Sequential Patterns in Social Interaction States for Regulation in Collaborative Learning

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Abstract

This study explored sequential patterns in social interaction states for group-level regulation of learning during collaborative learning. The participants were secondary school students (*N* = 92) performing collaborative physics tasks. The videotaped sessions were analyzed regarding participation, social interaction, and group-level regulation types of co- and socially shared regulation. The results show that group-level regulation emerged most frequently in social interaction state that included cognitive and socioemotional interaction and whole-group participation, which also led to and followed regulation most frequently. The findings highlight the role of joint participation in social interactions for regulation of learning in collaborative group settings.

Keywords

cognition, collaborative learning, group process, interaction, social

Since learning increasingly takes place in collaborative group settings, understanding the processes and aspects that contribute to smooth and effective *collaborative learning* (CL) has become the center of focus of many scholars. Previous research has aimed to identify why and when collaborative groups succeed or fail, and recognized a set of cognitive and social mechanisms that may facilitate or constrain successful collaboration (Larson, 2013; Nokes-Malach & Richey, 2015; Steiner, 1972), such as productive interactions (e.g., joint management of attention; Barron, 2003), team reflexivity (Li et al., 2021), or disciplinary engagement (Engle, 2002). Since decades of research has shown that self-regulation of learning is a crucial factor for successful individual learning (e.g., Winne, 2017; Zimmerman, 2000, 2008), more research has shifted towards studying regulation of learning also in CL context (e.g., Grau et al., 2018; Malmberg et al., 2017; Zhang et al., 2021).

Previous research has addressed that in CL, regulating one's own learning is not always sufficient, but learners also need to support and regulate the learning of others (*co-regulation of learning* [CoRL]) as well as the whole group (*socially shared regulation* [SSRL]) to overcome obstacles and succeed in collaborative tasks together (Hadwin et al., 2017; Järvelä et al., 2018; Lajoie & Lu, 2011). These social forms of regulation, which in this study are termed *group-level regulation types*, allow learners to plan, monitor, and evaluate their learning beyond the individual level when needed through *social interaction* (Järvelä & Hadwin, 2013; Näykki, Isohätälä, et al., 2017; Saab, 2012). Previous research has focused on investigating the relationship between group-level regulation of learning and social interaction, for example, through the lens of the emotional tone of the interactions, as in how positive or negative interactions are interrelated with regulation in group settings (e.g., Rogat & Linnenbrink-Garcia, 2011; Ucan & Webb, 2015). Since social interaction requires active participation (i.e., learners' contribution to communicative exchanges with each other; Clark & Brennan, 1991), research has also suggested that learner's or group's participation in social interaction may correlate with regulation of learning in group settings (Grau & Whitebread, 2012; Iiskala et al., 2015; Isohätälä et al., 2020; Sinha et al., 2015; Volet et al., 2009). Still, previous studies provide little to no empirical evidence on the time-related patterns of the relationship between these facets. While scholars have investigated the sequential mechanisms during regulation, such as patterns in learners' self-regulation (Bannert et al., 2014) or the temporal order of regulatory phases (Sobocinski et al., 2017), what remains unclear is what kinds of interaction patterns may facilitate regulation in group settings (Järvelä et al., 2019). Therefore, the present study does not aim to explain regulatory processes as such (e.g., the phases of regulation) but rather aims to explore the patterns of participation and social interaction that may facilitate group-level regulation during CL.

Previous studies have highlighted the importance of favorable interaction patterns for productive or successful collaboration in groups (e.g., Chang et al., 2017; Strauß & Rummel, 2021). Research in the context of work groups and organizational teams have also shown that the interaction processes group members engage in act as a mediator that may contribute to group's output (e.g., success, learning; Marks et al., 2001) and input (e.g., team characteristics) due to the cyclical nature of groups' collaboration processes (Ilgen et al., 2005). Such mediating mechanisms can be affective, cognitive, behavioral, or a combination of these facets (Ilgen et al., 2005). Also, team regulatory processes, such as team reflexivity, have been recognized to play a role in improving team performance (Schippers et al., 2013, 2018). In addition to investigating the patterns of participation and social interaction that may facilitate group-level regulation of learning as situational outcome, this study sheds light on different interaction and group-level regulation patterns in CL groups with higher or lower group performance.

Co- and Socially Shared Regulation of Learning in Collaborative Setting

Despite the benefits of collaborative groups, such as advancing learner's critical thinking skills and motivation (Laal & Ghodsi, 2012) as well as engagement, social skills, and achievement (Cohen & Lotan, 2014), collaboration in group settings is not always successful. There are several cognitive and social factors that may result in failure or poor performance in collaborative groups (Nokes-Malach & Richey, 2015), such as issues with group members' coordination or motivation (Steiner, 1972). While the issues in collaborative groups or processes may vary, what makes CL particularly difficult is that learners struggle to recognize the emerging challenges or operate in challenging learning situations as a group (Järvelä et al., 2016; Rogat & Adams-Wiggins, 2015). Research have shown that to overcome such challenges, successful and committed learners can regulate their learning through setting goals, monitoring, and adapting their learning to achieve the set goals (e.g., Barron, 2003; Järvelä & Hadwin, 2013; Pintrich, 2000). In this study, regulation of learning stems from Winne and Hadwin's (1998) self-regulated learning theory, which involves learner's strategic and cyclical planning, monitoring, adapting, and evaluating of the cognitive, behavioral, motivational, and emotional conditions of learning whenever needed. These conditions influence one another (Hadwin et al., 2017), create a context for learner engagement in regulatory processes (Bakhtiar et al., 2018), and can either serve or constrain regulation of learning (Winne & Hadwin, 2008).

Because CL is highly interactive and social, the management and regulation of learning processes can be needed beyond the "self," and may reach other individuals in the group (i.e., CoRL) as well as the whole group's learning process (i.e., SSRL; Hadwin et al., 2017; Järvelä et al., 2010). These group-level regulation types target the cognitive and socioemotional challenges that the learners or the group face during collaborative tasks (Hadwin & Oshige, 2011; Hadwin et al., 2017). What distinguishes CoRL from SSRL is the extent to which regulation emerges. CoRL can be described as regulation of learning on a "you" -level, as it refers to learners giving regulatory support or stimulation to each other when needed (Hadwin et al., 2017). CoRL requires group members to develop an awareness of each other's beliefs and goals, and it involves learners providing temporal regulatory support to one another (Järvelä et al., 2018). SSRL covers the regulation of learning on a "we" -level, as it specifically targets the group's learning process and occurs as a group-level phenomenon. In SSRL, multiple individual perspectives contribute collectively to joint regulation through negotiation and continual adaptation when needed (Järvelä et al., 2018). Thus, in SSRL, regulatory acts and strategies, such as setting goals, monitoring, and evaluating, are shared and negotiated collectively among learners as a group (Hadwin et al., 2017; Winne et al., 2013).

Empirical evidence on the distinction between CoRL and SSRL has been analyzed in a review by Panadero and Järvelä (2015) that included the examination of 17 research articles. Five of the reviewed studies showed direct evidence (Grau & Whitebread, 2012; Järvelä et al., 2013; Rogat & Linnenbrink-Garcia, 2011; Volet & Mansfield, 2006; Volet et al., 2009) and two studies showed indirect evidence (DiDonato, 2013; Janssen et al., 2012) of the difference between CoRL and SSRL. While the analysis showed that there is enough evidence for the distinction between SSRL and CoRL, different types of regulation are also considered as embedded into each other (Panadero & Järvelä, 2015). Specifically, CoRL plays a role in providing affordances (and sometimes constrains) for both self-regulated learning and SSRL (Hadwin et al., 2017). On the one hand this highlights the importance of distinguishing different regulation types to understand, for example, their relations, but on the other hand, it demonstrates the complexity of the phenomenon. Further, contrary to self-regulated learning, all CoRL and SSRL initiations, negotiations, and decisions are discussed between learners in the group through social interaction (Järvenoja & Järvelä, 2013; Salonen et al., 2005).

The Role of Social Interaction and Participation

Early research on social interaction in small groups (Bales, 1950a, 1950b) resulted in the development of Interaction Process Analysis, where temporally unfolding face-to-face interactions were captured through observing and classifying both verbal and nonverbal behaviors in twelve categories that represented either task-focused (i.e., focus on achieving group's goal) or socioemotional-focused (i.e., focus on interpersonal relationships) (inter)actions. The empirical investigation revealed that groups constantly aim to maintain equilibrium between the focus either being on the task or in the socioemotional aspects, two ends of the spectrum that, according to the model, were distinct and in conflict with each other (Bales, 1950a, 1950b). Since then, research has argued that the two types of interactions are not necessarily in conflict; rather, group interactions can be distinguished in either or both task and socioemotional dimensions (e.g., Fisher & Hawes, 1971). Further, while earlier research often treated task-related dimensions more importantly than socioemotional dimensions, later research (Keyton, 1999; Keyton & Beck, 2009) has especially highlighted the importance of investigating socioemotional dimensions to the same extent as task-related dimensions in group research.

The current study distinguishes two dimensions of social interaction: *cognitive interactions* (e.g., Järvelä et al., 2016) and *socioemotional interactions* (e.g., Bakhtiar et al., 2018). Where Bales' (1950a, 1950b) model distinguishes task-focused interaction as a behavior or communicative act that group members can engage in individually (e.g., repeating a sentence), the definition of cognitive interaction extends beyond this, since it includes responsive interaction between group members (Järvelä et al., 2016). This means that cognitive interaction entails reactive task-focused, metacognitive-level discussions between learners, such as interactions about content, the learning process, or knowledge processing (Dillenbourg et al., 1995, 1999; Hmelo-Silver & Barrows, 2008), and through them, learners can develop their understanding, reasoning, and co-elaborating knowledge (Kreijns et al., 2003). Similarly, socioemotional interaction involves responsive affective interchanges between learners (Bakhtiar et al., 2018; Kreijns et al., 2003; Rogat & Linnenbrink-Garcia, 2011), such as expressions of emotion as well as talking about emotions or motivation (Rogat & Adams-Wiggins, 2015; Rogat & Linnenbrink-Garcia, 2011). Through socioemotional interactions, learners can, for example, manage conflict, build each other's motivation and confidence, and regulate their emotions (Marks et al., 2001). Since the focus of this study is on the interpersonal group processes, social interactions are distinguished from taskwork as such (e.g., interaction with tasks, tools, and machines; Bowers et al., 1997). In addition, similarly to Fisher & Hawes (1971), during group processes, learners can focus on either or simultaneously both types of interactions.

Social interaction requires active and conscious participation by the group members, which in this study refers to learners' involvement in joint dialogues, where learners can, for example, build and elaborate on a partner's contributions or argue (e.g., Chi, 2009). More specifically, participation in cognitive interaction allows learners to share, elaborate, and analyze their domain-focused content knowledge (Baker, 1999; Dillenbourg, 1999), whereas participation in socioemotional interaction affords learners opportunities to collectively build a group's socioemotional climate (Sinha et al., 2015). Scholars have argued that being interactive, that is, participating actively in interactions, allows learners to gain the added advantage of another group member's contributions (e.g., additional information, a new perspective, corrective feedback) and hence benefit learning (e.g., Chi, 2009). Through participating in reciprocal interactions, learners can build shared understanding, which refers to a more advanced and novel mental model than that of an individual could have constructed (Chi, 2009; Jeong & Chi, 2007). Also, group productivity and learner achievement are supported by learners' reciprocal participation in social interactions during collaboration (Cohen, 1994). However, effective CL can be compromised by problems in participation, such as social loafing or the free-rider effect, where one or a few group members invest little to no effort into the collaboration relying on and benefiting from the efforts of others (Aggarwal & O'Brien, 2008; Karau & Wilhau, 2020; Karau & Williams, 1993).

Previous research has suggested that cognitive and socioemotional interactions shape one another and are intertwined with group members' participation. For example, the results of a case study investigating small-group interactions among primary school science students suggested that efficacious interaction required active participation and collaboration between group members (Määttä et al., 2012). Case analyses of two groups solving a mathematics problem showed that less productive participation in constructive cognitive interaction was connected to negative socioemotional interactions (Barron, 2003). A study that investigated the interrelationships among engagement facets and how they unfolded during a group activity in seventh-grade students' biology lessons indicated that joint on-task participation predicted more positive socioemotional interactions and higher-quality cognitive interactions (Sinha et al., 2015). Further, positive socioemotional interactions have been shown to facilitate higher-quality regulation of learning (Rogat & Linnenbrink-Garcia, 2011) and the emergence of co-and shared-regulation (Ucan & Webb, 2015).

The Relationship Between Participation, Social Interaction, and Regulation of Learning

While previous research has shown there is a link between social interaction and participation, as well as between social interaction and regulation of learning, little is known about the interconnection between all three facets. Some evidence comes from Volet et al. (2009), who compared three groups regarding their CL processes and interactions for productive high-level CoRL. The study revealed that learners' equal participation in interactions can enhance higher-quality regulation of cognition. In addition, the group with higher-level CoRL showed more participation by all learners, whereas the groups that did not participate actively showed less evidence of high-level CoRL (Volet et al., 2009). Grau and Whitebread (2012) explored regulation of learning during collaborative activities in two small groups of primary school children. Their research suggested a relationship between engaging in task-focused talk and social aspects of regulation. Moreover, the group with more egalitarian participation among the group members showed more SSRL than the group with less symmetrical participation in interaction (Grau & Whitebread, 2012).

Further, in their case study of two groups working in a computer-supported online environment, Sinha et al. (2015) discovered that engagement in social task-focused interaction was connected to SSRL. The group that participated in active and cohesive task-focused interactions showed more evidence of SSRL, whereas the group with limited task work and low cohesion showed less evidence of SSRL (Sinha et al., 2015). A case study by Iiskala et al. (2015) investigated the participation of a small group in socially shared metacognitive regulation (SSMR) in asynchronous computer-supported CL. The results underlined that all group members contributed to SSMR in interactions (Iiskala et al., 2015). A recent study by Isohätälä et al. (2020) explored the convergence of joint positive interactions and regulation in social interactions during six small groups' CL. The results showed that when groups enacted regulatory strategies, they participated more in social interaction and showed more socioemotional support than during interactions with no observed regulation (Isohätälä et al., 2020).

While research indicates a relationship between participation in interaction and regulation, the existing empirical evidence is limited due in part to the small sample sizes ($N \leq 6$ small groups; Grau & Whitebread, 2012; Iiskala et al., 2015; Isohätälä et al., 2020; Sinha et al., 2015; Volet et al., 2009). Second, the results are non-compatible because the conceptualization and operationalization of participation varied. For example, some research operationalized participation as how equally individual learners contribute to social forms of regulation in collaborative settings (Grau & Whitebread, 2012; Volet et al., 2009). This type of approach, which examines how individual contributions may be interconnected to regulation processes, limits the understanding of how group's participation (i.e., how jointly the group as an entity participates in social interaction) influences or is influenced by learning regulation. Third, the focus of regulation has also varied from *high-level co-regulation* (Volet et al., 2009) to concepts such as *socially shared metacognitive regulation* (Iiskala et al., 2015). Further, previous research has often been conducted in an online context (Iiskala et al., 2015; Sinha et al., 2015), leaving the context of authentic face-to-face collaboration understudied. Finally, research has focused on the convergences of participation, interaction, and regulation (Isohätälä et al., 2020), providing little empirical evidence on the sequential patterns of these processes. The only existing research conducted in a face-to-face context that focused on participation in interaction and regulation of learning as a group-level phenomenon that progressed over time investigated how SSRL emerged during the fluctuation of participation in social interaction in six small groups' CL sessions (Isohätälä et al., 2017). The results showed that SSRL involved more active participation in social interaction and that it often coincided with increases in participation (Isohätälä et al., 2017). However, this study did not investigate CoRL. Previous research has pointed out the role of CoRL in possibly shifting groups toward more productive SSRL (Hadwin et al., 2017), highlighting the importance of including both group-level regulation types when investigating social forms of regulation in learning.

Aims

This study investigates how group-level regulation emerges in social interactions and sheds light on the patterns of interactions and regulation in groups with higher or lower group performance. To this end, the present study is conducted by recognizing sequential patterns of groups' social interaction states, participation levels, and group-level regulation types in a CL context. The research questions are as follows:

> **RQ1:** How do co-regulation (i.e., CoRL) and socially shared regulation (i.e., SSRL) emerge in sequences of different social interaction states and participation levels?
>
> **RQ2:** What are the sequential patterns of social interaction states and participation levels and their relationship to group-level regulation types in CL?
>
> **RQ3:** What are the sequential patterns of social interaction states and participation levels for group-level regulation types in CL groups with higher or lower group performance?

Methodology

Participants, Context, and Data Collection

The participants in this study were 92 seventh-grade students (13–14 years old, female = 56, male = 36) from a comprehensive school in Finland with equal socio-economic background. The students worked on collaborative physics tasks in small groups of 3 (24 groups) or 4 (5 groups), resulting in a total of 29 groups (for access to metadata, see Järvelä et al., 2021). Permission for the research was obtained from the Ethics Committee of Human Sciences at University of Oulu. Data collection was conducted during curriculum-based physics lessons that all learners took as a part of their regular physics period. Participants and their legal guardians were informed about the research project and its aims beforehand. Participation in the study was voluntary and written consent was provided by the legal guardian of each participant. The students who did not participate in the research studied the topic with the same pedagogical structure but worked in a different classroom (for more details see Järvenoja et al., 2020).

Data collection occurred in the students' classrooms. The students were divided into small groups based on previous physics grades, so that each group was heterogeneous regarding student performance and had a mixed representation of both higher and lower performing students. The groups worked collaboratively on various light- and sound-related tasks based on the national physics curriculum. The student groups were videotaped for five sessions (90 minutes per session) over eight weeks using Insta360 Pro 360-degree cameras. All groups progressed at the same pace as their weekly lessons. Out of all the sessions, four were collaborative lessons and the fifth session was a collaborative exam about the topics covered (for more details see Järvenoja et al., 2020). The collaborative exam was graded on a scale from 4 to 10. The groups remained the same throughout the sessions, except for occasional student absences, which affected the group composition. Some video recordings were corrupted or empty due to group absence, which led to the exclusion of 10 videos from this study.

Data Analysis

Video data analysis. The video data (175 h, 30 min) were analyzed using Observer XT12.5 data analysis software. The video coding scheme (Table 1) consisted of lesson structure, social interaction, and participation. Lesson structure coding characterized the classroom activities based on lesson design: teacher instruction, tablet work, and collaborative work. For social interaction and participation coding, the video data were divided into 30-second segments to include a proper length of interaction, enable valid judgments of behavior, and allow for detailed observations. The social interaction coding categories were developed in several phases. First, before viewing the videos, a list of preliminary areas of interest was developed based on previous research on the topic. A coding scheme was then developed and adjusted based on previous research and theory (Järvelä et al., 2016; Whitebread et al., 2009). Second, the coding protocol was developed and discussed multiple times and elaborated on further after viewing the videos. Third, the final coding categories were tested several times, which included specifying evidence for a particular code and providing examples from the data.

Social interaction coding included cognitive interaction and socioemotional interaction, which were the interaction coding categories used in this study (for details, see Table 1). The interactions were not considered mutually exclusive; thus, it was assumed that the social interaction categories could occur parallel to each other. Participation coding indicated the degree to which group members were verbally active during collaboration; that is, whether the whole group was verbally participating in interactions or only part of the group was participating. The reliability of the coding was ensured by conducting inter-rater reliability testing for ten percent of all video data that were coded by two independent coders. Both coders were involved in the refinement of the coding system throughout the process. According to Cohen’s kappa coefficient, substantial agreement was reached for participation ($\kappa = .79$), socioemotional interaction ($\kappa = .77$), and cognitive interaction ($\kappa = .72$). While group collaboration could also include task execution (i.e., concrete work toward task completion that did not require interaction, such as reading or discussing task material or writing down calculations or answers) or other types of interaction (i.e., non-task-related interaction, such as discussion regarding free-time activities), these operationalizations of the construct were not used in this study, because the research focus was on the cognitive and socioemotional processes during collaboration.

Table 1.

Coding Criteria for CL Sessions.

Continuous coding	**A) Lesson structure**		**Notes**
	Teacher instruction		Directed to the class
	Tablet work		Using tablets
	Collaborative work (tasks)		From lesson plans
Sample coding (time interval 30 seconds)	**B) Social interaction**	**Description of behavior**	**Examples**
	Cognitive interaction (COG) Cognitive interaction was coded when group members' discussions targeted their cognitive processes.	Discussion regarding: - Task goals - Task understanding (e.g., checking task demands) - Prior knowledge - Resources (e.g., procedures, strategies) needed to solve the problem - Progress with the task (e.g., checking/evaluating progress) - Selecting strategies (e.g., help seeking) - Quality of task solution (e.g., evaluation of the correctness of the answer) and overall performance	*"Okay, what are our goals?"* *"Isn't this the first task? About volume?"* *"No, it is this way. We did this yesterday in math."* *"I don't think that we have time to do that. [The teacher] is already writing down the homework."* *"Jane, is this [answer] good?"*
	Socioemotional interaction (SOC-EM) Socioemotional interaction was coded when group members expressed clear indicators of positive/negative affect or made a positively/negatively charged comment. Emotional expressions included verbal or other clear indicators of positive or negative affect and negatively or positively charged interactions.	Verbal indicators (e.g., positive/negative content, positive/negative tone of voice, sarcasm, laughing, singing, groaning, whining) Bodily indicators (e.g., smiling, dancing, sighing, facepalm) Emotionally charged interaction (e.g., joking, praising, arguing, criticizing)	*"This [shimmer] gets stuck everywhere. I hate these. I wish this would be over already."* *"You sound like a hamster!" *Laughter** *"How are you able to draw such straight lines without a ruler? Look! She didn't even use a ruler to draw this line!"*

			"Can he be quiet? The mic doesn't like it when he does that all the time."
	C) Participation	**Description of code**	**Notes**
	Whole group (WHOLE) or Partial group (PART)	The degree to which group members verbally contributed	The teacher is not included in the participation.

The group-level regulation types, CoRL and SSRL (Table 2) were analyzed by seeking group-level regulatory episodes based on the preliminary social interaction coding during each 30-second segment. The focus was on the segments where cognitive or socioemotional interaction occurred. The coding protocol for CoRL and SSRL was developed and discussed multiple times and elaborated on further after researchers who were knowledgeable about the theoretical constructs viewed the videos. The coding categories were tested several times by specifying evidence for a particular code and providing examples from the video data. CoRL was coded when the following occurred: observation of an obstacle to an individual or the group's learning process, regulatory initiation from a group member or group members but no additional strategic content from other group members following the initiation, and strategic change in action. CoRL in socioemotional interaction situations could be coded without a clear obstacle or change in action when, for example, general encouragement or praise occurred. SSRL was coded when the following occurred: observation of an obstacle to the group's learning process, regulatory initiation from a group member or group members, active shared strategic negotiation between at least two group members, and strategic change in action. SSRL in socioemotional interaction situations could be coded without a clear obstacle or strategic change in action when, for example, general encouragement or praise occurred and was followed by related regulatory content from at least one other group member. Inter-rater reliability testing for ten percent of all video data was conducted to ensure the reliability of the coding. According to Cohen's kappa coefficient, strong agreement was reached for group-level regulation (κ = .79).

Table 2.

Coding Criteria for Group-Level Regulation Types.

Sample coding (time interval 30 seconds)		**Coded inside collaborative work and answering group assessment questions during tablet work; requires cognitive or socioemotional interaction/response**
Type of group-level regulation	**Description of behavior**	**Examples**
Co-regulation of learning (CoRL)	Co-regulation of learning was coded when the following occurred: 1) Observation of an obstacle to the individual or the group's learning process 2) Regulatory initiation from a group member 3) No additional strategic content from other group members following the initiation 4) Strategic change in action When CoRL was targeted to emotions and motivation, it could be coded without a clear obstacle or change in action to allow the strategic activities that were aiming to maintain and strengthen already favorable motivational and affective conditions.	*[Group is stuck on a task.]* *S1: "Are we supposed to first calculate how long it takes for it to travel? I don't know!"* *S2: "Should we just start with this other task?"* *S1: "Yes, let's do that!"* *[Group struggles with calculations and asks for help.]* *S1: "What the heck! These are all fractions! Our calculations are all screwed then!"* *S2: "We should ask for help."* *S1: [Raises hand]* *[S1 is frustrated.]* *S1: "We are going to get an F."* *S2: "No, we are not! We are getting an A."* *[Students are playing around and losing focus.]* *S1: "Hey, I can see through this mirror!"* *S2: "Can you? OMG! I can see your eye through it!"* *S1: "Well, maybe this is not the most important thing to do now."*
Socially shared regulation of learning (SSRL)	Socially shared regulation of learning was coded when the following occurred: 1) Observation of an obstacle to the group's learning process 2) Regulatory initiation from a group member	*[Students struggle to understand task.]* *S1: "This case looks exactly the same as the previous. What on Earth does this mean?"* *S2: [Raises hand to ask the teacher for help]* *S3: [To the teacher] "We understand nothing about this!"*

	3) Active shared strategic negotiation between at least two group members 4) Strategic change in action When SSRL was targeted to emotions and motivation, it could be coded without a clear obstacle or change in action to allow the strategic activities that were aiming to maintain and strengthen already favorable motivational and affective conditions.	*S2: [To the teacher] "How do we know which lens this is?"* *[Students maintain a positive atmosphere with self-deprecating humor.]* *S1: "We are a little bit stupid."* *S2: "Only a little bit. But not very."* *S1: "Yeah."* *S2: "Not that stupid. We are not complete bimbos. Almost though."* *S1: "Yep."* *[Students maintain motivational conditions.]* *S1: "It's great that we are all participating."* *S2: "Yes, everyone participates!"* *S1: "So then everyone is going to get an A."* *S3: [laughs] "Yep!"* *S4: [laughs] "Well, of course."*

Statistical analysis and process models. The data were reduced to intervals, including phases of tablet work and collaborative work, since social interactions and group-level regulation could occur in these structural parts of the lesson. As noted in the self-regulated learning model (Winne & Hadwin, 1998), learners' awareness of their behavioral, cognitive, motivational, and emotional states and desired goals fuel regulatory acts and strategies. In CL, this awareness can be shared and built among learners through interactions (Hadwin et al., 2017; Hadwin & Oshige, 2011), which in turn can build a relevant state for group-level regulation in collaborative settings. Thus, in this study, the emergences of cognitive and socioemotional interactions in which learners build shared awareness of the group's current state were conceptualized as the *social interaction states* of the group, which include three types: simultaneous cognitive and socioemotional interaction (COG&SOC-EM), cognitive interaction (COG), and socioemotional interaction (SOC-EM). Similarly, two levels of participation were identified in the sequences: whole group (WHOLE) and partial group (PART). To examine regulation of learning as a situational outcome, the concurrence and patterns between group-level regulation types (CoRL & SSRL), social interaction states, and participation levels were investigated.

For the first research question, the frequencies of CoRL and SSRL in the social interaction states and their distribution were calculated. Next, the emergence and distribution of CoRL and SSRL in the social interaction states were examined in relation to the groups' participation levels. A chi-square test of interdependence was performed to explore the relationships within each facet (group-level regulation types, social interaction states, and participation levels). Moreover, a chi-square test of interdependence was calculated to explore whether differences between participation levels and group-level regulation types emerging in social interaction states were determined by chance. Significant associations between whole group/partial group participation and group-level regulation types in social interaction states were examined further by exploring significant z scores from adjusted residuals with an alpha level of .05 ($z < 1.96$), which are values expressing the difference between observed and expected frequencies (Bakeman & Quera, 1995).

For the second research question, the analysis was conducted by investigating the patterns of social interaction states and participation levels leading to, occurring during, and following group-level regulation types in time-related process model analyses using the 30-second sequences before, during, and after an observed group-level regulation sequence. The process models were created using Fluxicon Disco analysis software (https://fluxicon.com/disco/) to investigate and visualize the patterns in which the different social interaction states characterized by participation level and group-level regulation types preceded and followed each other. Process models include every possible interconnection and path and therefore can provide extremely complex illustrations of real-life processes (Bannert et al., 2014). To simplify these complex illustrations of the possible sequential interconnections, the process model analyses were conducted separately for CoRL and SSRL, particularly focusing on the most frequent emergence of CoRL/SSRL in social interaction states and participation levels. In addition, the level of activities and paths were restricted to showing only the strongest, most frequent paths of interconnectivity.

For the third research question, two groups were selected for a case example analysis. The protocol for selecting the groups were as follows: the groups had to have had completed all five CL sessions with the same group composition throughout the sessions. Out of the groups meeting the criteria, the group with the highest and the group with the lowest group exam score were selected for further analysis. The high performing group had a group exam score 8.5, whereas the low performing group had a group exam score 5.5. For both groups the five ninety-minute collaborative sessions (in total 15 h) were investigated regarding the emergence and distribution of CoRL and SSRL in the groups' social interaction states and participation levels, and regarding the patterns of social interaction states and participation levels for each group-level regulation type. Process models were created to investigate and visualize the patterns. To simplify the illustrations, the level of paths was restricted while the level of activities was kept at 100% to include all possible combinations of group-level regulation types, interaction states, and participation levels in the models.

Results

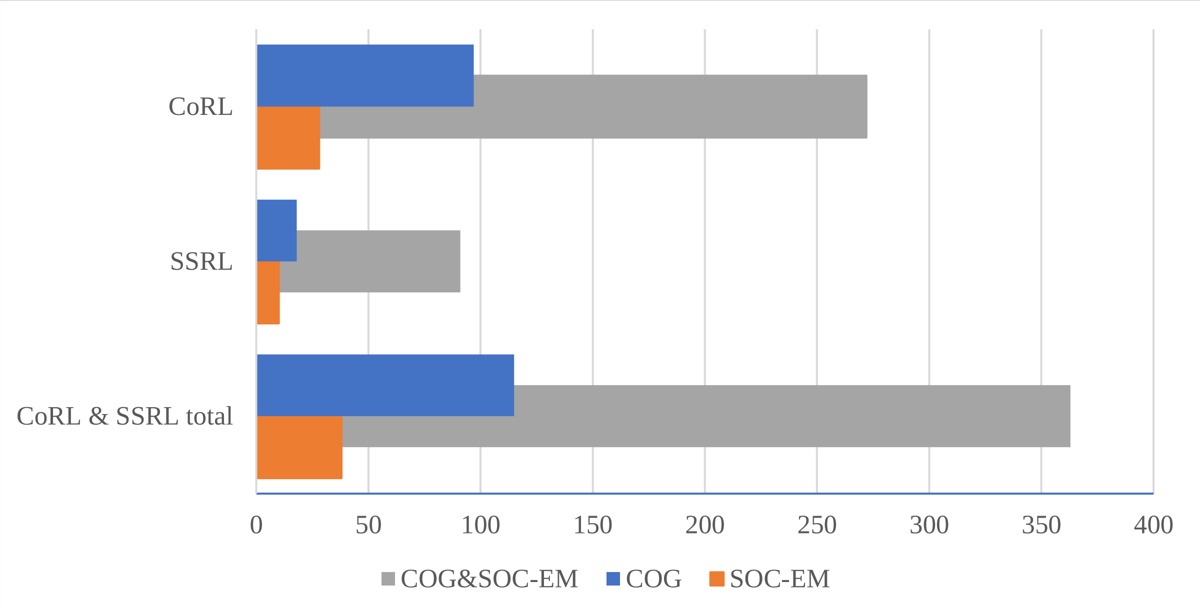
The Emergence of Co- and Socially Shared Regulation in Social Interaction States

Group-level regulation types (CoRL and SSRL) were investigated in relation to the three defined social interaction states (COG&SOC-EM, COG, SOC-EM). Overall, 516 observable group-level regulation sequences were identified, of which 397 sequences were identified as

CoRL and 119 as SSRL. Figure 1 presents the distribution of CoRL and SSRL in the social interaction states.

Figure 1

Distribution of Group-Level Regulation in Social Interaction States.

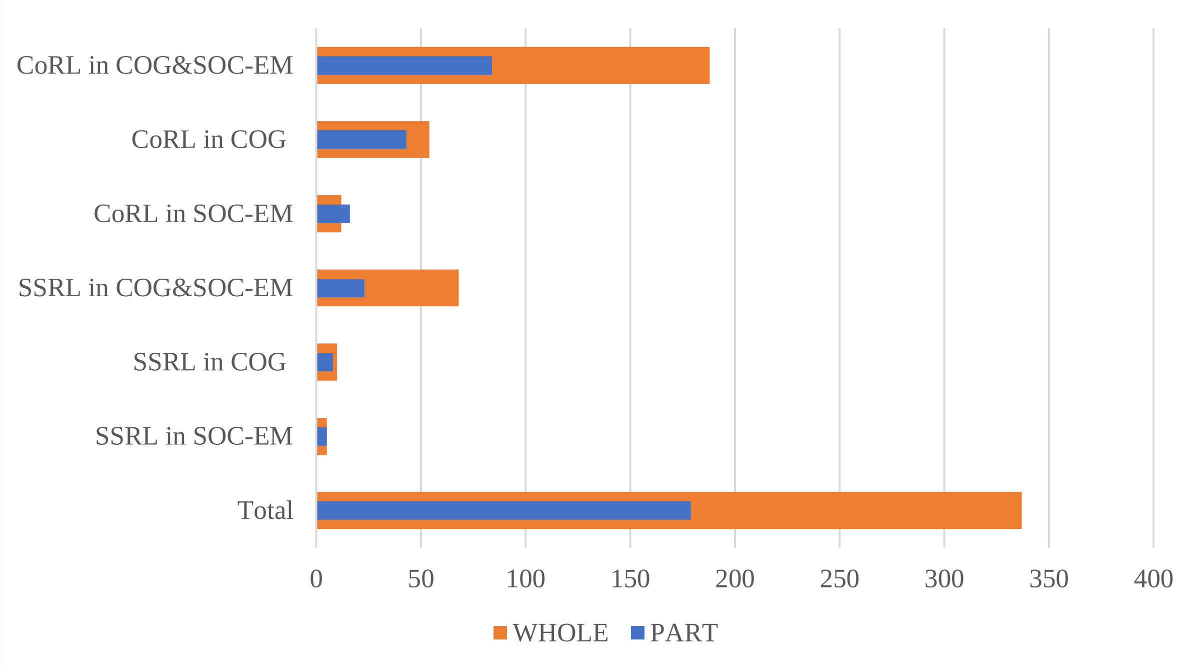


Note. CoRL: co-regulation; SSRL: socially shared regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; SOC-EM: socioemotional interaction

Next, group-level regulation types occurring in different social interaction states were investigated in terms of participation levels (WHOLE and PART). In general, both group-level regulation types emerged more frequently with whole group participation in social interaction (f = 337; 65.3%) compared to partial group participation in social interaction (f = 179; 34.7%). Figure 2 demonstrates the distribution of participation levels.

Figure 2

Distribution of Participation Level.



Note. CoRL: co-regulation; SSRL: socially shared regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; SOC-EM: socioemotional interaction; WHOLE: whole group participation; PART: partial group participation

A chi-square test of independence performed for each facet (social interaction states, participation levels, and group-level regulation types) revealed a significant association between social interaction states and participation levels (χ^2 (2) = 10.99, V = 0.14, p = .004). No significant associations were found between the other facets. However, a chi-square test between group-level regulation in different social interaction states in terms of participation levels indicated a significant association (χ^2 (5) = 17.30, V = 0.18, p = .004). When further investigating the associations (Table 3), the most significant differences were found in the frequency of CoRL in socioemotional interaction (42.9% for WHOLE vs. 57.1% for PART, z = 2.57, $p < 0.05$), frequency of CoRL in cognitive interaction (55.7% for WHOLE vs. 44.3% for PART, z = 2.21, $p < 0.05$), and frequency of SSRL in simultaneous cognitive and socioemotional interaction state (74.7% for WHOLE vs. 25.3% for PART, $z = 2.08$, $p < 0.05$).

Table 3

Group-Level Regulation Types in Social Interaction States and Adjusted Residuals (z) in Terms of Participation Levels.

	Participation level of the group						
	WHOLE			**PART**			**Codes in all**
Group-level regulation in social interaction states	***f***	**%**	***z***	***f***	**%**	***z***	***f***
CoRL in COG&SOC-EM	188	69.1	1.92	84	30.9	-1.92	272
CoRL in COG	54	55.7	-2.21	43	44.3	2.21	97
CoRL in SOC-EM	12	42.9	-2.57	16	57.1	2.57	28
SSRL in COG&SOC-EM	68	74.7	2.08	23	25.3	-2.08	91
SSRL in COG	10	55.6	-0.89	8	44.4	0.89	18
SSRL in SOC-EM	5	50.0	-1.03	5	50.0	1.03	10
Total	337	65.3		179	34.7		516

Note. CoRL: co-regulation; SSRL: socially shared regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; SOC-EM: socioemotional interaction; WHOLE: whole group participation; PART: partial group participation

To conclude, the statistical analyses showed that both CoRL and SSRL emerge most frequently in social interaction state with simultaneous cognitive and socioemotional interactions. In addition, both group-level regulation types emerge more frequently with whole-group participation. Moreover, a statistically significant association was found between social interaction states and participation levels and, with further investigation, between group-level regulation types emerging in different social interaction states of varying participation levels.

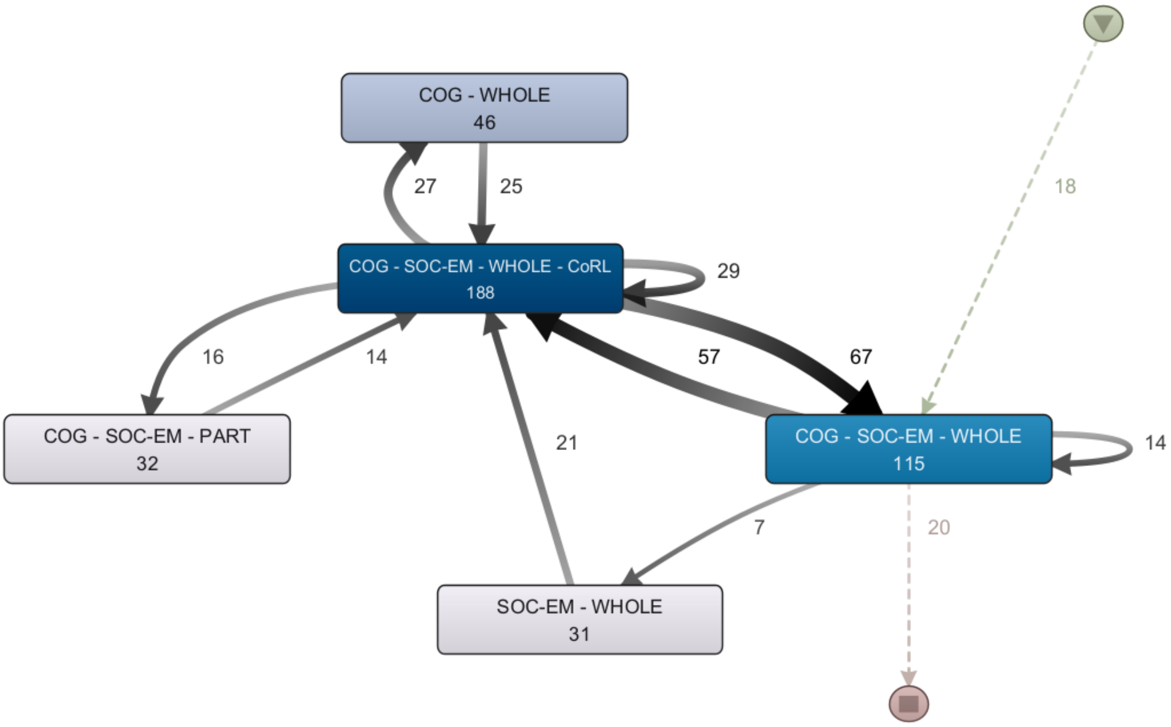
Patterns of Social Interaction and Participation in Regulation of Learning

The patterns of social interaction states and participation levels leading to, occurring during, and following group-level regulation types were investigated in time-related process model analyses for the most frequent occurrences of group-level regulation of learning. According to analyses conducted to answer RQ1, CoRL emerged most frequently in simultaneous cognitive and socioemotional interactions of the whole group (COG&SOC-EM&WHOLE); thus, for RQ2, the process model analysis was conducted to investigate what kind of sequential social interaction and participation patterns led to and followed CoRL in this state (Figure 3). While the analysis focused on CoRL in COG&SOC-EM&WHOLE, the sequences before and after CoRL in this state were not restricted to any specific regulation type, interaction state, or participation level; hence, all possible combinations could emerge in these sequences.

The process model for CoRL revealed that the most frequent sequential pattern in CoRL episodes included simultaneous cognitive and socioemotional interaction with whole-group participation (darkest blue boxes in Figure 3). The CoRL episodes most frequently started with a state of simultaneous cognitive and socioemotional interaction with whole-group participation (COG&SOC-EM&WHOLE, f = 115) and were followed by CoRL in the same state (f = 188 for occurrence and f = 57 for path). In addition, CoRL was most frequently followed by the same state (f = 67 for path). The frequent pattern was also a loop created by the sequences of CoRL in the state of both cognitive and socioemotional interaction and whole-group participation (f = 29), showing that this event occurred several times consecutively. CoRL episodes could also be preceded with cognitive interaction with whole-group participation (COG&WHOLE, f = 46 for occurrence and f = 25 for path) and followed by the same state (*f* = 27 for path). CoRL could also be preceded by socioemotional interaction and whole-group participation (*f* = 31 for occurrence and 21 for path). Finally, CoRL could be preceded (*f* = 32 for occurrence and 14 for path) and followed by simultaneous cognitive and socioemotional interaction on the partial group participation level (*f* = 16 for path).

Figure 3

Process Model Illustrating the Strongest Patterns between Social Interaction States, Participation Levels, and CoRL.

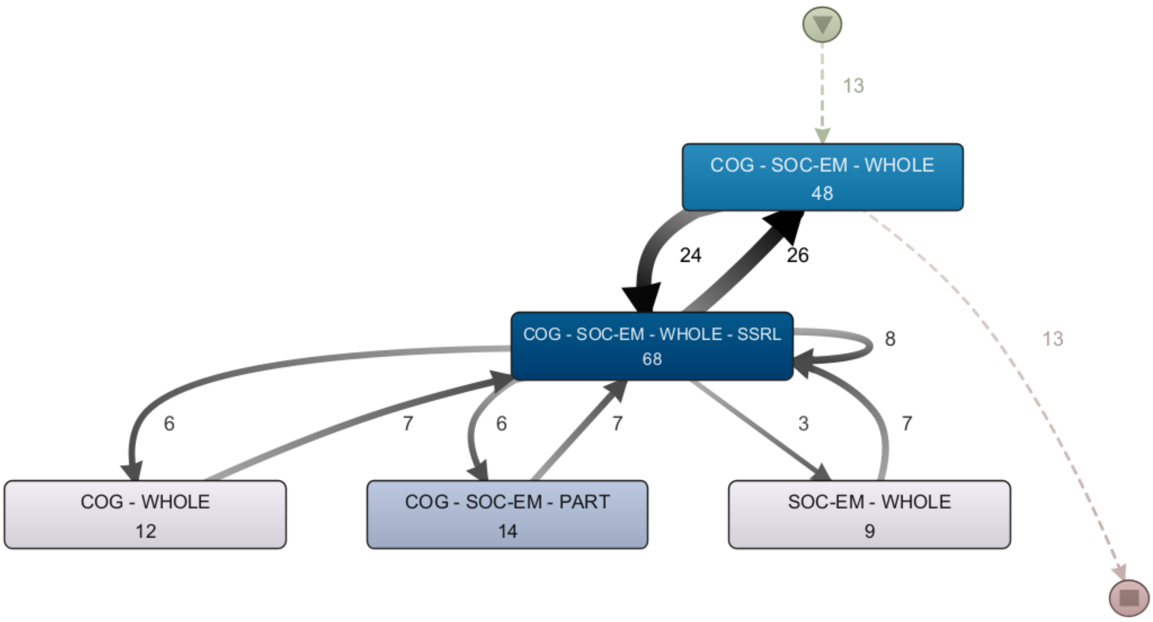


Note. CoRL: co-regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; WHOLE: whole group participation; PART: partial group participation

According to analyses conducted to answer RQ1, SSRL also emerged most frequently in simultaneous cognitive and socioemotional interactions of the whole group (COG&SOC-EM&WHOLE); hence, the patterns for SSRL in this interaction state and participation level were further investigated in the process model analysis for RQ 2 (Figure 4). As the same as it was for the process model analysis conducted for CoRL, in the SSRL process model analysis, the sequences before and after SSRL in COG&SOC-EM&WHOLE were not restricted to any specific regulation type, interaction state, or participation level. The process model for SSRL revealed that the most frequent sequential pattern in SSRL episodes included simultaneous cognitive and socioemotional interaction on the whole-group participation level (darkest blue boxes in Figure 4). The SSRL episodes most frequently started with simultaneous cognitive and socioemotional interaction with whole-group participation (COG&SOC-EM&WHOLE, $f = 48$) and were followed by SSRL in the same state ($f = 68$ for occurrence and $f = 24$ for path). In addition, SSRL was most frequently followed by the same state ($f = 26$ for path). SSRL in COG&SOC-EM&WHOLE could also create a loop within itself ($f = 8$). SSRL episodes could also be preceded with simultaneous cognitive and socioemotional interaction with partial group participation (COG&SOC-EM&PART, $f = 14$ for occurrence and $f = 7$ for path) and followed by the same state ($f = 6$ for path). Other patterns preceding SSRL found in the process model were as follows: COG&WHOLE ($f = 12$ for occurrence and 7 for path) and SOC-EM&WHOLE ($f = 9$ for occurrence and 7 for path). SSRL was also followed by COG&WHOLE ($f = 6$ for path) and SOC-EM&WHOLE ($f = 3$ for path).

Figure 4

Process Model Illustrating the Strongest Patterns between Social Interaction States, Participation Levels, and SSRL.



Note. SSRL: socially shared regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; SOC-EM: socioemotional interaction; WHOLE: whole group participation; PART: partial group participation

To conclude, the process models for both CoRL and SSRL showed that a state with both cognitive and socioemotional interaction with whole group's participation level is not only a favorable state for group-level regulation to occur in, but it is also the most frequent pattern preceding and following it. Both CoRL and SSRL also looped within themselves. The second most frequent pattern preceding and following CoRL was cognitive interaction with whole-group participation, while for SSRL, it was simultaneous cognitive and socioemotional interaction with partial group participation.

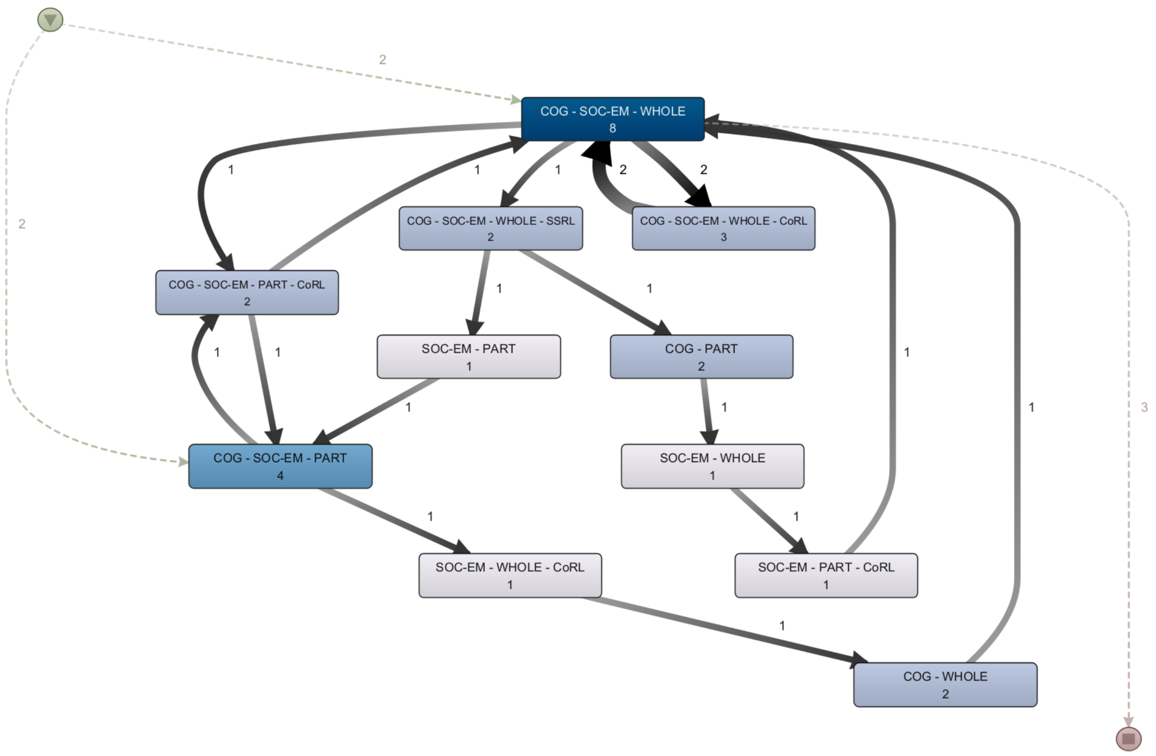
Group Performance and Patterns of Social Interaction and Participation for Regulation

The social interaction and participation patterns for group-level regulation types in two case example groups (higher group performance, Figure 5; lower group performance, Figure 6) were investigated in time-related process model analyses. The investigation focused on the most frequent patterns for group-level regulation. Overall, the process model analyses revealed a notable difference in the frequency of CoRL between the higher performing and the lower performing group. In total, the higher performing group had 9 (100%) observable group-level regulation sequences, of which 7 (77.8%) were identified as CoRL and 2 (22.2%) as SSRL. The lower performing group had 34 (100%) observable group-level regulation sequences, of which 31 (91.2%) were identified as CoRL and 3 (8.8%) as SSRL.

Overall, complex patterns of paths were observed in both groups. The process model for the higher performing group indicated more consistent patterns than those of the lower performing group. SSRL emerged only in simultaneous cognitive and socioemotional interaction with whole-group participation (COG&SOC-EM&WHOLE, $f = 2$), followed by socioemotional interaction with partial group participation (SOC-EM&PART, $f = 1$ for occurrence and $f = 1$ for path) or cognitive interaction with partial group participation (COG&PART, $f = 2$ for occurrence and $f = 1$ for path). Similarly, CoRL emerged the most frequently in the same state ($f = 3$). Moreover, group-level regulation was also frequently preceded and followed by simultaneous cognitive and socioemotional interaction on the whole-group participation level ($f = 8$). This state preceded CoRL in simultaneous cognitive and socioemotional interaction with partial group participation (COG&SOC-EM&PART, $f = 2$ for occurrence and $f = 1$ for path, reciprocal), CoRL in simultaneous cognitive and socioemotional interaction of the whole group (COG&SOC-EM&WHOLE, $f = 3$ for occurrence and $f = 2$ for path, reciprocal), and SSRL in the same state (COG&SOC-EM&WHOLE, $f = 2$ for occurrence and $f = 1$ for path). For all patterns, see Figure 5.

Figure 5

Process Model Illustrating the Patterns of Social Interaction States and Participation Levels for Group-level Regulation Types in the Higher Performing Group.



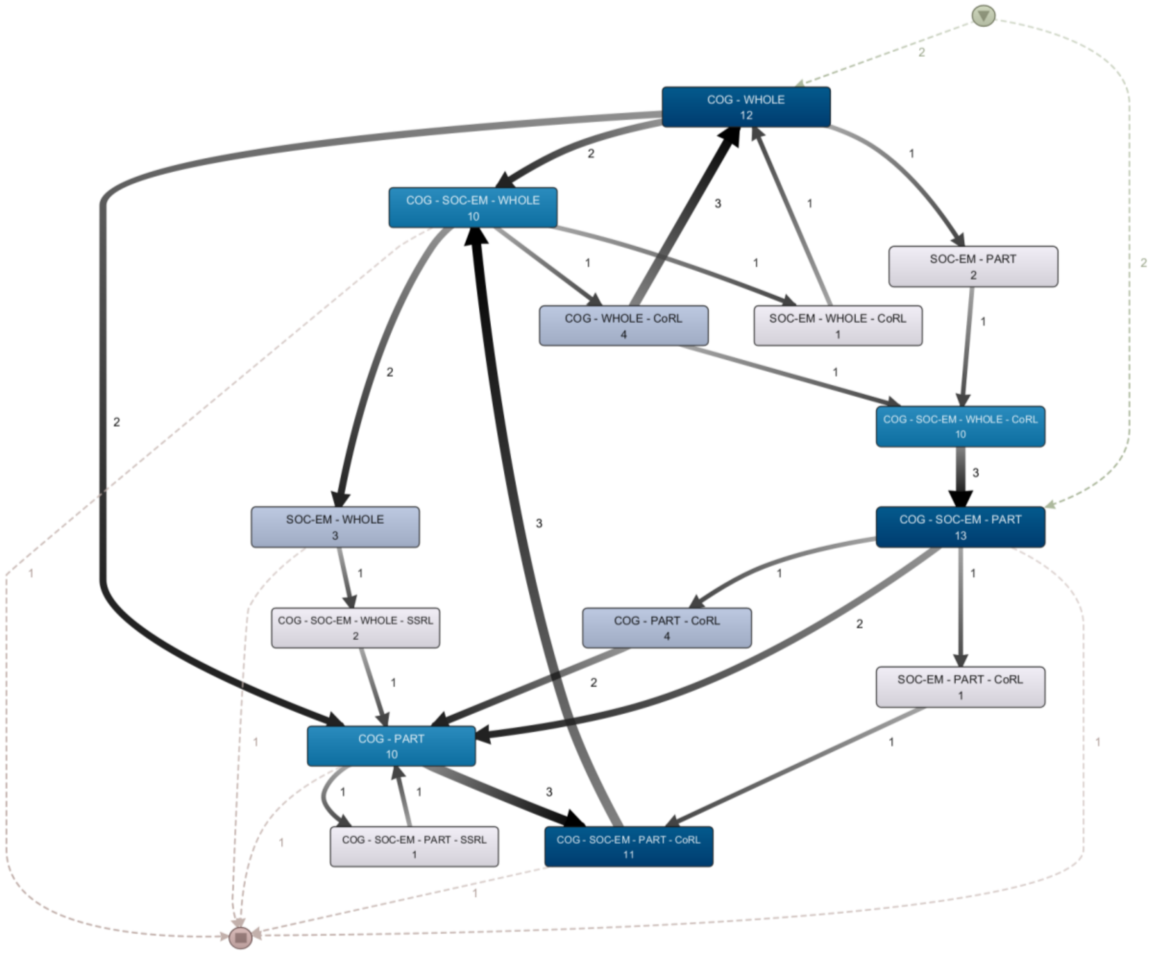
Note. CoRL: co-regulation; SSRL: socially shared regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; SOC-EM: socioemotional interaction; WHOLE: whole group participation; PART: partial group participation

The process model for the lower performing group indicated more inconsistent patterns than those of the higher performing group. SSRL emerged the most frequently in simultaneous cognitive and socioemotional interaction with whole-group participation (COG&SOC-EM&WHOLE, *f* = 2), which was preceded by socioemotional interaction of the whole group (SOC-EM&WHOLE, *f* = 3 for occurrence and *f* = 1 for path). SSRL could also emerge in simultaneous cognitive and socioemotional interaction on the partial group level (COG&SOC-EM&PART, *f* = 1) that was preceded and followed by cognitive interaction on the partial group participation level (COG&PART, *f* = 10 for occurrence and *f* = 1 for path).

CoRL emerged the most frequently in simultaneous cognitive and socioemotional interaction with partial group participation (COG&SOC-EM&PART, *f* = 11), which was most frequently preceded by cognitive interaction with partial group participation (COG&PART, *f* = 10 for occurrence and *f* = 3 for path) and followed by simultaneous cognitive and socioemotional interaction with whole group participation (COG&SOC-EM&WHOLE, *f* = 10 for occurrence and *f* = 3 for path). CoRL emerged the second most frequently in simultaneous cognitive and socioemotional interaction with whole group participation (COG&SOC-EM&WHOLE, *f* = 10), which could be preceded by CoRL with cognitive interactions of the whole group (COG&WHOLE&CoRL, *f* = 4 for occurrence and *f* = 1 for path) or socioemotional interaction with partial group participation (SOC-EM&PART, *f* = 2 for occurrence and *f* = 1 for path), and followed by simultaneous cognitive and socioemotional interaction with partial group participation (*f* = 13 for occurrence and *f* = 3 for path). For all patterns, see Figure 6.

Figure 6.

Process Model Illustrating the Patterns of Social Interaction States and Participation Levels for Group-level Regulation Types in the Lower Performing Group.



Note. CoRL: co-regulation; SSRL: socially shared regulation; COG&SOC-EM: simultaneous cognitive and socioemotional interaction; COG: cognitive interaction; SOC-EM: socioemotional interaction; WHOLE: whole group participation; PART: partial group participation

To conclude, the process models for the higher performing group and lower performing group showed differences in the frequency of CoRL and the patterns for group-level regulation. The higher performing group had significantly less CoRL and more consistent patterns than the lower performing group. In particular, results indicated that simultaneous cognitive and socioemotional interaction with whole group participation influenced and is influenced by group-level regulation episodes in the higher performing group. On the other hand, the lower performing group had significantly more CoRL and more inconsistent patterns, indicating that group-level regulation could emerge from several different combinations of interaction states and participation levels.

Discussion

This study investigated how episodes of group-level regulation types, CoRL and SSRL, emerged in social interactions during CL and shed light on the patterns of interactions and regulation of groups with different group performance. The investigation was conducted by recognizing groups' social interaction states and participation levels as they unfolded sequentially, creating patterns for regulation of learning. The results highlight three main points. First, the results showed that both types of group-level regulation emerged most frequently when the group's collaboration included both cognitive and socioemotional interaction on the whole-group participation level. Second, the process models showed that the connection between the simultaneous interaction state and group-level regulation was reciprocal; similar interactions both led to and followed group-level regulation, regardless of the type of regulation. Third, the case example investigation on two groups indicated different regulation frequency, especially for CoRL, and different interaction and regulation patterns in groups of varying performance.

We provide explanations for the emergence of both CoRL and SSRL in simultaneous cognitive and socioemotional interactions with whole group participation. First, due to the nature of CL, collaborative groups often engage in intertwined task-focused cognitive and socioemotional interaction processes (Kreijns et al., 2003) that require responsiveness among group members (Keyton & Beck, 2009). The early empirical evidence by Bales (1950a, 1950b) indicates that there is a movement back and forth between task-focused and socioemotional interactions, because group members try to maintain balance between them. Later research focus shifted to the intertwined or overlapping nature of both task- and socioemotional-focused interactions (Keyton, 1999; Keyton & Beck, 2009), highlighting the coexistence of these facets in responsive interactions between group members (Keyton & Beck, 2009). Similar interplay between cognitive and emotional facets has also been recognized in the social forms of regulation in the context of learning groups (Bakhtiar et al., 2018; Järvelä et al., 2016; Lobczowski, 2020), which supports the findings of the present study. While group-level regulatory acts and strategies that focus on the cognitive aspects of the learning process (e.g., task goals, evaluating progress, or selecting strategies) may often be seen as “the core” of regulation of learning, merely regulating cognitive processes in CL is not sufficient. Learners in groups can experience a range of emotions regarding themselves, their tasks, the environment, other group members, or the group’s joint strategies that may facilitate or hinder the collaborative process (Järvenoja & Järvelä, 2005; Wosnitza & Volet, 2005). Therefore, in addition to cognition, regulating emotions in collaborative groups is vital, and interactions during regulation can simultaneously include both cognitive and socioemotional content. For example, previous research has indicated that emotions can be regulated through cognitive strategies by aiming to move the focus from negative emotions to task execution (Järvenoja et al., 2019; Mänty et al., 2022). The intertwined nature of cognitive and emotional processes in groups (e.g., Keyton, 1999; Keyton & Beck, 2009) and also in regulation of learning (e.g., Efklides, 2011) can explain why both CoRL and SSRL emerged most frequently when both cognitive and socioemotional interactions concurred. However, the degree to which group members actively and jointly participate in social interactions is distinct for group-level regulation of learning. Findings of the present study are consistent with existing evidence that more active participation in a group coincides with regulation in social interaction (e.g., Isohätälä et al., 2017, 2020). High-level CoRL has been connected to active participation by all group members (Volet et al., 2009), and SSRL is a jointly constructed group-level process that requires reciprocal exchanges between learners (Hurme et al., 2009; Iiskala et al., 2011, 2015; Järvenoja & Järvelä, 2013). Although learners may adopt different participatory roles in social interactions, only active and reciprocal participation by several learners can lead to the strategic negotiation of CL processes that SSRL requires (Iiskala et al., 2015).

In this study, a significant association was found between social interaction states and participation levels, highlighting the interconnection between these two facets. Our finding is consistent with existing evidence indicating that cognitive and socioemotional interactions and facets of participation are interrelated and can have reciprocal influence on each other (Sinha et al., 2015). Further, a significant association was found between group-level regulation types in social interaction states and participation levels, and the most significant differences were found in CoRL in socioemotional interaction, CoRL in cognitive interaction, and SSRL in simultaneous socioemotional and cognitive interactions. Of these, CoRL in socioemotional interaction was the only one that emerged more frequently with partial group participation compared to whole-group participation. Although the frequency was small, this result could indicate that peer-level (i.e., not all group members) interactions can also play a role in CoRL when the interactions are socioemotional in nature and may target the socioemotional challenges in the group (Lajoie et al., 2015; Törmänen et al., 2021) and serve a situational purpose (Järvenoja et al., 2019). This has also been suggested in a previous study by Törmänen et al. (2021), who studied 12-year-old students' collaborative work and found that groups' affective conditions were related to their overall regulatory behavior, particularly for the purpose of restoring participation of non-participating students (Törmänen et al., 2021).

Regarding the patterns of interactions, the process model analyses for both CoRL and SSRL revealed that a favorable state that precedes and follows group-level regulation includes both cognitive and socioemotional interactions and whole-group participation. This result is consistent with existing evidence that active participation in social interaction is beneficial for regulation (e.g., Grau & Whitebread, 2012; Isohätälä et al., 2017; Sinha et al., 2015), although time-related investigation of the phenomenon has been scarce. Some supporting evidence comes from an exploratory qualitative analysis of a time-related interaction episode that indicated both cognitive (e.g., question asking, background knowledge) and socioemotional (i.e., shared positive emotions) aspects play a role in maintaining groups' engagement in high-level CoRL (Volet et al., 2009). Moreover, a study by Isohätälä et al. (2017) indicated increases in participation in the moments of SSRL. The current study strengthens and furthers previous findings by showing that group's active participation in both cognitive and socioemotional interactions can also follow both CoRL and SSRL frequently. This result indicates that group-level regulation that is specifically built in joint cognitive and socioemotional interactions of the group may also further activate learners to engage in continual joint interaction targeting both cognitive and socioemotional content. The current study extends the CL literature, since it adds an analytical approach with a larger dataset and a time-related process-oriented method, which has been advocated for in CL research (Järvelä et al., 2019) but also in small group research (Arrow et al., 2004). The present study investigated how learners' interactions may shape and be shaped by regulation (Järvelä et al., 2019) by utilizing extensive, video-recorded data of authentic CL sessions occurring over several weeks and with the help of process model analyses focused on finding sequential patterns. While investigating the "micro-level" sequential patterns of regulatory processes in detail (e.g., Molenaar & Chiu, 2014) has been crucial for understanding the phenomenon of regulation, this study provides evidence about the "large-scale" patterns of interactions that may precede or follow regulation in group settings as CL progresses and evolves in reciprocal social interactions between learners (Fischer & Järvelä, 2014; Kirschner et al., 2018). The present study highlights the role of group-level regulation for engaging learners to participate in joint cognitive and socioemotional interactions that may, for example, allow learners to build shared understanding (e.g., Chi, 2009) and maintain group's socioemotional climate (Sinha et al., 2015).

The results of the interaction and regulation patterns in the two case example groups with high and low group performance showed that, while the frequency of SSRL was almost the same in the two groups, the lower performing group had significantly more CoRL than the higher performing group, and the CoRL episodes of the lower performing group frequently occurred on a partial group participation level. This indicates that the lower performing group frequently faced obstacles that were overcome through regulatory support that the group members gave each other, although often only between some of the group members. This finding, alongside with the group's poor performance, may be explained with previous research suggesting that regulation strategies may not always be sufficient for the specific situation at hand (Bakhtiar & Hadwin, 2020; Mänty et al., 2020). For example, comparison of motivation regulation showed that low productivity group faced more motivation challenges originated from lack of group interactions and interpersonal conflicts and failed to match their regulation to the faced challenges (Bakhtiar & Hadwin, 2020). The results of the present study indicate that the lower performing group was potentially not successful in matching their regulation to the faced challenges as regulation often targeted individuals, not group, and only occurred among some of the group members. Further, the higher performing group showed more consistent interactions and participation during regulation episodes, and the group frequently participated as a whole in both cognitive and socioemotional interactions. The lower performing group, on the other hand, showed more inconsistent patterns during regulation episodes, as they engaged in several combinations of interactions with both partial group and whole group participation. These findings shed light on the role of active participation by all group members in CoRL (Volet et al., 2009) and in SSRL (Hurme et al., 2009; Iiskala et al., 2011, 2015) in CL, and highlights that learners should use appropriate, adaptive regulation strategies timely to match their situational needs (Järvenoja et al., 2019).

Limitations and Future Research

While the sample size and use of large video-recorded data were the strengths of this study, they also pose certain limitations. First, the observational nature of the video-recorded data is a limitation, since such data can be prone to human bias, confounding, and does not include self-reported data to show what the subject is thinking. However, video recordings allowed the investigation of CL groups' interactions in a natural setting and over multiple CL sessions. Further, data were collected in real-world contexts (i.e., classroom), providing more generalizable results than lab experiments (Nokes-Malach & Richey, 2015).

Second, data analysis was restricted to the coded and labeled 30-second sequences of the video recordings, which limited capturing nuances of the social interaction or group-level regulation processes, such as the valence of the interactions or exactly when and what kind of processes were targeted by group-level regulation. However, the decision to segment the data into 30-second sequences was a necessary practical choice that enabled the coding of a large and complex dataset. In addition, the length of the unit of analysis allowed the matching of different coding categories (i.e., social interaction, participation, and regulation) during the analysis. Understanding how social interaction, participation, and regulation interacted each other was main goal of the present study, given that collaborative groups' regulation should be studied in relation to other processes of the group (Järvelä & Bannert, 2021; Järvenoja et al., 2015; Taub & Azevedo, 2019). Group-level regulation is context-and situation-specific, and to understand the sources and reasons for emerging regulation, the type (i.e., cognitive, socioemotional) and the level of intensity (i.e., whole group, partial group) of social interaction that students engage in during learning can provide insight into the targets that are being regulated (cognition, emotions, motivation) and how that regulation is achieved in a group. In the same vein, our results should be interpreted carefully by taking into account the context where the study was conducted, especially regarding the results of the two case example groups. The environment of the science classroom, the group compositions, the age and other demographic factors of the participants, for example, may have shaped how the group members engaged or did not engage in interactions and regulation of learning.

Another limitation of the present study is that the results depended on how CoRL and SSRL were operationalized. While there are different ways to operationalize CoRL and SSRL, the operationalization in the present study was based on existing theory and research findings on types of group-level regulation that can be activated when groups' collaboration and knowledge co-construction processes are jeopardized or when groups need to redirect or adapt their joint work; thus, when joint work goes smoothly, the need for regulation at the group level decreases (Hadwin et al., 2017). Further, the coding of regulation was discussed and elaborated upon with multiple researchers after viewing the videos of the groups' CL. While previous studies have used various concepts and operationalization when investigating social forms of regulation, consistency in construct operationalization would benefit future research.

Fourth, in this study, the process model analyses were constructed using the 30-second sequences before, during, and after an observed group-level regulation sequence. Thus, the process models did not demonstrate the whole CL process as such; rather, they focused on meaningful interaction episodes for group-level regulation. In the present study, regulation emerged quite infrequently, as compared to social interactions in the CL sessions, and consequently, regulation sequences could “get lost” in the process models. Not including all data sequences throughout the CL process in the final analysis was thus a practical choice, since analyzing complex real-life learning processes with process models requires the simplification of the models (Bannert et al., 2014; Dolak, 2019; Malmberg et al., 2015). In this study, the process models for RQ2 were constructed separately for CoRL and SSRL, and the models focused on the interaction states and participation level at which CoRL and SSRL emerged most frequently. While the level of activities and paths was restricted to showing only the strongest paths or patterns of interconnectivity, the sequences before and after regulation were not restricted in terms of regulation type, interaction state, or participation level, affording all possible combinations of these facets to emerge in the preceding and following sequences. Thus, despite of limitations, the sequences preceding and following regulation showed all possible and the strongest patterns for regulation in a relevant state – that is, when the whole group participated in cognitive and socioemotional interaction.

Finally, while this study shed light on different patterns of interactions and regulation of learning in groups with high and low group performance, more research on this matter is warranted. For example, future research could explore the patterns of social interactions and regulation throughout the CL process to reveal more timely information about their temporal progression. Further, it could be valuable to investigate temporal interaction and regulation processes in relation to either individual attributes (e.g., individual learner performance), or the group’s CL success. While previous research has tentatively indicated, for example, that individual’s monitoring accuracy and engagement in (meta)cognitive interactions accompanied with CoRL plays a role for individual learning achievement (Haataja et al., 2022), and that regulation processes such as monitoring can facilitate group performance (Näykki, Järvenoja, et al., 2017), more research on temporal progression of CL processes, such as regulation, and successful CL is needed.

Conclusion

CL skills are increasingly emphasized in schools (Hmelo-Silver et al., 2013), in everyday life (Dede, 2010), as well as in diverse work environments (Lobczowski et al., 2021), which underlines the importance of understanding the social regulation processes in various collaborative group settings. The results of this study support and elaborate on previous findings (e.g., Grau & Whitebread, 2012; Isohätälä et al., 2017, 2020) and advance the understanding of the characteristics of social interaction processes that are beneficial for group-level regulation of learning in a small group setting. This understanding is crucial in the field of learning sciences, where the aim is to understand learning processes and eventually to design and utilize various learning technologies and tools to support learning (Fischer et al., 2018). The results highlight the importance of joint participation in social interaction, both cognitive and socioemotional, for group-level regulation of learning. In addition, the results shed light on different social interaction and regulation patterns in groups with high and low group performance. As the case examples indicated, it is not necessarily the amount of regulation of learning that makes a difference; rather, it may be the way group members participate in social interactions and group-level regulation that plays a role in successful learning in collaborative groups. Upon these remarks it may be important for practitioners to consider and aim to support joint, reciprocal interactions that focus on both cognitive and socioemotional content when planning and implementing their CL designs or using learning technologies and tools for group collaboration.

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Declaration of Conflicting Interests

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