Socially shared regulation of learning and participation in social interaction in collaborative
learning

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Abstract

This study investigated how socially shared regulation of learning (SSRL) emerged during the fluctuation of participation in interaction in collaborative learning. Twenty-four student teachers in six small groups were video-recorded during collaborative tasks in mathematics. Manifestations of SSRL and students' participation were micro-analytically coded. Next, the concurrence between manifestations of SSRL and the fluctuation of participation was examined and illustrative examples were described. The results show that SSRL involved more active participation than task-focused interaction overall and that SSRL often coincided with increases in participation to a higher level than general. The findings suggest that manifestations of SSRL involved activated participation during the moments when interaction was needed to reciprocally resolve situative challenges and to coordinate activities.

Keywords: socially shared regulation of learning, social interaction, participation, collaborative learning, video data

Highlights

- SSRL involved more active participation than task-focused interaction overall.
- SSRL often emerged when participation increased to a higher level than general.
- SSRL as a strategic activity had a role in the dynamics of participation.

1 Introduction

Social interaction in collaborative learning invites individuals to share and elaborate divergent perspectives and ultimately extend their thinking beyond individual capabilities (Chi & Wylie, 2014; Dillenbourg, 1999; Scardamalia & Bereiter, 2014; Webb, 2013). However, such interaction cannot emerge without the skill and will of individuals and the group as a collective (Hadwin & Oshige, 2011). Students' individual and joint learning efforts need to be fueled by strategic regulation of cognition, emotion, motivation and behavior (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000). The benefits of self-regulated learning for individual learning have been clearly evidenced (Zimmerman, 2000), but because learning takes place in increasingly interactive settings, it is necessary to explore regulation processes beyond the individual (Hadwin, Järvelä, & Miller, 2011).

Socially shared regulation of learning (SSRL) occurs as a group-level phenomenon where students collectively negotiate and align common perceptions of the collaborative learning process and take control of the task through shared and negotiated, iterative fine-tuning of cognitive, behavioral, motivational and emotional conditions (Hadwin, Järvelä, & Miller, 2016; Järvelä & Hadwin, 2013; Winne, Hadwin, & Perry, 2013). Previous studies about SSRL have explored, for example, the quality of regulation processes (Backer, Van Keer, Moerkerke, & Valcke, 2015; Järvelä, Järvenoja, Malmberg & Hadwin, 2013; Järvelä, Malmberg, & Koivuniemi, 2016; Lee, O'Donnell, & Rogat, 2015) and the relations between SSRL and knowledge co-construction (Volet, Summers, & Thurman, 2009), goals (Volet & Mansfield, 2006), feelings of difficulty (Hurme, Merenluoto, & Järvelä, 2009) and performance (Janssen, Erkens, Kirschner, & Kanselaar, 2012). However, despite the prevalence of using process-oriented data (Panadero & Järvelä, 2014), relatively few studies have explored the dynamics of interaction and the emergence of SSRL.

1.1 Emergence of socially shared regulation of learning in interaction

Socially shared regulation of learning is a metacognitive and adaptive mental process that is negotiated and fine-tuned in collaboration. While originating in learners' intents, beliefs and past socio-historical experiences, SSRL is also inherently transactive as it invites individuals to jointly co-construct shared perceptions of metacognitive, cognitive, behavioral and motivational processes (Hadwin, Järvelä, & Miller, 2016). A small number of studies have micro-analytically described the interaction through which SSRL manifests in collaborative learning.

Iiskala, Vauras and Lehtinen (2004) and Iiskala, Vauras, Lehtinen and Salonen (2011) analyzed shared metacognitive regulation during dyads' face-to-face interaction in problem solving. Their findings suggested that socially shared metacognitive regulation manifested when students externalized metacognitive thinking and complemented each other's utterances, creating a flow of comments. The authors noted that this flow of comments was not always detectable in isolated sequences but appeared throughout the collaboration, intertwining with cognitive processes. Similar findings were reported of interaction in asynchronous collaboration (Hurme, Merenluoto, & Järvelä, 2009; Iiskala, Volet, Lehtinen, & Vauras, 2015).

Järvenoja and Järvelä (2011) described how socially shared regulation of emotion emerged in a case group of university students. Narratives, flowcharts and transcriptions illustrated how a socio-emotional challenge emerged, how students elaborated each other's regulative utterances, and how socio-emotional balance was restored. The study suggested that SSRL emerged as a situative phenomenon which manifested through multiple connected utterances by multiple learners. None of the students' utterances could be individually defined as regulation but, rather, SSRL surfaced as a transactive phenomenon.

An in-depth study of social regulation in two case groups was conducted by Ucan and Webb (2015). The authors found that shared regulation affected the flow of group discussion. For example, shared monitoring facilitated and simultaneously occurred during cognitive processes. Shared emotional and motivational regulation, in turn, sustained students' reciprocal interaction by

restoring socio-emotional balance. Episodes of shared regulation were marked by attentive listening and openness to divergent ideas.

The earlier studies highlight the importance of learners' reciprocal contributions. To elaborate these findings, the present study investigates SSRL from the point of view of participation in social interaction which affords reciprocal exchanges to occur. After all, participation in social interaction is the prerequisite for creating shared understandings (Clark, 1996; Clark & Brennan, 1991), and the importance of coordinated and cohesive participation has been repeatedly emphasized in collaborative learning research (e.g., Barron, 2001, 2003; Cohen, 1994; Erkens, Prangma, & Jaspers, 2006; Kreijns, Kirschner, & Jochems, 2003).

1.2 Socially shared regulation of learning and participation in social interaction

Previous studies have suggested that participation is positively linked to the manifestation of SSRL in interaction. Early evidence comes from Volet, Summers and Thurman (2008), who found that equal participation in interaction enhanced higher quality regulation of cognition. The authors focused on co-regulation, but their operationalization of high-level co-regulation came close to the concept of SSRL in interaction (also noted by Panadero & Järvelä, 2015). Their comparison of three groups revealed that a group with more evidence of high-level co-regulation also showed more participation by all group members. Other groups had less evidence of high-level co-regulation, and in most cases, the whole group did not actively participate.

These findings were supported by Grau and Whitebread (2012) in their study of self and social aspects of regulation in two groups of primary school children. The results indicated that the group showing more egalitarian participation also showed more SSRL than co-regulation. In contrast, the group with less symmetrical participation showed less SSRL in interaction.

Similar results were reported by Sinha, Rogat, Adams-Wiggings and Hmelo-Silver (2015), who revealed that engagement in social, task-focused interaction was connected to displays of

SSRL. Their case study of two groups showed that a group with low-quality social and task-focused interaction, i.e., limited task work and low cohesion, showed less evidence of SSRL. Contrastively, more evidence of SSRL manifested in the group with active and cohesive task-focused interaction. These results bear resemblance to the findings by Rogat and Linnenbrink-Garcia (2011) who noted that interaction in a group with high quality social regulation was predominantly collaborative rather than non-collaborative, i.e., the group shared ideas and worked jointly.

The recent study by Iiskala et al. (2015) analyzed individual students' participation in exchanges that included socially shared metacognitive regulation in asynchronous online interaction. The results highlighted that all four students in a case group contributed to the displays of SSRL in interaction but their roles were somewhat different. For example, the contributions of some students produced more reactions and, thus, activated regulatory interaction.

In conclusion, earlier studies point to a close relationship between learners' active participation and manifestation of SSRL in interaction. However, previous studies have not focused on the temporal aspects of participation and the emergence of SSRL. While it is evident that participation in interaction is necessary for SSRL to manifest, there is a lack of process-oriented evidence of how SSRL emerges in relation to the dynamics of participation in interaction.

2 Aim

The aim of the study is to investigate how socially shared regulation of learning emerges during the fluctuation of students' participation in interaction in collaborative learning. The analysis is guided by the following research questions: 1) "How does SSRL emerge during higher and lower levels of participation in social interaction?" and 2) "How does SSRL emerge during changes in participation in social interaction?"

3 Methods

3.1 Context and Participants

The participants of this study were teacher education students who worked on collaborative tasks in a mathematics education course at a Finnish university. As 2nd year students of the same class, the students already knew each other well. The students had followed the same course schedule and curriculum and they were accustomed to the local practices of teacher education which emphasize collaborative learning. Given students' age, education and previous experience of collaboration with each other, it could be expected that students had appropriate conditions for engaging in strategic interaction.

The course was held in a classroom-like research space with spherical 360-degree cameras. The course included six lessons in which students worked on collaborative tasks about the following mathematical and didactical topics: 1) Planning a mathematics education project, 2) Estimation and mental calculation, 3) Percentages, 4) Assessing mathematics skills, 5) Problem solving and 6) Learning algebra with a balance scale. Altogether 40 hours of video data was collected but, for the purposes of this micro-analytical study, we focused on groups' collaboration on two lessons which involved more mathematical than didactical content and a similar set of tasks and level of difficulty. The selected topics were Estimation and mental calculation and Problem solving. The estimation and mental calculation tasks required students, for example, to estimate the results of various brain-teasing calculations and to solve a problem with several unit transformations. The problem-solving tasks included four problems, for example "A fake among nine coins", "Seven bridges of Königsberg" and a challenging task involving combinatorics. While the tasks were rather structured, they were difficult enough to challenge students' mathematical understanding and required them to explore different strategies for solving the tasks.

Students were asked to work collaboratively during the tasks. The groups started their collaboration by reading the task instructions and using a tablet tool called S-REG (Laru, Malmberg, Järvenoja, Sarenius, & Järvelä, 2015; Järvelä, Kirschner, Hadwin, Järvenoja, Malmberg,

Miller, & Laru, 2016) to evaluate and discuss perceptions about their cognitive capabilities, motivation and emotions concerning the task. Next, groups began working on the tasks at their own pace. The groups had approximately one hour to complete the tasks.

3.2 Data

The collaboration of eleven groups was video-recorded during the chosen lessons, but the videos of six groups were chosen for analysis. Other groups were omitted because of absences in one of the two lessons that were selected for analysis. The six remaining groups each had four members ($n = 24$, 20 women, $M_{age} = 24$ years, $Std = 4$ years), though in four of the twelve videos only three students were present. All in all, twelve videos (10 h 31 min, $M_{duration} = 53$ min., $Std = 3$ min.) were used for micro-level analysis.

3.3 Data Analysis

We adopted a qualitative, process-oriented method (Arrow, Poole, Henry, Wheelan, & Moreland, 2004; Reimann, 2009) for analyzing the video recordings with the help of QSR International's NVivo 10 Software. Our primary research method was interaction analysis (Jordan & Henderson, 1995), which was initially supported by theory-based coding categories but which evolved to a more detailed descriptive analysis of case examples. The analysis proceeded by analyzing participation, identifying manifestations of SSRL in interaction, examining the concurrence of manifestations of SSRL and participation, and finally describing illustrative examples. Throughout the analyses, the content and functions of students' speech as well as gestures, action and prosody were taken into consideration.

The analysis concentrated only on task-focused interaction, i.e., joint discussion related to the task and the groups' collaboration. Task-focused interaction included, for example, agreeing on ways of working, discussing initial views about the task, solving tasks, reflecting on ways of

working and discussing motivation or emotion related to the task. Other interaction such as technical activities with microphones or tablets, discussions of other coursework and stories of personal life were considered off-task interaction and excluded from analysis. The reliability of coding task-focused interaction was checked by calculating the Cohen's kappa value ($\kappa = .88$) after two researchers had coded 20 % of the data. The mean duration of task-focused interaction in the videos of the current study was 43 minutes (Std = 5 min) whereas mean duration of off-task interaction was 10 minutes (Std = 3 min).

3.3.1 Participation. Students' participation in task-focused interaction was first analyzed at the individual level. The analysis was grounded on the core principles of social interaction: engaging in interaction requires participants to initiate turns and to provide evidence of understanding with, e.g., short back-channeling responses (e.g., mm, yes, nodding), relevant responses and continued attention (Clark & Brennan, 1991; Sacks, Schegloff, & Jefferson, 1974; Schegloff, 1982). The individual participation of each 24 students was coded moment by moment using three mutually exclusive categories: *active conversing*, *attunement* and *non-responsiveness*. The criterion for *active conversing* was that the student contributed verbally to the joint discussion, e.g., initiated turns or responded to turns. *Attunement* meant that the student did not substantially contribute to the joint discussion but showed signs of joint attention by back-channeling or nonverbal reactions (e.g., laughing, leaning in, eye contact, attentive gaze on a common object of attention). *Non-responsiveness* was characterized by a student not contributing and showing little or no signs of attunement.

The categories were coded on video as the collaboration unfolded. A systematic threshold of 20 seconds was used: a lack of attention had to continue for 20 seconds in order to be categorized as *non-responsiveness* and verbal contributions were considered *active conversing* as long as they were observed at least every 20 seconds. The time-based threshold was used because it allowed for some momentary variation in participation and it enhanced the consistency of analysis. The

reliability of the coding was checked by double-coding the individual participation of six randomly selected students of the six groups. A high Cohen's kappa value ($\kappa = .84$) was achieved, indicating that the analysis was conducted reliably (Landis & Koch, 1977).

Because our study focused on the manifestation of SSRL as a group-level phenomenon, the analysis of individual participation was aggregated to the level of the group. This was to explore how actively the whole group participated in task-focused interaction. The aggregation was performed by locating episodes where codes for individual participation overlapped. Three mutually exclusive levels of group participation were automatically coded on video: *Low* level of participation included moments when at least one student of the group did not indicate attunement or actively participate in the group's discussion. *Intermediate* level of participation meant that all students showed signs of attunement but at least one student did not contribute to the discussion verbally. On *high* level of participation, all students in the group actively participated in the discussion through verbal contributions.

After analyzing participation at the group-level, the total durations of each level of participation were extracted. In addition, changes in the temporal fluctuation of participation were visualized on a timeline by calculating the midpoint of each episode of low, intermediate and high participation and off-task interaction. Time points where participation was at a higher level than the preceding or following time point were considered peaks in participation. Time points where participation was at a lower level than the preceding or following time point were considered drops in participation. Because this study focused on on-task participation, transitions to off-task interaction were considered drops in participation in task-focused interaction. Figure 1 visualizes the coded levels of participation as well as peaks and drops in group 1 during the first 30 minutes of their collaboration on the lesson about estimation and mental calculation.

Figure 1. Fluctuation of participation in group 1 on the lesson about estimation and mental calculation.

3.3.2 Emergence of SSRL in interaction. To identify manifestations of SSRL, a theory-driven coding scheme was developed based on the definitions by Järvelä and Hadwin (2013) and other earlier work on SSRL (Järvelä, Malmberg, & Koivuniemi, 2016; Järvenoja & Järvelä, 2011; Malmberg, Järvelä & Järvenoja, 2016). We acknowledge that SSRL is a profoundly mental and metacognitive process that occurs as students' response to their perceptions of situated challenges (e.g., time, efficiency, difficulty) (Winne & Hadwin, 1998). Therefore, we did not attempt to observe the whole phenomenon but rather examined the communicative exchanges which mediate SSRL. We defined manifestations of SSRL as moments where students negotiated and aligned perceptions of collaborative processes in order to co-construct shared awareness and perceptions of the task and its requirements, goals, standards and plans, learning strategies, the groups' collective progress, strengths and weaknesses of the group, and the group's positive or negative feelings toward the task. Negotiation and alignment entailed that students discussed different perspectives and formed joint perceptions. Because the focus of this study was the characteristics of interaction, we did not distinguish between different phases or targets of regulation.

The unit of analysis was a meaningful event (Jordan & Henderson, 1995). A manifestation of SSRL in interaction was considered to begin at the onset of planning, monitoring, adapting or evaluating (e.g., "But can this be right?" or "I'm too tired to do these right now"). The event had to

continue by others responding to the initiation by elaborating it, e.g., sharing another perspective, or agreeing with the initiation and suggesting what to do. Students' contributions and actions had to reflect the acknowledgement and integration of others' contributions, but simple agreement or acceptance of the initiation was not enough. The event was sustained until students' behavior or speech indicated that a consensus was reached. Manifestations of SSRL could involve two, three or all four members of the group.

The reliability of the analysis was checked by double-coding six of the twelve videos (5 h 17 min, 50 % of the data). Two researchers viewed videos independently and identified manifestations of SSRL using the same criteria. The Cohen's kappa value was calculated by checking if the inter-raters had identified the same events. The initial kappa value ($\kappa = .62$) indicated substantial agreement (Landis & Koch, 1977). While the kappa did not reach the commonly used threshold of 0.70, the value can be considered satisfactory for coding interaction on raw video data. The initial non-agreement was due to the difficulty of differentiating events of SSRL from co-regulation or knowledge co-construction. To resolve differences in coding, the inter-coders compared and discussed all the non-agreements and negotiated the discrepancies until 100 percent agreement was achieved. The negotiations allowed making slight refinements to the coding criteria and especially afforded consistency in determining what not to consider as SSRL. Based on the negotiations, one of the researchers continued coding the remaining data.

3.3.3 Participation and emergence of SSRL in interaction. The analyses of participation and SSRL were utilized in combination to examine the concurrence of SSRL and the levels of and changes in participation. First, we extracted the total durations of low, intermediate and high participation and compared how the levels of participation were distributed in task-focused interaction in general and in manifestations of SSRL. We also calculated the proportion of manifestations of SSRL out of the total duration of low, intermediate and high participation. A Kruskal-Wallis H test was used to examine differences in the proportions. A non-parametric test

was used due to the limited number of observations, i.e. proportions derived from the analysis of twelve videos. Next, we examined how manifestations of SSRL coincided with changes in participation. We extracted the frequencies of peaks and drops and examined their number in task-focused interaction in general and in manifestations of SSRL. We also calculated the proportion of peaks and drops coinciding with manifestations of SSRL out of the total number of peaks and drops in each video. A Mann-Whitney *U* test was performed to investigate differences in the proportions.

Finally, we enriched the investigation with a descriptive analysis of illustrative examples. The examples were selected from different groups, lessons and phases of task performance so that the examples would showcase the variety of situation-specific factors that shaped participation and the emergence of SSRL.

4 Results

4.1 How does SSRL emerge during higher and lower levels of participation in social interaction?

The groups' participation fluctuated between *high* participation where all group members actively contributed, *intermediate* participation where all group members indicated attunement but did not actively contribute and *low* participation where at least one group member did not contribute or show attunement. Low participation accounted, on average, for 40 percent (Std = 12 %) of groups' task-focused interaction. Intermediate participation covered, on average, 41 percent (Std = 9 %) of groups' task-focused interaction. High participation was the scarcest as it amounted, on average, to 20 percent (Std = 12 %) of the groups' task-focused interaction.

Manifestations of SSRL were observed in all videos under analysis. Their mean total duration in each group lesson amounted to approximately 10 minutes (Std = 4 minutes). Manifestations of SSRL emerged most commonly during intermediate and high participation and the least during low participation. On average, 21 percent (Std = 13 %) of the manifestations of

SSRL involved low participation, 46 percent (Std = 12 %) involved intermediate participation, and 33 percent (Std = 17 %) involved high participation. Thus, manifestations of SSRL occurred on all levels of participation but they concurred with a higher level of participation than task-focused interaction in general.

The prevalence of SSRL varied in the different levels of participation. The mean proportion of SSRL occurrences in the total duration of intermediate participation was 28 percent and of low participation 12 percent (Table 1). In contrast, manifestations of SSRL accounted, on average, for 43 percent of the total duration of high participation. Variance (Std = 22 %) was somewhat high due to situative differences that influenced the total duration of SSRL and of high participation (See example A and C in Chapters 4.2.1 and 4.2.3) but, nevertheless, SSRL consistently accounted for the largest proportion of high participation. A Kruskal-Wallis test showed a significant difference in the proportion of SSRL occurrences between the three levels of participation ($H(2) = 15.549, p < .001$). Pairwise comparisons showed a significant difference ($p = .023$) in the proportion of SSRL between low (mean rank 9.17) and intermediate participation (mean rank 20.62) as well as a significant difference ($p < .001$) between low and high participation (mean rank 25.71). In sum, manifestations of SSRL accounted for a major proportion of high participation which was least common level of participation in task-focused interaction. In contrast, SSRL covered a significantly smaller proportion of low participation even though low participation was generally common in task-focused interaction. Thus, SSRL manifested especially during moments when participation was the more active than in task-focused interaction overall.

Table 1

Mean durations of levels of participation in total and coinciding with manifestation of SSRL

	Total		SSRL		SSRL of total	
	<i>M</i> (<i>n</i> = 12)	<i>Std</i>	<i>M</i> (<i>n</i> = 12)	<i>Std</i>	<i>M</i>	<i>Std</i>
High participation	0:08:07	0:04:11	0:03:29	0:02:19	43 %	22 %
Intermediate participation	0:17:22	0:04:36	0:04:49	0:02:24	28 %	10 %

Low participation	0:17:15	0:05:42	0:02:06	0:01:24	12 %	7 %
All	0:42:44	0:04:49	0:10:24	0:03:42	24 %	9 %

4.2 How does SSRL emerge during changes in participation in social interaction?

Next, we examined how SSRL concurred with changes, i.e. peaks and drops, in participation. The average number of peaks and drops in each video was approximately equal: on average, 27 peaks and 28 drops were observed in participation during each lesson (Table 2). However, the number of peaks coinciding with SSRL was consistently higher than the number of drops coinciding with SSRL. On average, SSRL events coincided with 9 peaks (Std = 3) and 4 drops (Std = 1) in each video. Proportionally, manifestations of SSRL coincided, on average, with 35 percent of all peaks in the groups' participation. In contrast, drops coinciding with manifestations of SSRL accounted, on average, for 14 percent of all drops in the groups' participation. Based on a Mann-Whitney U test, the difference between the proportions of peaks (mean rank 17.62) and drops (mean rank 7.38) was statistically significant ($U = 133.500, p < .001$).

Table 2

Mean frequencies of peaks and drops in total and coinciding with manifestation of SSRL

	Total		SSRL		SSRL of total	
	$M (n = 12)$	Std	$M (n = 12)$	Std	M	Std
Peak in participation	27	4	9	3	35 %	12 %
Drop in participation	28	4	4	1	14 %	5 %

Table 3 shows how manifestations of SSRL coincided with peaks and drops in each level of participation. Clearly, the events coincided most frequently with peaks on high level of participation. In contrast, drops on low level of participation rarely concurred with manifestations of SSRL even though drops on low participation were frequent in task-focused interaction in general. This indicates that decreases in participation usually occurred before and after the SSRL event.

Overall, the results suggest that SSRL manifested particularly when participation increased to a higher level than general. To illustrate the findings in more depth, we describe three case examples in more detail.

Table 3

Frequencies of peaks and drops on levels of participation in total and coinciding with manifestations of SSRL

	Peaks			Drops		
	Total <i>n</i>	SSRL <i>n</i>	SSRL of total %	Total <i>n</i>	SSRL <i>n</i>	SSRL of total %
High participation	223	89	28 %	0	0	0 %
Intermediate participation	92	17	5 %	73	23	7 %
Low participation	5	2	1 %	193	24	7 %
Off-task interaction	0	0	0 %	64	0	0 %
Sum	320	108	34 %	330	47	14 %

4.2.1 Example A. The first example presents a manifestation of SSRL in the collaboration of group 1 (Juuli, Iina, Alisa and Erika) on the lesson about estimation and mental calculation. During this lesson, the proportion of SSRL was relatively large and manifestations of SSRL during high and intermediate participation were more prevalent than average (Table 4). The characteristics of the group's collaboration shed light on the findings: In the beginning of the lesson, the students discussed their mixed feelings towards mathematics and decided that the group would give everyone time to think individually before discussing the tasks together. The group enforced this decision which meant that low participation often involved individual reflection. During higher levels of participation, the group commonly aligned task perceptions, resolved challenges in understanding and monitored their progress. Thus, activated participation was commonly met with manifestations of SSRL, as illustrated by the following example.

Table 4

Durations of levels of participation and frequencies of peaks and drops in total and coinciding with manifestations of SSRL in group 1 on the lesson about estimation and mental calculation.

	Total	SSRL	SSRL of total
High participation	0:08:22	0:05:17	63 %
Intermediate participation	0:19:07	0:08:33	45 %
Low participation	0:20:23	0:00:59	5 %
All	0:47:52	0:14:49	31 %
Peak in participation	32	13	41 %
Drop in participation	34	6	18 %

In this example, the group is about to move from one task to another, but a need for regulation emerges as the group notices that everyone has not finished the previous task. During the discussion, the level of group participation fluctuates between low, intermediate and high (Figure 2). A manifestation of SSRL emerges at the peak of participation.

Figure 2. Example of participation and manifestation of SSRL in group 1.

Prior to the manifestation of SSRL (43:22–43:59), the level of group participation is low as the students finish their notes of their previous task. At 43:59, the level of participation increases to intermediate as Alisa and Erika start reading the task instructions of their next task, indicating readiness to move on. Subsequently, Juuli's participation is activated as she notices that Iina is still making notes of the previous task. The manifestation of SSRL is initiated at 44:10 as Juuli asks if Iina is ready (A1). At this point, the level of group participation rises from intermediate to high.

Juuli's question conveys a possible need for regulating the group's behavior. Because Iina admits that she is not ready (A2), Juuli, Alisa and Erika agree to wait (A3–A8).

(Example A, 44:10–44:22)

A1 Juuli: *Is Iina ready yet? (Looks at Iina who is making notes)*

A2 Iina: *No but you can go on, I'll...*

A3 Alisa: *No we won't. (Looks at Iina)*

A4 Juuli: *No. (Looks at Iina)*

A5 Alisa: *Go ahead.*

A6 Iina: *Oh, okay.*

A7 *(3 second silence. Iina continues her notes while others sit still)*

A8 Erika: *We'll wait for you.*

A9 *(2 second silence. Iina continues her notes while others sit still)*

The discussion continues as Iina states that she is uncomfortable with others waiting for her (A10). This activates others to respond to the potential emotional challenge: Juuli, Alisa and Erika change their behavior so that they would not appear to be waiting (A11–A13). Juuli assures that Iina need not hurry (A13). The students continue to joke about their behavior (A14–A17). Next, the group makes a new agreement: instead of waiting for Iina, the others will start thinking of the next task individually (A18, A20). At this point, Iina continues working on her notes (A19), and the level of group participation decreases to low. In the following moments (44:34–45:20), participation remains low as others do not start to discuss the next task until Iina is ready.

(Example A, 44:22–44:38)

A10 Iina: *No but don't wait. (Stops making notes) It's making me anxious. (Laughs)*

A11 *(Juuli, Alisa and Erika laugh as they start to behave as if they are not waiting)*

A12 Erika: *Well, hey...*

A13 Juuli: *We can just chat here. No hurry. (Taps the table, looking around)*

A14 Juuli: *Awful tapping! (Jokingly taps harder on the table as if waiting impatiently.)*

- A15 *(Erika and Iina laugh out loud. Alisa smiles amusedly.)*
- A16 *Erika: (Sarcastically) “No hurry” (Imitates Juuli by tapping on the table and laughs)*
- A17 *Iina: “We’re waiting – go ahead” (Imitates Juuli and Erika by tapping on the table and laughs)*
- A18 *Juuli: (With a more serious tone of voice) We’re not waiting. We can think about this already. (Points to the instructions of the next task)*
- A19 *(Iina turns her gaze to her notes)*
- A20 *Alisa: Yeah, exactly. I’m already thinking about it on my own.*

The example highlights how a need for regulation activated students to participate in discussing their progress. Students’ participation afforded reciprocal negotiation which allowed the group to re-direct their behavior so that all group members could be ready for the upcoming task. Through active contributions by all group members, the group achieved a joint decision that reinforced their commitment to work as a group. The subsequent decrease in participation was the direct consequence of the group’s shared agreement not to move on before everyone was ready. A socio-emotional valence was evident in the way Iina externalized her feelings of anxiety and others responded by joking and assuring Iina that she could take her time.

4.2.2 Example B. The second example highlights a manifestation of SSRL in group 5 (Ella, Inna and Siiri) during the lesson about problem solving. On this lesson, the group showed slightly more low participation than average (Table 5). This may have been caused by students’ unbalanced mathematical abilities and prior knowledge. For example, Ella revealed that she had trained problem solving strategies during her free time whereas Inna repeatedly expressed that she is struggling to understand the tasks. Due to her difficulties, Inna sometimes disengaged from interaction during challenging tasks. This resulted in episodes of low participation. However, despite struggling to contribute to problem solving, Inna usually participated in negotiating task perceptions, reflecting the group’s performance and resolving challenges. Thus, manifestations of SSRL, such as the following example, mostly concurred with intermediate and high participation.

Table 5

Durations of levels of participation and frequencies of peaks and drops in total and coinciding with manifestations of SSRL in group 5 on the lesson about problem solving

	Total	SSRL	SSRL of total
High participation	0:07:30	0:03:23	45 %
Intermediate participation	0:18:00	0:05:07	28 %
Low participation	0:22:33	0:02:06	9 %
All	0:48:04	0:10:35	22 %
Peak in participation	27	10	37 %
Drop in participation	27	4	15 %

During this example, the group is discussing in how many ways a bunny can jump a 10-step staircase if the bunny can only jump one or two steps at a time. The level of group participation fluctuates between low, intermediate and high (Figure 3). In the two manifestations of SSRL, the group establishes that their strategy is insufficient and agree that they need to find a new way of solving the task.

Figure 3. Example of participation and manifestations of SSRL in group 5.

Prior to the first manifestation of SSRL (29:39–31:13), the group tries to solve the task using trial and error. However, at 31:13, a challenge is externalized by Inna who cannot follow the group's calculation (B1). This initiates the regulation. Ella, Inna and Siiri begin to discuss an

alternative strategy (B3–B5) and comment on their initial strategy (B6–B9). At 31:27, the level of participation briefly decreases to intermediate as Ella does not contribute to the discussion. At this point, the group shows difficulties in resolving the challenge: Siiri admits that she can't remember how to calculate such tasks anymore (B12) and Inna jokingly begins to focus on irrelevant aspects of the problem (B13, B15). At 32:07, Ella's participation is reactivated as she makes a new suggestion (B16, B18). However, the idea does not help the group advance (B17, B19). The manifestation of SSRL is briefly paused by the teacher who discusses with the group about a previous task (32:19–32:40).

(Example B, 31:13–32:19)

B1 Inna: *I'm totally mixed up! (Puts her pen down on the table)*

B2 *(Ella and Siiri laugh. Inna smiles and shakes her head.)*

B3 Ella: *You can probably make some kind of equation out of this.*

B4 Inna: *I think so too.*

B5 Siiri: *Yeah you can but I don't know how it goes. How do you calculate those?*

B6 Inna: *So what was our strategy? (Starts writing on her notes)*

B7 Inna: *"Trial and error equals not good." (Writes and reads out loud, laughs)*

B8 *(Ella laughs)*

B9 Ella: *We only achieved the error. (Laughs)*

B10 Siiri: *So how do you calculate these, I mean tasks like this? (Sighs) Is it some sort of multiplication calculation where ten... No... How does it go?*

B11 Inna: *Don't ask me, I don't know.*

B12 Siiri: *I can't remember.*

B13 Inna: *I think the bunny can decide how many ways it uses for jumping up the stairs.*

B14 *(Ella and Siiri laugh)*

B15 Inna: *I'm not so interested in that per se. As a bunny owner I'm only concerned about whether the bunny is interested in the stairs and wants to do exercise.*

B16 Ella: *Are you supposed to do some kind of double...*

B17 Siiri: *I can't remember at all.*

B18 Ella: *Five times x is ten y and... (Laughs)*

B19 Siiri: *No, I can't be like that.*

At 32:40, Siiri returns to the earlier discussion by proposing that the task requires understanding factorials (B20). This activates Ella and Inna to recall their prior knowledge. The level of participation remains high as the group members discuss what they remember of factorials (B22–B28). However, since the students are unable to remember anything substantial, the level of group participation briefly decreases to intermediate at 32:59 and the discussion momentarily halts (B29).

(Example B, 32:40–33:20)

B20 Siiri: *So aren't these the kind of tasks where there's something multiplied by something multiplied by something and then there's like some freaking exclamation mark? (Looks at Ella and Inna)*

B21 Ella: *Yeah, that's true.*

B22 Siiri: *Something like that. But I can't remember how they go. (Shakes her head)*

B23 Ella: *I can't either.*

B24 Inna: *Yeah, this is one of those! From probability calculus course.*

B25 Siiri: *Mm, yeah. (Nods to Inna)*

B26 Ella: *I hated that course.*

B27 Siiri: *Me too.*

B28 Inna: *I got a good grade but I never understood what I did.*

B29 *(Everyone turns their gaze to the task instructions and sits quietly. 9 second silence.)*

The students' participation is reactivated once more at 33:20 as Ella and Siiri propose a resolution: looking up information (B30–B31). A consensus is communicated by speech and behavior as Ella and Inna reach for their tablets and begin to search for information (B32–B36). Thus, the group is able to continue with the task. Subsequently, the level of group participation decreases to low (33:44) as Ella and Inna start discussing suitable key words and Siiri waits for the others.

(Example B, 33:20–33:39)

- B30 Ella: Could it be a problem solving strategy that we go to Google and do a search?
(Changes her position and looks at the others)*
- B31 Siiri: Yeah, let's look for the formula. Alright.*
- B32 Inna: Yeah! (Drops her pen and reaches out to a tablet)*
- B33 Ella: Yeah. (Grabs a tablet and sets in front of her)*
- B34 Ella: We have all these tools here.*
- B35 Inna: Yeah, we can use these. They're here for that purpose.*
- B36 Siiri: Alright. (Looking what the others are doing)*

This excerpt showcases how the group recognized their common lack of knowledge and jointly agreed how to act on it. The group's participation was activated and sustained by their need to adapt their problem solving strategy. Momentary decreases in participation aligned with the moments during which the students were unsure how to resolve the challenge. However, the discussion was promptly reactivated. The manifestation of SSRL incorporated socio-emotional elements such as humor and discussion about feelings. Once the challenge was resolved by agreeing on a new strategy, the acute need for regulatory interaction was relieved and the level of participation decreased.

4.2.3 Example C. The final example showcases the collaboration of group 3 (Elena, Laura, Antti, Ilona) on the lesson about estimation and mental calculation. During this lesson, the group showed slightly more high participation but slightly less SSRL than average (Table 6). This reflects some general characteristics of the groups' interaction: On one hand, all the group members actively participated in interaction and no student was clearly the most or least engaged. This resulted in relatively frequent high participation. On the other hand, the students' interaction was not always particularly cohesive. Thus, the moments of high participation did not necessarily afford manifestations of SSRL. The proportion of SSRL on high participation was consequently relatively low. However, the absolute duration of SSRL during high participation did not notably differ from

average. This suggests that, despite having less cohesive discussions at times, the whole group also commonly participated in SSRL. This is illustrated by the following example of two SSRL events.

Table 6

Durations of levels of participation and frequencies of peaks and drops in total and coinciding with manifestations of SSRL in group 3 on the lesson about estimation and mental calculation

	Total	SSRL	SSRL of total
High participation	0:11:46	0:03:08	27 %
Intermediate participation	0:19:00	0:05:01	26 %
Low participation	0:18:05	0:01:52	10 %
All	0:48:51	0:10:01	21 %
Peak in participation	34	6	18 %
Drop in participation	35	3	9 %

In this example, the group is preparing for their collaboration. The group's participation fluctuates between intermediate and high participation as the group discusses their initial perceptions of the task (Figure 4). Because the example includes a rather lengthy episode of interaction, we will only focus on the first manifestation of SSRL and a piece from the second event. The first event showcases how the group becomes aware that a group member is not feeling optimally motivated. The second piece of interaction demonstrates how the students discuss their strengths as a group.

Figure 4. Example of participation and manifestations of SSRL in group 3.

The first manifestation of SSRL concurs with a simultaneous increase in the level of group participation from intermediate to high (10:42). Elena, who was briefly only listening to the others, initiates the event by stating that she is feeling anxious about mathematics tasks (C1). Elena's statement entails a need for regulating emotion. The challenge triggers other members of the group to react. In the subsequent turns, Antti, Laura and Ilona encourage Elena and offer their support (C2–C5, C7). Laura and Ilona also share their feelings toward the task (C10, C12) and the group agrees to work together on the mathematics tasks (C4, C14, C16–19). The groups' humorous attitude and support for Elena enforce a positive socio-emotional climate. The manifestation of SSRL ends as the group starts discussing other aspects of the task (11:18).

(Example C, 10:42–11:18)

C1 Elena: *I'm so stressed now about these maths tasks. I'll never survive.*

C2 Antti: *Heyy, now-*

C3 Laura: *You will survive, Elena.*

C4 Ilona: *In a group! (Places her hand on Elena's shoulder)*

C5 Antti: *We will help you. (Taps Elena on the shoulder)*

C6 *(Elena jokingly acts as if she is crying. Everyone laughs.)*

C7 Antti: *We like support you in this.*

C8 Ilona: *There's always someone on the bottom.*

C9 *(Elena laughs and places her arms on Antti's and Elena's shoulder.)*

C10 Laura: *This is so upside down cause last time Antti and I were jumping off a cliff and now we're superexcited.*

C11 *(Everyone laughs.)*

C12 Ilona: *Well I'm quite okay.*

C13 Elena: *No but these are okay but all of these, all those which we got last time also.*
(Grabs the task instructions)

C14 Ilona: *We can do those together also. (Places her hand on her shoulder)*

C15 Antti: *Hey, one thing at a time.*

C16 Ilona: We can do those together also. (Leans to Elena)

C17 Laura: We can organize a mathematics workshop instead of a game night. (Laughs)

C18 (Elena nods to Laura and laughs.)

C19 Antti: We can share this thing.

A second manifestation of SSRL starts with discussion about task understanding (12:22–13:15) and continues with a discussion about the group's strengths (13:15–13:59). At the beginning of the latter discussion, the level of participation is intermediate since Laura is briefly only listening to the discussion. However, the whole group becomes activated and the level of participation increases as the students begin to share and elaborate their perceptions of the group's capabilities: Ilona suggests that the group has a positive attitude (C20, C24), Elena praises the group's mathematical talent (C25) and logical thinking (C31), Laura highlights that the group encourages each other (C32), and Antti adds that the group boosts each other's confidence (C34). The explicated team spirit is enforced by humor, appraisals and cheering as well as eye contact and touching. Students also engage each other by referring to the group as a collective and by addressing one another directly. Thus, participation remains high until the end of the event (13:59).

(Example C, 13:15–13:59)

C20 Ilona: We have a positive attitude... At least some do. (Laughs jokingly)

C21 Elena: (Smiles at Ilona) Some have a negative attitude to balance. (Laughs jokingly)

C22 Ilona: No, now the positive. (Looks at Elena and waves her finger)

C23 Antti: Supporting each other.

C24 Ilona: We have a positive attitude.

C25 Elena: We have such mathematically talented people. (Gestures towards the others)

C26 Ilona: Laura. (Gestures towards Laura and laughs)

C27 Laura: Ilona. (Smiles and looks at Ilona)

C28 Antti: Elena. (Looks at Elena)

C29 Elena: Yes, thank you, thank you Antti. (Smiles and pats Antti on the shoulder)

C30 Antti: Yeah yeah. (Smiles, nods and lowers his gaze modestly)

C31 Elena: And people who think logically.

C32 *Laura: We encourage each other. (Smiles and makes a cheering gesture with her arm)*

C33 *Ilona: Yes.*

C34 *Antti: Yes, we try to boost each other's confidence.*

C35 *Ilona: We have a good team spirit. (Waves her arm between her and the others)*

C36 *Elena: We have a good team spirit, yes.*

C37 *Antti: Yes.*

C38 *All: Wooooo! (Everyone sets their fists together and throws them up)*

C39 *(Everyone laughs)*

This example showcased how an externalized emotional challenge activated students' participation. Participation during the given excerpts was high as students engaged and encouraged each other and transactively elaborated each other's contributions. As a result, the group established a shared sense of group cohesion and externalized their goal to support each other. This was not only communicated in the content of the students' speech but also in the functions of their speech, such as praising, and their nonverbal communication. These elements evidenced a strong socio-emotional valence.

5 Discussion

This study investigated how socially shared regulation of learning emerged during the fluctuation of students' participation in interaction in collaborative learning. The findings show that manifestations of SSRL involved more active participation than task-focused interaction in general and that SSRL manifested most prevalently when all students in a group, rather than only some, contributed to the discussion and were attuned to each other's contributions. The results support and elaborate previous studies by Grau and Whitebread (2012), Sinha et al. (2015), Rogat and Linnenbrink-Garcia (2011) and Volet et al. (2009) who found that participation in interaction is beneficial for shared regulation. Their results suggested that shared regulation was more common in groups with more active participation. However, the studies did not focus on how SSRL emerged

temporally, i.e., how SSRL manifested during the possible fluctuation of participation. The current study showed that manifestations of SSRL were scarce when at least one group member was disengaged. The moments of the most active participation, in turn, were the best grounds for SSRL to emerge in interaction even though these moments were the rarest in task-focused interaction overall. Moreover, there were more increases than decreases coinciding with manifestations of SSRL even though the number of increases and decreases was generally equal in task-focused interaction. SSRL was especially common when groups' participation increased to the highest level. Thus, the limited moments of increased participation were often marked by manifestations of SSRL. This was also illustrated in the case examples where lower levels of participation preceded and followed manifestations of SSRL.

The prevalence of SSRL on higher levels of participation indicates that students' active participation in interaction afforded reciprocal exchanges which are necessary for SSRL. This in accordance with the studies by Hurme et al. (2009), Iiskala et al. (2004; 2011; 2015) and Järvenoja and Järvelä (2013), who emphasized that SSRL is a jointly constructed group-level phenomenon which is built in reciprocal interaction between the group members. While students may have different roles in interaction including SSRL, only reciprocal participation by several students can lead to true negotiation of collaborative processes (Iiskala et al., 2015). Other studies have also highlighted the importance of active, equal, reciprocal and transactive interaction for SSRL. For example, De Backer, Van Keer and Valcke (2015) found a positive correlation between manifestations of socially shared metacognitive regulation and students' transactive discussions in which speakers' contributions reflected previous contributions. Rogat and Adams-Wiggings (2014; 2015), in turn, investigated the implications of other-regulation for the overall quality of regulation in collaborative groups. Though their study focused on other-regulation, they additionally found that shared regulation occurred less when students participated unequally and ignored regulation by their peers. In contrast, shared regulation was afforded by group members taking up others'

regulatory contributions and by soliciting equal participation and the inclusion of divergent ideas. These characteristics of interaction were also evident in the case examples of the present study.

The temporal concurrence between manifestations of SSRL and students' increased participation suggests that SSRL had a particular role in the dynamics of participation in social interaction. Our results show that joint attention and participation by the whole group was not continuous throughout task-focused interaction but SSRL typically coincided with moments when students' participation increased to a higher level than general. This reflects the fact that students' coordinated engagement can fluctuate during collaboration (Barron, 2001, 2003) but, in the face of challenges, SSRL allows groups to create joint awareness of the situation and to realign their processes in order to optimally engage in cognitive processes (Järvelä et al., 2013). Our case examples highlighted that participation in task-focused interaction was often low because students needed time for individual reflection or because some students struggled to contribute to mathematical discussions. However, a need for regulation often activated the whole group to negotiate how to resolve the challenge. This helped the group proceed with cognitive efforts that generally involved less intensive participation. These findings reflect the role of regulation as a means to facilitate and inhibit the groups' previous direction or activity (Iiskala et al., 2011), to sustain the groups' knowledge co-construction process (Ucan & Webb, 2015) and to focus and organize groups' cognitive activities toward their goal (Molenaar & Chiu, 2014).

6 Limitations

The results presented in this study are based on the collaboration of six groups on two mathematics lessons which means that the evidence is highly situated in the selected tasks and groups. For example, it is likely that as future teachers and adult learners, the participants had better abilities for engaging in SSRL than children or adolescents. Furthermore, the distribution of the levels of participation evidenced in this study could reflect the nature of the mathematics tasks

which may have required more individual reflection and caused more fluctuation in participation. However, while the size and situated nature of the data does not afford generalizations, this study answers the current need for process-oriented research from real, inevitably “messy” learning settings (Fischer & Järvelä, 2014) and research which aim to understand the situative and temporal dynamics of regulation in collaboration (Järvenoja, Järvelä, & Malmberg, 2015; Volet, Vauras, & Salonen, 2009; Molenaar & Järvelä, 2014).

7 Conclusions

The results of this study suggest that SSRL as a strategic activity had a role in the dynamics of participation in interaction in collaborative learning. Manifestations of SSRL involved activated participation during the moments when interaction was needed to reciprocally resolve challenges and to coordinate activities. This shows that coordinated collaboration (Barron, 2001, 2003; Erkens et al., 2006) calls for joint efforts to regulate learning (Järvelä & Hadwin, 2013; Hadwin & Oshige, 2011). However, SSRL does not emerge automatically, but requires students to activate it in reciprocal interaction. Though much of regulated learning is concealed in learners’ internal mental appraisals (Hadwin, Järvelä, & Miller, 2016), students’ activated participation in social interaction affords regulation to become shared. To this end, students’ ability to engage in SSRL during collaboration should be developed by supporting reciprocal exchanges and students’ awareness of when strategic regulation is needed (Järvelä et al., 2015; Jeong & Hmelo-Silver, 2016).

In future research, it may be fruitful to examine the influence of socio-emotional processes on participation and SSRL. The present study did not focus on socio-emotional characteristics of interaction, but our examples showed a socio-emotional valence in manifestations of SSRL and concurrent increases in participation. Socio-emotional aspects could hypothetically play a part in activating students’ participation during manifestations of SSRL. Earlier evidence suggests that positive emotions can reinforce students’ learning behaviors (Linnenbrink-Garcia & Pekrun, 2011;

Pekrun, Goetz, Titz, & Perry, 2002) and recent studies have repeatedly highlighted the relationship between socio-emotional aspects and regulation in collaborative learning (Järvelä, Järvenoja, Malmberg, Isohätälä, & Sobocinski, 2016; Kwon, Liu, & Johnson, 2014; Lajoie et al., 2015; Rogat & Linnenbrink-Garcia, 2011; Ucan & Webb, 2015). In general, there is more to be explored about participation in interaction during collaborative learning. For example, the scope of this study did not afford comparisons between groups or an analysis of the factors triggering fluctuation in participation (Määttä, Järvenoja, & Järvelä, 2012). More research exploring the temporal aspects of participation is warranted.

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