions are as follows:

- RQ1: Is there a relationship between regulatory and deliberative characteristics of interactions in response to cognitive and emotional regulatory triggers?
- RQ2: What are the patterns of the regulatory and deliberative characteristics of interactions through different types of regulatory triggers?

Theoretical background

Socially shared regulation in collaborative learning

Three types of regulation emerge as necessary for success in the context of collaboration: (a) self-regulated learning in which individuals systematically adapt their own regulation processes, beliefs, and goals; (b) co-regulated learning in which individuals support or influence another team member's regulation processes, beliefs, and goals; and (c) socially shared regulation of learning in which team members collectively negotiate, realign, or adapt group regulation process, strategies, beliefs, and goals (Järvelä et al., 2016). In this model, phases of collaborative solving are defined as task understanding, planning, task enactment, and reflection and adaptation (Hadwin et al., 2018). Thus, group regulation is a cyclical and social phenomenon requiring both regulations of cognitive and relational states of collaboration.

Research has shown many learners lack regulatory skills and struggle to enact them when working on complex collaborative tasks (Järvelä et al., 2019). This inability to regulate cognitive and relational states may explain why learners often struggle to collaboratively problem-solve and co-construct knowledge. In this paper, we aim to study the nature of group regulation during problem-solving in the presence of cognitive and emotional triggers to better understand how to support learners during these collaborative challenges.

Challenges and negotiation in SSRL

A critical marker of successful regulation is a learner's ability to adaptively respond to challenges during collaboration to optimize both personal and group goal progress. This adaptation is not spontaneous but rather emerges only when strategically and purposefully enacted during moments that the task, situation, or social domain requires it (Hadwin et al., 2018). It is well established that this complex, multifaceted phenomenon is difficult to observe and rarely occurs naturally in collaborative contexts (Nguyen et al., 2022). Consequently, experimentally studied data collection must be carefully designed to introduce these challenges to effectively and timely capture these situated responses and interactions (Järvelä et al., 2019). Accordingly, this study presents a systematic introduction of treatments comprising cognitive and emotional triggers to better collect and analyze interactions during critically situated regulatory phases.

While these challenges introduce difficulty in regulation on both the individual and group levels, they also provide opportunities for learners to engage in active and purposeful negotiation to align goals, motivations, and beliefs. Deliberative negotiation is described as one important mechanism by which productive groups can strategically take control of collaborative challenges and adapt to them as they arise. Prior research supports that increasing opportunities for purposeful deliberation during collaborative challenges may lead to beneficial outcomes. Less successful collaboration is often characterized by parallel working and ignorance of other group members' contributions (Haataja et al., 2022). Challenges make group members' different understandings more visible and individual emotions more explicit (Kreijns et al., 2013), which in turn offers opportunities for learners to better negotiate and align their collaboration (Rogat & Linnenbrink-Garcia, 2011). In other words, the presence of these challenges provides more opportunities and awareness for team members to purposefully regulate learning so that group goals, motivation, and beliefs can be better deliberated and aligned (Hadwin et al., 2018).

However, despite the interest in these deliberative interactions, a dearth of past research has focused on examining group regulation from a negotiation-based deliberative perspective. Most research on regulation has been explored from a macro-perspective at the level of an episode (Nguyen et al., 2023) rather than a more granular perspective required to effectively study back-and-forth negotiation. Therefore, our study explores regulation from a fine-grained lens at the unit of a single discussion contribution to better examine patterns during deliberative negotiation.

Research methods

Participant, context, research design

Data collection involved thirty secondary school students (N=30) working on a face-to-face collaborative learning task for 30-40 minutes. They are randomly assigned into 10 groups of three students each then being required to plan together a healthy breakfast smoothie based on nutritional needs. Each group has a shared document for the task and each student has their own laptop. After the first half of the learning task, the cognitive trigger will be presented to the group in the form of a customer voice message, stating an allergy to a certain product. This is followed by an emotional trigger after three minutes, with the customer calling to express impatience in an unpleasant voice. Video and audio data were collected using Insta360 Pro video cameras and a group microphone.

Data analysis

To answer the research questions, we first examined group interactions based on their regulatory and deliberative characteristics through qualitative coding and content analysis of video-recorded student collaborative learning sessions. A granular coding was conducted for the period from 2 minutes prior to the first cognitive trigger to 3 minutes after the emotional trigger. While quantitative statistical analyses were performed to check the correctness of our assumption, a process mining approach was utilized to reveal the patterns within these characteristics.

Video qualitative analysis

As a means of capturing the relatively abstract phenomenon of SSRL that is suitable for sophisticated AI analysis, two coding schemes for qualitative video analysis are employed, one for high-level regulatory (SSRL) characteristics and one for low-level deliberative characteristics of group interactions that is easier to conceptualize, code, and capture in the data. This enables the modelling of high-level SSRL on low-level activities for a more comprehensive and accurate understanding of the multi-level complexities of SSRL. First, to identify different types of regulatory characteristics of interactions, a coding instrument was adopted from prior studies (Näykki et al., 2021; Nguyen et al., 2022). Four different categories (as described in **Table 1**) were included: metacognitive interaction, cognitive interaction, socio-emotional interaction, and task execution interaction. This study adopted Järvelä et al. (2023)'s human-AI collaboration approach, in which a micro-analytical recording technique was employed to enable fine-grained qualitative video coding of students' every speaking turn. This approach allowed for a more sophisticated and detailed analysis in contrast to the previous episode-level coding approach. The data were then coded by a researcher, which included 1,220 utterances with different regulatory characteristics defined in total ($f_{\text{Metacognitive}} = 407$, $f_{\text{Cognitive}} = 379$, $f_{\text{Socio-emo}} = 61$, $f_{\text{Task execution}} = 373$). A reliability test of the coding was done with two coders for 239 utterances resulting in moderate to high Cohen's Kappa value (κTask execution= 0.63; κCogntive = 0.69; κMetacognitive =0.71; κSocio-emo =0.88).

Table 1

Coding scheme for video quantitative analysis

Categories	Description	Example
Regulatory characteristics of interactions		
Metacognitive interaction	Meta-level mental processes toward the control and monitoring of cognitive and emotional activities (orienting, planning, monitoring, evaluating, and regulating). The connection and reflection are aimed at task-related strategies, group processes, or dynamics.	*S1: By the way, I don't use this ingredient page at all, I just put it in there and see what happens.* *S2: If we just keep the ingredients the same, but increase their number in the same ratio, so then those percentages go absolutely nowhere.*
Cognitive interaction	Interaction focuses on higher-order learning-related thinking skills such as understanding, analyzing, reasoning, and evaluating at the object-level related to task content.	*S2: Well, here are the others, here are all the chia seeds, hazelnut spread, whey protein powder.* *S1: But here would be pineapple or blueberry, then they would be the kind where there would be very little of everything.*
Socio-emotional interaction	Action and interaction relevant to the expression of one's emotion in social contexts with clear negative/positive affect nature (e.g., showing gratitude, joking, disputing)	*S1: Oh good time, this guy first orders a smoothie, and then tells us to make it again and then complains that it's taking us a long time to make it this. [Express annoyance with group show shared feeling]*
Task execution interaction	Actions and interactions that primarily focus on carrying out task requirements, and completing the task include: i.e. typing on the computer, reading the instruction	*S1: Yeah, I'll change them to one hundred and twenty-five. [Inform current process]* *S2: One hundred and twenty-five. OK that should be twenty-five then.*

Since the present study has been one of the first attempts to thoroughly examine the deliberative characteristics of interactions in SSRL at the granular level, there is no existing coding scheme found suitable. Accordingly, we conducted the qualitative content analysis for deliberative characteristics by following Onwuegbuzie et al. (2009)'s constant comparison method. Group utterances first underwent an open coding stage, in which each was assigned a descriptor that describes an aspect of the deliberation process. Next, researchers developed and refined themes that express the content of each code or group of codes. Notwithstanding more comprehensive reliability testing should be conducted to establish a formal coding scheme for deliberative characteristics, the results of the content analysis certainly add to our understanding of the processes of deliberation in SSRL. The resulting coding themes are reported in Table 2.

Table 2

Types of deliberative characteristics of interactions as the results of constant comparison analysis

Deliberative characteristics of interactions		
Define the problem	Share understanding of the problem, defining the present situation and the desired future, to make the current issues problem clearer to group members.	*S1: So, what couldn't be there?* *S2: Natural rubber and milk protein allergy.* *S1: Well, should the natural rubber be that low or…* *S2: Yes, all of them should be low. [..]It's not good when hazelnut spread has natural rubber so high…*
Establish strategy	Suggestion and implementation of process steps (how to approach the tasks, ways of executing certain aspects of the task)	*S1: […] we need another 250 kilocalories, half of it.* *S2: Yes, […] And then we'll get increased protein and fat if we only put these […] Let's raise everyone a little, so it won't change these ratios.* *S1 & S3: Yeah. (Okay).*
Specify information needs	Identify technical background information that is pertinent to the issue; identify information that is available and information that is needed.	*S1: Where does it say natural rubber?* *S2: It reads over there, on the other side.* *S3: That last one of those nutrients.*
Educate each other	For back-and-forth discussions of group members trying to work on disagreement and align shared understanding by identifying and sharing understanding, interests, reasons, needs, etc.	*S1: Well, but you mustn't bring a lot of fat at once.* *S2: We already have a package.* *S3: Let's put something in it.* *S2: We don't have that […] You can't put anything left.*
Generate options	Brainstorm and generate a solution for task-related problem-solving: offer alternatives of choices.	*S1: Where can I get more energy?* *S2: Shall we put that oatmeal in there?*
Evaluate options	Make a judgment about the generated options	*S1: Shall we put kale in there when?* *S2: It sounds a bit strange*
Reach agreement	Confirm shared agreement on the options, ideas, and opinions.	*S1 & S2: Oat or almond, is it either?* *S3: Oat drink* *S1: Okay, let's make an oat drink.*
Implement the agreement	Carry out the selected options or attempt ideas.	*S1: Yeah, I'll change them to one hundred and twenty-five. [Inform current process from previous agreement]*
Attempt ideas	Apply for testing out alternatives/solutions without forethought & discussion between group members.	*S1: I'm going to try a bit of randomness here now, there's a moderate one, so not really*
Monitor the time	Keep track and check on the time	*S1: There are now four hundred and ninety-eight calories. Isn't it about time?* *S2: I don't think it's the time*
Monitor group operation	Observe and check on the group's focus and shared agreement, current progress within the task, and quality of the procedure.	*S1: It's time we think about how we can produce protein* *S2: So here…*
Monitor environmental context	Observe and check on other conditions around the task, i.e., technical and resources; social conditions.	*S1: Oh yeah, isn't it, and it's just a visual glitch of ours that the fat is half of what it should be?*
Monitor the result	Check on task requirements and how the current result is meeting those.	*S1: Now we have a little too many calories.* *S2: Isn't the maximum - about 500 didn't read here?*
Evaluate group operation	Make a judgment about group focus, shared agreement, current progress, and procedure quality.	*S1: Now it's good. Wise one about 500 [Complement group's strategy]*
Evaluate the result	Make a judgment about the current result in accordance with the task requirement.	*S1: If we score it 15 g, then five hundred and five, pretty much those. I guess there is nothing to complain.*
Regulate group emo-mo	Interaction with the intention of regulating group focus or emotional - motivation about the situation	*S1: Well, it's probably right for us.* *S2: If it's the same for you, then we'll trust it.*
Positive socioemotional interaction	Positive socio-emo interaction without the intention of regulation.	*S1: Well, it's not- (It's my own fault when I forgot my allergy.)* *S2 & S3: synchronous laughing and agreeing to*
Negative socioemotional interaction	Negative/ neutral socio-emo interaction without the intention of regulation.	*S1: Well, if only we scored something. [all group member non-verbal show lack of motivation]*

Process mining

A process-oriented analysis is utilized to identify and describe the sequences and patterns of regulatory and deliberative characteristics of group interactions throughout regulatory triggers. Fuzzy Mining, a process-mining algorithm, was used to explore the time-related pathways among different phases before the cognitive trigger (269 utterances), after the cognitive trigger (483 utterances), and after the emotional trigger (468 utterances). The analysis was performed using Fluxicon Disco, a process mining software program commonly used in learning sciences research for describing sequences in learning logs or activities (e.g., Nguyen et al., 2022).

Result and findings

RQ1: Is there a relationship between regulatory and deliberative characteristics of interactions in response to cognitive and emotional regulatory triggers?

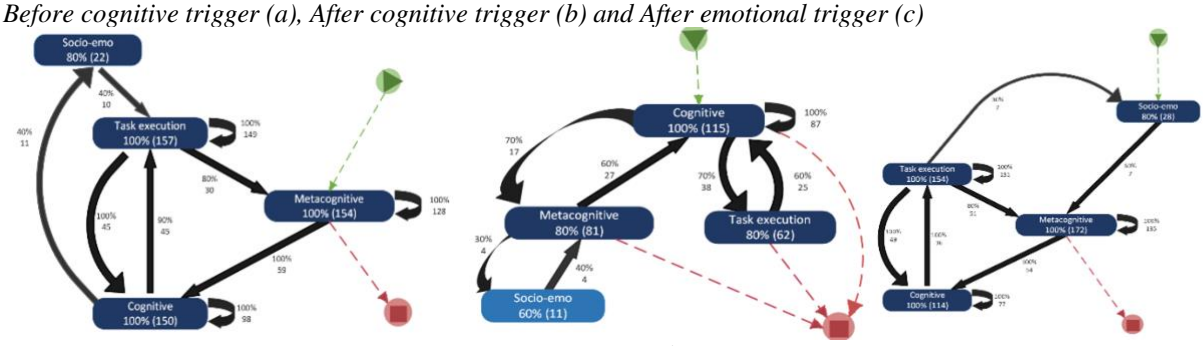
To answer this research question, Chi-square and Cramer's V tests were applied to first validate the impact of regulatory triggers on the regulatory and deliberative characteristics of group interactions, then to examine the correlation between these two types of characteristics. First, we assessed the distributions of interactions based on their regulatory and deliberative characteristics among three timespans: before triggers; after the cognitive trigger; and after the emotional trigger. The result showed that the distribution of regulatory characteristics of interactions significantly differed among the timespans before and after the regulatory triggers ($\chi 2 = 76.7$; df = 12; $p < .001$). The effect size for this finding, Cramer's V, was small, 0.12 (df = 3). This finding validated the effects of our experimental treatments as regulatory triggers and corresponded with existing literature on social forms of SRL which found that negative incidents and challenges raise students' metacognitive awareness and trigger more interactions for regulation (Järvelä et al., 2016; Saariaho et al., 2019). However, some dynamic factors of the group, such as participation levels or group characteristics (Ucan, 2017) may mediate the effect on the occurrence of regulatory characteristics manifested in interactions, which would explain the small magnitude of the effect. Second, the Chi-square and Cramer's V tests for deliberative characteristics of interactions and the timespans indicated a significant difference in the proportions associated with each timespan with a medium effect ($\chi 2 = 503.9$; df = 68; $p < .001$, V = .26). This result again confirmed the role of the regulatory triggers in activating group regulation and altering the dynamics of deliberative characteristics in collaborative learning. Last, we examined the association between the distributions of regulatory and deliberative characteristics of interactions. The results showed that the amount of variance in different types of interactions for regulation based on the deliberative interactions was significant ($\chi 2 = 3006.2$; df = 51; $p < .001$) with a large effect size (V = .75, df = 3). It was thus appropriate to say that there was a significant association between different types of regulatory and deliberative characteristics of group interactions.

RQ2: What are the patterns of interactions for regulation and deliberative interactions through different types of regulatory triggers?

The process maps (see Figure 1) showed the most dominant trajectory of regulatory characteristics, which were engaged in different phases before and after regulatory triggers by all groups. The maps reported absolute frequency and case coverage in the percentage of interactions for regulation of all groups.

Figure 1

Process maps for patterns of interactions for regulation through cognitive and emotional regulatory triggers: Before cognitive trigger (a), After cognitive trigger (b) and After emotional trigger (c)

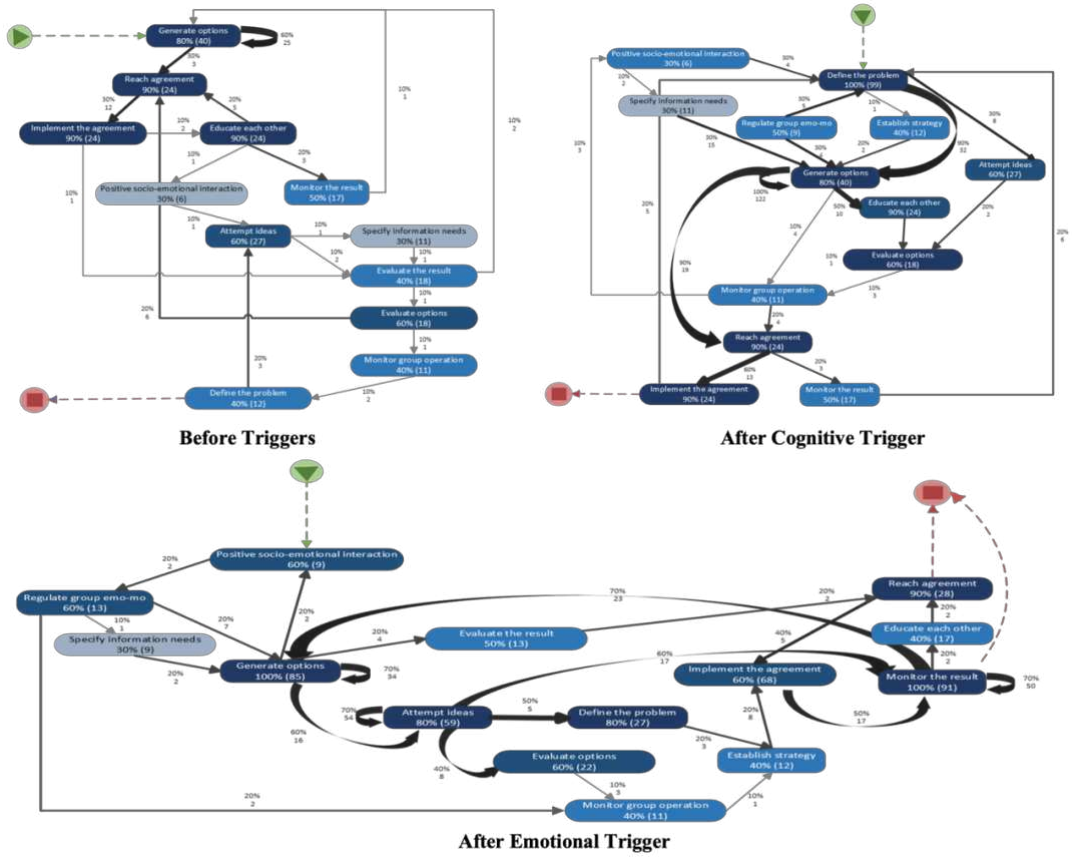


(a) (b) (c)

Overall, it is evident that there has been a clear shift in the pattern of regulatory characteristics in response to different triggers. The result indicates that prior to regulatory triggers, most groups started by engaging in *cognitive interaction* (f = 100%) repeatedly which then led to *task execution* ($f_{\text{Cognitive -> Task execution}}$ = 70%) and looped back. After the first cognitive trigger, the most dominant process flow started instead with 1) *metacognitive interaction* (f = 100%) then in a path in the following sequence: 2) *cognitive interaction*, 3) *task execution interaction*, and looped back. Succeeding the emotional trigger, the majority of groups became involved in *socio-emotional interaction* (f = 80%) then followed by the previously observed pathways after the cognitive trigger. We also examined the absolute frequency of regulatory characteristics of interactions. There was a significant increase in instances of metacognitive ($f_{\text{Before CT}}$ = 62 -> $f_{\text{After CT}}$ = 154) and socio-emo interactions ($f_{\text{Before CT}}$ = 11 -> $f_{\text{After ET}}$ = 28). In addition to confirming previous studies that have discussed the impact of cognitive and social challenges on facilitating regulation (Näykki et al., 2021), our results provide empirical evidence for the potential of triggers to locate and capture the types and sequences of regulatory characteristics of interactions as they occur in practice. Moreover, the shared sequence of regulatory characteristics manifested in interactions in response to cognitive and emotional triggers identified in our study can be an indicator of strategic actions that are more adaptive to learning.

Figure 2

Process maps for patterns of deliberative interactions through cognitive and emotional regulatory triggers



Turning to the patterns of deliberative characteristics through cognitive and emotional triggers, the process maps in **Figure 2** revealed the difference between phases of regulatory triggers. Our results showed that immediately preceding the regulatory trigger, most groups engaged in a deliberative pattern that is adequately conventional in collaborative learning contexts, starting with *generate options* (f = 80%), followed by *reach agreement* ($f_{\text{Generate options -> Reach agreement}}$ = 30%), and then *implement the agreement* ($f_{\text{Reach agreement -> Implement agreement}}$ = 30%). However, group deliberative characteristics after cognitive and emotional triggers shifted more toward metacognitive in nature such as focusing on the strategies to complete the tasks or providing support to one another. While this shift is highly correlated with that regulatory characteristics, our study found that the patterns and utterance types groups engaged in were different between cognitive and emotional triggers. After the cognitive trigger, the most dominant process flow started instead with *define the problem* (f = 100%). While the

expected path for collaborative learning remains prominent, the patterns of deliberative utterance types prior to and after *generating options* are different from those of the previous stage. Most groups engaged in *regulate group emo-mo* (f = 50%) or *establish strategy* (f = 40%) as a prelude to *generate options* and followed by *educate each other* (f = 50%) or *monitor group operation* (f = 10%) before *reach agreement*. The deliberative pattern reflects a strategic control of group behavior to solve problems that are cognitive in nature. In comparison, the deliberative characteristics after the emotional trigger focused more on group emotion regulation, beginning with *positive-socioemotional interaction* (f = 60%), followed by *regulate group emo-mo* (f = 60%) before *generate options* (f = 85). Taken together, these findings support our assumption of using deliberative utterance as a lens for examining how SSRL occurs in collaborative learning at a more granular level.

Discussion and implications

The aim of this study was to provide empirical evidence of how regulatory triggers can be utilized as a part of (S)SRL research designs to capture critical in-situ regulatory phases in challenging learning situations. Previous studies have pointed out a significant link between challenging situations and their ability to invite metacognitive awareness and create opportunities for regulatory activities (Järvelä et al., 2019; Näykki et al., 2021). However, it is well established that (S)SRL is a complex, dynamic, cyclical, and multifaceted process that is difficult to capture and rarely happens in most learning contexts (Nguyen et al., 2022) and more is needed to examine this relationship (Raković et al., 2022). Recent research has introduced the trigger concept to examine SSRL (Järvelä et al., 2023). Our study is one of the first to attempt to introduce control treatments of regulatory triggers and to examine SSRL processes in the context of face-to-face collaborative learning at a granular level.

This study provided evidence that regulatory triggers facilitate regulatory processes in collaborative learning and confirm our theoretical predictions (Järvelä et al., 2023). Our findings revealed a significant difference in the proportions of different types of regulatory and deliberative characteristics manifested in interactions before and after regulatory triggers. More specifically, our findings revealed that groups switched from a more cognitive collaborative task-solving process to engage in more metacognitive interactions after the cognitive trigger and socio-emotional interactions after the emotional trigger. In light of these findings, it is argued that regulatory triggers could serve as a marker to locate the regulation taking place to overcome it. This current study responds to a recent call for a new methodological approach to effectively obtain richer data to advance our understanding of SSRL and how to support it in the face of collaborative challenges (Järvelä et al., 2019).

The second objective of this study was to examine how the deliberative characteristics of interactions progressed throughout SSRL in collaborative learning. Based on the progress in understanding and conceptualization of SSRL over the past two decades, the current SSRL theory posits that in collaboration, all three forms of regulation (SRL, CoRL, and SSRL) co-exist and influence each other via negotiation and social interactions (Bakhtiar & Hadwin, 2020; Järvelä et al., 2019). Despite the importance of the negotiation mechanisms for regulation in collaborative learning, there is little published data that examine group regulation through the lens of negotiation processes. Accordingly, this study appears to be one of the first studies to closely examine the deliberative negotiation process in SSRL.

It has been argued that the existing studies often examined SSRL from a macro perspective of phases and meaningful episodes with fixed time intervals, which has been deemed inadequate for advanced methods such as machine learning (Nguyen et al., 2022). Furthermore, although prior studies offered valuable insights into SSRL, the current approaches with fixed time intervals are not sufficient for examining regulatory adaptation at different levels of granularity to comprehensively address the cyclical and dynamic nature of SSRL (Järvelä et al., 2019). Our study attempts to bridge this gap by exploring the possibility of analyzing SSRL from a deliberative process perspective incorporated within fine-grain utterances for every discussion contribution. The present study not only contributes to a better understanding of SSRL, but also delivers a methodological contribution with a novel video analysis approach to examine SSRL in collaborative learning (Järvelä et al., 2019).

The current study has some limitations. First, this study has a small sample size. Moreover, the high level of contextualization in the collaborative task limits the generalizability of these findings to other learning environments. Second, as aforementioned in the video analysis, further research is needed to thoroughly examine the reliability of the content analysis results for deliberative characteristics of interactions. In spite of its limitations, the study contributes to a better understanding of SSRL in collaborative problem-solving contexts, establishing a new basis for methodological and theoretical progression, thus potentially increasing our understanding of how SSRL manifests. Further research could be conducted to investigate how to utilize and apply AI techniques to comprehend the fine-grain analysis approach for offering a new lens through which SSRL could be better understood and support could be designed for promoting SSRL in face-to-face collaborative learning settings.

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