Cognitive and Socio-Emotional Interaction in Collaborative Learning: Exploring fluctuations in students' participation

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Abstract

Collaborative learning involves fluctuations in how students participate in social interaction and how they engage in interactions that are cognitive (e.g., sharing knowledge, monitoring learning) and more socio-emotional (e.g., encouragement, positive appraisal) in nature. Few studies have investigated how participation in social interaction fluctuates in relation to these varying types of interaction. The aim of this process-oriented study was to explore how actively students participated in cognitive and socio-emotional interactions and what characterized the moments when participation changed during transitions between the types of interaction. The qualitative analysis focused on video-recorded collaborative learning of six groups of student teachers (N = 24). We found that socio-emotional interaction involved more active participation than cognitive interaction. Changes in participation during transitions between types of interaction were characterized by shifts between domain-focused and metacognitive activities. Implications for supporting and studying productive social interaction in collaborative learning are discussed.

Keywords: participation, social interaction, collaborative learning, process-oriented study

Introduction

In collaborative learning, learners engage in cognitive processes as well as social and socio-emotional processes, which dynamically shape one another and the performance of the group (Kreijns, Kirschner, & Jochems, 2003; Miyake & Kirschner, 2014). Cognitive processes involve the learners' efforts toward deepening their understanding through thinking, reasoning, and co-elaborating knowledge, whereas socio-emotional processes[1] refer to the ways in which learners interact and relate to each other and how they feel about their collaboration (e.g., Kreijns et al., 2003). The cognitive and socio-emotional processes, such as thinking or perceptions of psychological safety, are partly internal (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006). Nevertheless, they are also shared in and shaped by *social interaction* (Kreijns et al., 2003).

Participation in social interaction refers to contributing to communicative exchanges, responding to turns of talk, and providing evidence of attention and understanding (Clark & Brennan, 1991; Sacks, Schegloff, & Jefferson, 1974). Studies show that active, reciprocal participation in social interaction supports group productivity (Cohen, 1994), whereas productive collaborative learning can be hindered by problems in participation (Hämäläinen & Arvaja, 2009), such as social loafing and free-riding (e.g., Karau & Williams, 1993; Kerr & Bruun, 1983; Salomon & Globerson, 1989). Participation in social interaction is crucial as it mediates interactions that are essential for collaborative learning: it affords learners opportunities to share, elaborate, and scrutinize their knowledge on domain-focused content (Baker, 1999; Dillenbourg, 1999; Roschelle, 1992) and to jointly regulate their learning by metacognitively planning, monitoring and evaluating their goals, progress and performance (Iiskala, Vauras, Lehtinen, & Salonen, 2011; Khosa & Volet,

[1] The current study was grounded in Kreijns et al.'s (2003) two-dimensional distinction between the cognitive and socio-emotional processes of collaborative learning, though in the literature, many terms have been used to conceptualize the latter processes, including *social* and *relational aspects* (Damsa, Ludvigsen, & Andriessen, 2013; Janssen, Erkens, Kirschner, & Kanselaar, 2010), *group processes* (Rogat & Linnenbrink-Garcia, 2011), *socio-relational* and *affective dimensions* (Baker et al., 2013), and *social* and *behavioral engagement* (Linnenbrink-Garcia, Rogat, & Koskey, 2011; Sinha et al., 2015). These also relate to Barron's (2000, 2003) conceptualization of the *relational space* of collaborative learning.

2014; Näykki, Järvenoja, Järvelä, & Kirschner, 2017). We conceptualize such interactions as *cognitive interactions* (Järvelä, Järvenoja, Malmberg, Isohätälä, & Sobocinski, 2016), which facilitate the cognitive processes that can enable learning. Participation in social interaction also serves as a medium for sharing emotions and building a respectful and cohesive socio-emotional climate, for example through encouragements or positive appraisals (Barron, 2003; Isohätälä, Näykki, Järvelä, & Baker, 2017; Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015). We conceptualize these as *socio-emotional interactions* (Bakhtiar, Webster, & Hadwin, 2017), which influence the forming of the socio-emotional processes in collaborative learning.

Prior studies suggest that group members' participation in social interaction and the types of their interaction during collaborative learning are related; for example, groups in which students participate more jointly also tend to show more positive socio-emotional interactions and higher-quality cognitive interactions (Barron, 2003; Sinha et al., 2015). However, studies have rarely addressed the fact that social interaction in collaborative learning is not static: the degree of group members' participation in social interaction during collaborative learning can fluctuate (Engin, 2017; Määttä, Järvenoja, & Järvelä, 2012; Rocksén, 2017) and their engagement in cognitive and socio-emotional interactions can vary from moment to moment (Järvelä, Järvenoja et al., 2016). Few studies have investigated how group members' participation in social interaction fluctuates in relation to varying types of interactions. We argue that more process-oriented evidence could shed light on the reasons behind more and less active moments of participation in different types of interaction and the meaning of these moments for the progress of collaborative learning. This can enrich the understanding of collaborative learning as a temporally unfolding process and help educators monitor the flow of groups' collaborative learning more accurately and provide targeted support (Wise & Schwarz, 2017).

Participation in Cognitive and Socio-emotional Interactions

We differentiate between two types of task-focused interaction in collaborative learning: cognitive interaction and socio-emotional interaction. By task-focused *cognitive interaction* we refer generally to groups' interactions about the content or about their learning process (Dillenbourg, Baker, Blaye, & O'Malley, 1995). This includes interactions about domain-focused content to be learned, such as the sharing, elaborating, and processing of knowledge (Hmelo-Silver & Barrows, 2008; Roschelle, 1992; Webb, Troper, & Fall, 1995). Cognitive interaction also includes groups' interactive, metacognitive planning, monitoring the conditions and progress of collaborative learning, or evaluating performance, which are fundamental regulation processes in successful collaborative learning (e.g., Iiskala et al., 2011; Khosa & Volet, 2014; Näykki, Järvenoja et al., 2017). We argue that cognitive interactions are the baseline of task-focused interaction in collaborative learning, which allow students to make use of the affordances of learning as a group (Clark & Brennan, 1991) and regulate their learning so that optimal performance would be possible (Hadwin, Järvelä, & Miller, 2018).

Alongside cognitive interaction, groups' task-focused interactions can also involve expressions of emotion or talking about emotions or motivation (Rogat & Adams-Wiggins, 2015; Rogat & Linnenbrink-Garcia, 2011). According to Bakhtiar et al. (2017, pp. 62), these *socio-emotional interactions* are "purposeful interchanges (often communication) among group members that shape perceptions of emotions and socio-emotional climate". Task-focused socio-emotional interaction can be about the content to be learned or metacognitive awareness of the learning process, but what sets it apart from cognitive interaction is that socio-emotional interactions additionally involve expressions of emotion or ways of communicating that shape the socio-emotional climate of the group (Järvelä, Järvenoja et al., 2016).

Rogat and Adams-Wiggings (2015), and Kwon, Liu, and Johnson (2014) argue that participation in socio-emotional interactions manifests as positive ways of communicating, such as encouraging and conveying group cohesion, which support productive collaboration. Socio-

emotional interactions can also be disruptive if they manifest as negative interactions, such as rudeness, overruling, undermining, exclusion, and insulting (Chiu & Khoo, 2003; Linnenbrink-Garcia, Rogat, & Koskey, 2011; Näykki, Järvelä, Kirschner, & Järvenoja, 2014). In addition, socio-emotional interactions include how learners explicitly talk about their emotions or express their emotions, which may help learners become aware of others' emotions and afford the regulation of emotions at the group level (Järvenoja & Järvelä, 2013; Näykki, Isohätälä, Järvelä, Pöysä-Tarhonen, & Häkkinen, 2017; Näykki et al., 2014).

The literature suggests that cognitive and socio-emotional interactions are intertwined with each other and the overall degree of group members' participation. For example, in her case analyses of two groups of schoolchildren, Barron (2003) suggested that the group with negative socio-emotional interaction, such as competitive interaction, showed less productive participation in constructive cognitive interactions, such as the co-elaboration of knowledge. Sinha et al. (2015), in turn, reported that Grade 7 student groups with more active on-task participation engaged in higher-quality cognitive interactions and more positive socio-emotional interactions, such as respectful and cohesive interactions. Sinha et al. (2015) concluded that aspects of participation and cognitive and socio-emotional interactions were highly interrelated and influenced each other mutually. However, these analyses did not fully address the temporal fluctuations of participation and types of interaction, or the relation between the two.

Temporal Perspectives

Collaborative learning is a temporally unfolding process, and as such, can only be captured as a series of interactions emerging over time (Fischer & Järvelä, 2014). Participation in joint activities need not be continuous throughout collaboration, but engagement can occasionally diverge and again converge when social interaction is needed for optimal performance (Roschelle & Teasley,

1995). This raises the question of how fluctuations of participation in social interaction are related to the varying types of interactions groups engage in.

A few studies tentatively suggests that there are links between the fluctuations of participation and the varying types of interaction during collaborative learning. Määttä et al. (2012) showed that increases in Grade 4 students' group-level participation were especially triggered by group processes, including interaction involving encouragement or getting support from peers. In contrast, Linnenbrink-Garcia et al. (2011) suggested that upper-elementary students' negative interactions, such as discouraging participation, could spark negative emotions in collaboration. Negative emotions, in turn, could lead students to disengage from working collectively, unless positive interactions followed negative ones. Näykki et al. (2014) further showed how higher education students' overruling, status-centric, undermining and normative interaction created a socio-emotional conflict in a case group, which led the group to lower their on-task engagement. These results reflect Do and Schallert's (2004) study, which showed that individual students' emotions and their moment-by-moment fluctuations played an important role in how learners' attended, listened, talked, and tuned out during classroom interactions.

Though previous studies have addressed participation and types of interactions in different ways, the findings suggest that changes do occur in group members' participation as well as the types of interaction groups engage in, and that these may be interrelated. Especially transitions—that is, changes between types of interaction—toward socio-emotional interactions may involve concurrent changes—increases or decreases—in participation. However, because evidence remains limited, more process-oriented studies are needed about the fluctuations of group members' participation in cognitive and socio-emotional interaction and the characteristics of the moments when concurrent changes in participation and types of interaction occur.

Aim

The aim of this process-oriented study was to qualitatively examine students' participation in two types of task-focused interaction—cognitive and socio-emotional interaction—during collaborating learning. The study was guided by two research questions: 1) How actively do students participate in cognitive and socio-emotional interactions? 2) What characterizes the moments when participation in social interaction changes during transitions between cognitive and socio-emotional interactions?

Method

Context and Participants

This study was part of a larger project that examined the characteristics of strategic collaborative learning in higher education. The specific context was teacher education and a mathematics education course at a Finnish university, where 84 hours of student teachers' interactions were video-recorded (Järvelä, Järvenoja, et al., 2016). The data for the current micro-analytical study included a smaller portion of the corpus. The dataset consisted of video-recorded collaboration in six groups that each had four members (n = 24, 20 women, M_{age} = 24 years, SD = 4 years), but in four of the twelve videos, only three students were present. The large proportion of women resembles the gender distribution in Finnish teacher education. The groups were composed beforehand by the researchers to ensure that the few men among the participants would be distributed in different groups and that students would not choose groups based on their own preferences. However, the students knew each other well because they had been in the same classes for the past two years. The dataset was considered sufficient because we could observe several groups in two tasks and several subtasks, thus providing a varied set of rich data of social interactions that did not only represent a single group or task. However, the dataset was also limited enough to enable a micro-level, moment-by-moment analysis of social interaction.

The course took place in a classroom-like research space with 360-degree cameras and individual microphones for each student. The course was one of the obligatory courses in the teacher education curriculum, but students could choose if they wished to take part in the research. Video material was collected in two mathematics lessons. The topics of the two video-recorded lessons were "Estimation and mental calculation" and "Problem solving." These two lessons were chosen because they included a similar set of mathematics tasks requiring problem-solving and mental calculation skills. For example, students had to estimate the results of calculations, solve mathematical tasks with several unit transformations, and work through different problem-solving tasks, such as "A fake among nine coins," "Seven bridges of Königsberg," and a challenging task involving combinatorics.

Though the tasks were structured, they challenged students' mathematical understanding and required them to discuss strategies as a group. Students were also asked to collaborate on the mathematics tasks. The participants were familiar with collaboration as a pedagogical practice, as it is emphasized in the local teacher education curriculum. The groups started their work by reading the task instructions and by discussing their perceptions of the task with the help of an HTML5 mobile application called S-REG, aimed at raising students' awareness of their cognitive, motivational, and emotional states prior to beginning their tasks (Järvelä, Kirschner, et al., 2016). The discussions using S-REG were a few minutes in length. Afterwards, the groups started their collaboration and were given approximately one hour to complete the tasks.

Data Analysis

Twelve videos (10 h 31 min, $M_{duration}$ = 0:52:37, *SD* = 0:02:49) of student teachers' collaborative learning were analyzed. The analysis concentrated on task-focused interaction ($M_{duration}$ = 0:42:19, *SD* = 0:04:57), such as agreeing on ways of working, solving tasks, and performing other activities related to the task at hand. Task-focused interaction also included students' interactions about their

emotion or motivation related to mathematics, the tasks, or the context of learning. Because the focus of the study was on task-focused interaction involving collaborative cognitive, motivational, or emotional interaction for the purposes of learning and task performance, we did not analyze participation or the type of interaction in interactions that were completely off-task. Such interaction included technical activities with microphones or tablets, discussions about the following lunch hour, stories of personal life that were unrelated to mathematics or learning in general, or discussing other coursework.

Our approach to analyzing the video-recorded interactions was process-oriented (Arrow, Poole, Henry, Wheelan, & Moreland, 2004; Reimann, 2009), because we aimed to examine how students' participation and types of interaction fluctuated and overlapped. The method was qualitative interaction analysis (Jordan & Henderson, 1995). First, we relied on the coding and counting of video material (Derry et al., 2010), based on theory-inspired coding schemas, to identify how actively students participated in the types of task-focused interaction (cognitive and socio-emotional). Second, we identified moments where changes in participation occurred during transitions between the types of task-focused interaction and adopted an inductive approach to qualitatively describe what characterized these moments.

Participation in Social Interaction

A coding scheme was developed to examine students' participation in social interaction at the individual and group levels (see Table 1). As explained by Isohätälä, Järvenoja et al. (2017; a study exploring participation from a different perspective—namely, socially shared regulation of learning), the coding scheme examined whether or not learners contributed to the discussion or indicated that they were listening to each other. Contributing and listening were examined because they are core elements of communication; interaction requires participants to initiate turns and

provide evidence of understanding with back-channeling (e.g., mm, yes, nodding), responses, and continued attention (Clark & Brennan, 1991; Sacks, Schegloff, & Jefferson, 1974).

[Table 1]

First, individual-level participation in social interaction of each of the 24 students was observed moment by moment and coded using three mutually exclusive coding categories: *active conversing* (student contributes verbally), *attunement* (student does not contribute, but signals listening), and *non-responsiveness* (student neither contributes nor signals listening). In order for an event of interaction to be coded under any of the codes, the criteria for the given category had to be observed every 20 seconds (active conversing) or for at least 20 seconds (attunement, non-responsiveness).

Next, the analysis of individual-level participation was taken to the group level in order to identify moments in which all or only some students participated in the interaction. The coding was aggregated to the group level by identifying where the codes of individual-level participation overlapped. Three mutually exclusive categories of group-level participation were coded: *high* (all group members verbally contribute), *intermediate* (all group members listen, but all do not contribute), and *low* (at least one student neither contributes nor listens).

Furthermore, we examined the changes—namely, increases and decreases—in group-level participation. The midpoint of each episode of low, intermediate, and high participation as well as off-task interaction was calculated. The midpoints where group-level participation was higher than in the preceding and following midpoint, were named *increases*. The midpoints where group-level participation was lower than the preceding and following midpoint, were named *decreases*. Off-task interactions (e.g. technical activities, discussions about other coursework or stories of personal life) were unrelated to the mathematics tasks or to students' motivation or emotion in learning and thus,

were not considered task-focused cognitive or socio-emotional interaction. Therefore, transitions to off-task interaction were considered decreases in participation because they marked the whole group's disengagement from task-focused interaction. Figure 1 visualizes an example of the coded levels of group-level participation as well as increases and decreases in the social interaction.

[Figure 1]

Types of Interaction

Different types of task-focused interaction were coded according to the coding schema presented in Järvelä, Järvenoja, et al. (2016; see Table 1). During coding, we identified cognitive interaction (e.g., domain-focused interactions and activities, metacognitive discussions) and socio-emotional interaction (e.g., interactions about emotions or motivation, encouraging peers, laughing together). The criteria for identifying the types of interactions were based on prior research on cognitive interaction (Dillenbourg et al., 1995; Roschelle, 1992) and socio-emotional interaction in collaborative learning (Bakhtiar et al., 2017; Rogat & Linnenbrink-Garcia, 2011). In initial coding, the two codes could overlap when interactions included signs of both cognitive interaction and socio-emotional interaction, for example when students expressed positive or negative emotions while simultaneously discussing cognitive or metacognitive aspects of the task. However, as we continued to analyze the results, we did not analyze these overlapping interactions as a separate category but considered them as socio-emotional interaction, because they involved expressions of emotion or talking about emotions or motivation and could shape perceptions of emotions and socio-emotional climate. In contrast, cognitive interaction involved *only* cognitive interaction with no overt positive or negative socio-emotional tone.

Participation in Types of Interaction

The durations of coded material and the frequencies of increases and decreases were extracted. We compared how frequently the levels and changes of participation occurred in cognitive and socio-emotional interactions. For the comparisons, the proportions of individual-level participation (*active conversing*, *attunement*, *non-responsiveness*) and group-level participation (*high*, *intermediate*, *low*) were calculated out of the total duration of cognitive and socio-emotional interactions. The number of changes (*increases*, *decreases*) in group-level participation were compared between cognitive and socio-emotional interactions. Nonparametric Mann-Whitney *U* tests were used to explore the differences.

We further examined how frequently changes in participation (*increases* or *decreases*) occurred during transitions between cognitive and socio-emotional interactions and inductively explored what characterized these moments. Figure 2 provides an example of an increase in participation during a transition from cognitive to socio-emotional interaction. Each of these situations were reviewed and descriptions were written about the activities observed. In the first step of the inductive analysis, two researchers iteratively reviewed the descriptions and identified the common activities (e.g., starting a new task, taking notes, planning how to work, or monitoring progress or conditions) that occurred in the events prior to and after the change in participation during the transition between cognitive and socio-emotional interactions. The identified activities were compared between the researchers and distinct groups of activities were given a label. Next, both researchers again individually reviewed all the descriptions and annotated them with the agreed labels of activities. The researchers then discussed and compared their annotations and resolved all discrepancies.

[Figure 2]

In the subsequent step of the inductive analysis, the researchers explored the annotations and compared how shifts between the annotated activities occurred prior to and after the increase or decrease in participation during the transition between cognitive and socio-emotional interaction. To further clarify the results, the researchers grouped the activities into two broader categories (domain-focused and metacognitive activities). The two categories were found to sufficiently characterize the changes in participation and cognitive and socio-emotional interactions. Data examples were selected to illustrate the results.

Results

Individual-level Participation

The mean duration of task-focused interaction in each group was 42 minutes (*SD* = 0:04:57). On average, 64% ($M_{duration}$ = 0:27:03, *SD* = 0:06:33) of task-focused interaction involved cognitive interaction and 34% ($M_{duration}$ = 0:15:16, *SD* = 0:04:56) involved socio-emotional interaction. Students' (N = 24) level of participation in task-focused interaction involved, on average, 60% active conversing with verbal contributions ($M_{duration}$ = 0:25:03, *SD* = 0:07:50), 24% attunement with signs of listening ($M_{duration}$ = 0:10:01, *SD* = 0:05:28), and 16% non-responsiveness with no verbal contributions or signs of listening ($M_{duration}$ = 0:06:57, *SD* = 0:04:22).

We compared the average the distributions of levels of individual students' participation in cognitive and socio-emotional interactions (Figure 3). In cognitive interaction, students showed, on average, 56% active conversing ($M_{duration}$ = 0:15:23, *SD* = 0:06:57), 23% attunement ($M_{duration}$ = 0:06:22, *SD* = 0:03:43), and 21% non-responsiveness ($M_{duration}$ = 0:05:27, *SD* = 0:03:18). In socio-emotional interaction, students showed, on average, 65% active conversing ($M_{duration}$ = 0:08:52, *SD* = 0:04:25), 25% attunement ($M_{duration}$ = 0:03:47, *SD* = 0:02:55), and only 10% non-responsiveness ($M_{duration}$ = 0:1:30, *SD* = 0:01:22). Based on the averages and standard deviations, cognitive interaction especially involved more non-responsiveness compared to socio-emotional interaction.

This was also visible when examining the data individual to individual: apart from one student, all students showed more non-responsiveness in cognitive interaction than in socio-emotional interaction.

[Figure 3]

Group-level Participation

The groups' task-focused interaction ($M_{duration}$ = 42 min) in the video-recorded lessons (N = 12) involved, on average, 40% ($M_{duration}$ = 0:17:15, *SD* = 0:05:42) low participation, where at least one student was disengaged, 40% ($M_{duration}$ = 0:17:22, *SD* = 0:04:36) intermediate participation, where all students showed signs of listening, and 20% ($M_{duration}$ = 0:08:07, *SD* = 0:04:11) high participation, where all students verbally contributed to the discussion. Thus, it was most common for only some students to contribute while others listened or some were disengaged.

Group-level participation differed in cognitive and socio-emotional interactions (Figure 4). Cognitive interaction ($M_{duration}$ = 0:27:03) clearly had the greatest proportion of low participation ($M_{\%}$ = 48%, $M_{duration}$ = 0:12:52, *SD* = 0:04:10) and intermediate participation ($M_{\%}$ = 37%, $M_{duration}$ = 0:10:13, *SD* = 0:03:51), but only a small proportion of high participation ($M_{\%}$ = 15%, $M_{duration}$ = 0:03:57, *SD* = 0:02:09). In contrast, socio-emotional interaction ($M_{duration}$ = 0:15:16) involved proportionally the most intermediate participation ($M_{\%}$ = 44%, $M_{duration}$ = 0:06:56, *SD* = 0:03:22) and approximately the same proportions of high participation ($M_{\%}$ = 29%, $M_{duration}$ = 0:04:08, *SD* = 0:03:00) and low participation ($M_{\%}$ = 27%, $M_{duration}$ = 0:04:12, *SD* = 0:02:46).

Thus, high participation was more prevalent in socio-emotional interaction, whereas low participation was more prevalent in cognitive interaction. However, the amount of high participation in socio-emotional interaction varied quite significantly between the observed lessons (*SD* = 20%). Thus, a more considerable difference between cognitive and socio-emotional

interactions could be seen in the proportion of low participation, which was consistently larger in cognitive interaction (mean rank = 16.92) than in socio-emotional interaction (mean rank = 8.08, U = 19.000, p = .001).

[Figure 4]

Changes in Group-Level Participation

Altogether, 317 increases and 325 decreases were identified in group-level participation. The distribution of changes differed in cognitive and socio-emotional interactions (Figure 5). Per session, cognitive interaction involved, on average, similar numbers of increases (M_f = 16, $M_{\%}$ = 50%) and decreases in participation (M_f = 15, $M_{\%}$ = 50%). In contrast, socio-emotional interaction involved more increases (M_f = 11, $M_{\%}$ = 66%) than decreases in participation (M_f = 6, $M_{\%}$ = 34%). A clear difference was seen between the types of task-focused interaction: socio-emotional interaction involved a clearly larger proportion of increases in participation (mean rank = 17.46) compared to cognitive interaction (mean rank = 7.54, U = 131.500). Similarly, socio-emotional interaction involved a smaller proportion of decreases in participation (mean rank = 7.54) compared to cognitive interaction (mean rank = 17.46, U = 12.500).

[Figure 5]

Altogether, 55 increases (17% of all increases) and 55 decreases (17% of all decreases) in participation occurred during transitions between cognitive and socio-emotional interactions. During transitions from cognitive to socio-emotional interactions, most changes involved increases (f = 37) (Figure 6). During transitions from socio-emotional to cognitive interactions, most changes in participation were decreases (f = 38). In contrast, fewer decreases in participation occurred during

transitions from cognitive to socio-emotional interactions (f = 17) and increases in participation during transitions from socio-emotional to cognitive interactions (f = 18).

[Figure 6]

Changes in Group-Level Participation during Transitions between Types of Interaction

To characterize the moments when group-level participation changed during transitions between cognitive and socio-emotional interactions, we observed what kinds of activities groups engaged in when (a) participation increased during a transition to socio-emotional interaction, (b) participation decreased during a transition to cognitive interaction, (c) participation increased during a transition to cognitive interaction, and (d) participation decreased during a transition to socio-emotional interaction. We identified observable activities both before and after the change in participation and type of task-focused interaction.

Based on the initial overview of the written descriptions, we first narrowed the observed activities down to six types: task performance (e.g., calculating, discussing a task), taking notes (e.g., writing the correct answer or making corrections to notes), starting a new task (e.g., reading task instructions, beginning to think about the next task), planning how to work (e.g., discussing what to do next), monitoring progress or conditions (e.g., discussing a mistake or lack of understanding, discussing task value or difficulty, discussing motivation), and evaluating performance or ways of working (e.g., discussing how well the group worked). We further grouped these elements into two broader activities: *domain-focused activities*, including task performance, taking notes, and starting a new task; and *metacognitive activities*, including planning, monitoring progress or conditions, or evaluating performance or ways of working. Domain-focused and metacognitive activities could sometimes intertwine, for example, when students planned their work while starting a new task. We called these *mixed activities*.

Next, we examined what kinds of shifts between activities occurred before and after changes in participation during transitions between cognitive and socio-emotional interactions. Mostly, there were shifts from domain-focused activity toward more metacognitive activity (e.g., from note-taking to evaluating) or from metacognitive activity toward more domain-focused activity (e.g., from monitoring to task performance). In fewer cases, the shift was mixed if metacognitive and domain-focused activities occurred before and after the increase in participation. In these cases, the shift oftentimes occurred within the kinds of metacognitive or domain-focused activity (e.g., from evaluating and note-taking to planning and starting a new task).

Based on comparing shifts between activities before and after changes in participation during transitions between cognitive and socio-emotional interactions (Table 2), we saw that increases in participation during a transition from cognitive to socio-emotional interaction mostly involved shifts toward more metacognitive activity (f = 34). Decreases in participation during a transition from socio-emotional to cognitive interaction involved shifts toward more domain-focused activity (f = 34).

The other changes were more complex: increases in participation during transitions toward cognitive interaction mostly involved shifts toward more domain-focused activity (f = 11), but also shifts within mixed metacognitive and domain-focused activities (f = 7). Similarly, decreases in participation during transitions toward socio-emotional interaction sometimes involved a shift toward more metacognitive activity (f = 7), but also shifts within mixed metacognitive and domain-focused activities (f = 9). The following chapters explain and illustrate the findings in more detail.

[Table 2]

Increases in Participation from Cognitive to Socio-Emotional Interactions

When participation increased during a transition from cognitive to socio-emotional interaction, it usually involved a shift from domain-focused activity toward metacognitive activity—namely, monitoring of progress or conditions or evaluating performance. A typical case involved a shift from domain-focused activity, such as performing calculations, to monitoring how the group was making progress and, oftentimes, discussing challenges in the efforts toward task completion. The monitoring of progress and challenges involved heightened participation and emotional expressions, such as frustration or laughter, or interactions that boosted moral, such as encouragement.

Example A (Table 3) illustrates how the level of participation in group 1 increased as the group shifted from simply making calculations and notes to also discussing the meaningfulness of the task ("This is crazy") and motivation to perform the task ("This needs patience, which ended already"). Example A evinces a shift from domain-focused activity to metacognitive activity, with the latter concurring with increased participation and socio-emotional interaction. In other cases, the shift could have been more gradual if monitoring had already begun during cognitive interaction, but as it continued, participation increased and the interaction took on a socio-emotional tone.

Another typical case of an increase in participation during a transition from cognitive to socio-emotional interaction involved the students shifting from the completion of a task to evaluating their performance, either positively or negatively. Thus, the students moved from concentrated, domain-focused activity to actively participating in metacognitive evaluation, which involved emotional appraisal, such as praising good performance. Example B (Table 3) presents how the level of participation in group 4 changed from lower participation, while the group performed calculations and students gave advice to each other, to higher participation, as the group members established that they had reached the same result ("That's right"). This led the students to praise each other for their good performance ("Well done"; "Good approximation").

[Table 3]

Decreases in Participation from Socio-Emotional to Cognitive Interaction.

Decreases in participation during a transition from socio-emotional to cognitive interaction mostly involved shifts from more metacognitive activities, such as monitoring progress or conditions, to more attention-consuming, domain-focused activities—namely, starting a new task and reading task instructions, taking notes, performing calculations, or solving a mathematical problem. Thus, the changes were generally triggered by a shift to more concentrated activities.

The level of participation commonly decreased during a transition from socio-emotional to cognitive interaction when students moved from one task to another. A typical case involved the group moving from monitoring task completion or evaluating their performance to taking notes or starting a new task. In these cases, students' metacognitive discussions of their progress or performance involved more intensive participation and a heightened socio-emotional tone in their interaction. The subsequent decrease in participation during a transition to cognitive interaction was triggered by the students directing their attention to taking notes, correcting notes, reading the instructions for the next task, or starting the next task.

Example C (Table 4) shows how students in group 3 finished a task and started a new one. The students first showed higher participation in socio-emotional interaction (e.g., laughter) as they monitored their final answers ("It has to be"; "I don't know; could someone check?") and established that some had the correct answer ("Hey, we have it right!") while others did not. The level of participation then decreased and turned to cognitive interaction as some group members directed their attention to checking their calculations, while Antti started reading the instructions for the next task.

In another common case, the students first monitored their progress and particularly their challenges—incorporating socio-emotional interaction with higher participation—but their participation decreased as the group returned to performing task activities in order to continue their

work and resolve possible challenges. In practice, after taking a moment to monitor their progress or challenges, the group members continued exerting further efforts toward task completion.

Example D illustrates how students in group 5 returned to task performance after having monitored a challenge in their calculation. The level of participation was first higher in socio-emotional interaction as the students amusedly discussed that they had got different results for the multiplication calculation ("I got different"; "I probably have it wrong"). Next, the level of their participation decreased as they moved to cognitive interaction involving domain-focused activities: Johanna started using a tablet to check the calculations while the others started assisting Inna with her calculation.

[Table 4]

Increases in Participation from Socio-Emotional to Cognitive Interaction.

Increases in participation during a transition from socio-emotional to cognitive interaction involved a mix of domain-focused and metacognitive activities and shifts between the two. In common cases, the situations started with metacognitive activity, particularly monitoring challenges, fused with concentrated domain-focused efforts toward task completion. Participation was first lower because some students were engaged in domain-focused efforts, but the interaction involved a socio-emotional tone, because some students expressed emotions related to monitoring, such as frustration with a problem. Acts of monitoring led to the subsequent shift toward more domain-focused activity—namely, the increase in participation—as students began to continue their task efforts and resolve challenges through actively explaining their understandings.

Example E (Table 5) illustrates a case where participation in group 1 increased in cognitive interaction as the group actively started discussing a resolution to a challenge that they had just monitored. At the beginning of the event, Alisa and Juuli were concentrating on the calculations,

while Erika and Iina explicated that the group was having trouble making progress together and that they were becoming frustrated. The interaction turned more active as Juuli also explicitly monitored her understanding ("I can't remember unit transformations"). This triggered the whole group participate in clarifying their understandings, evincing a shift toward more domain-focused activity.

In other cases, the increases in participation during a transition to cognitive interaction involved shifts between different types of metacognitive or domain-focused activities that were oftentimes mixed together. These situations started with students concentrating on domain-focused activities, which explained the lower participation, while some students also monitored their progress, which induced a socio-emotional tone. The situations continued with more active participation by planning how to work, such as requesting the group to explain, and initiating active domain-focused discussions about the task.

Example F (Table 5) introduces a situation where group 6 was first engaged in task performance, while some students noted that the group was not making coherent progress and laughed because of their situation. This triggered the group members to coordinate their answers and understandings and ask for further elaborations. The whole episode involved metacognitive activity, but a gradual shift toward active domain-focused activity.

[Table 5]

Decreases in Participation from Cognitive to Socio-Emotional Interaction

The situations where participation decreased during a transition from cognitive to socio-emotional interaction, again, involved shifts between metacognitive and domain-focused activities that were oftentimes fused together. Typically, participation was first higher in cognitive interaction while students engaged in active domain-focused activities, such as discussing calculations, which sometimes incorporated planning how to work or monitoring potential errors in calculations. The

level of participation decreased as some students continued engaging in more attention-consuming, domain-focused activities, such as calculating or taking notes. The interaction also turned more socio-emotional as others continued to monitor their progress or evaluate their performance. The domain-focused activities, which demanded concentration, seemed to account for the decrease in participation in socio-emotional interaction, while the concurrent metacognitive activities induced a socio-emotional tone, such as encouragement or explications of frustration.

Example G (Table 6) illustrates how students in group 1 moved from active domain-focused interaction to taking notes and monitoring their progress. At first, the whole group was actively engaged in co-elaboration of knowledge, which helped them come to an agreement on a solution. Next, their level of participation decreased because the group members started writing down their answers. However, while taking notes, Juuli and Alisa praised each other for their good collaboration, thus integrating socio-emotional support in monitoring their progress.

Example H (Table 6) shows how group 6 discussed their calculations, but struggled with a challenge with unit transformations. Valtteri, then, showed metacognitive planning by deciding to check whether 1 cm^3 is a deciliter. This led to a decrease in participation in social interaction as Valtteri sought help with his smartphone. Meanwhile, the others began to explicitly monitor their challenges ("These are too difficult"), which induced sighing, frowning, and looks of frustration.

[Table 6]

Summary

Increases and decreases in participation between cognitive and socio-emotional interactions typically involved a shift between metacognitive and domain-focused activities. In moments where participation increased during a transition from cognitive to socio-emotional interaction, students generally became actively engaged in metacognitive activity, such as monitoring challenges or

evaluating performance, which induced emotional expressions, such as joy, frustration, encouragement, or explications of motivation. In moments where participation decreased during a transition from socio-emotional to cognitive interaction, students typically redirected their attention from active metacognitive discussions with a socio-emotional tone to domain-focused activities, which required concentration and decreased participation.

In less frequent cases, these activities were more mixed. Group-level participation could sometimes decrease during a transition from cognitive to socio-emotional interaction if some students were immersed in domain-focused activities, which seemed to account for the decrease in participation, while others monitored their progress or evaluated their performance, which incorporated or induced the socio-emotional tone. In contrast, participation could increase during a transition from socio-emotional to cognitive interaction when students began engaging in active co-elaboration of knowledge, oftentimes in reaction to the preceding monitoring of a challenge, which had involved emotional expressions.

Discussion

In this study, we explored how student teachers participated in cognitive and socio-emotional interactions during collaborative learning in a mathematics education course. Earlier research showed preliminary signs that the type of interaction groups engage in, particularly socio-emotional interaction, may be linked to group members' participation (Linnenbrink-Garcia et al., 2011; Määttä et al., 2012; Näykki et al., 2014). Our results revealed that students' participation indeed differed among the types of interaction. In particular, *increased participation occurred more often in socio-emotional than in cognitive interactions*. Increases in participation were also more common when students transitioned from cognitive to socio-emotional interaction, whereas decreases in participation were more frequent when students transitioned from socio-emotional to cognitive interaction. The analysis further revealed that *the moments when participation changed during*

transitions between cognitive and socio-emotional interactions were especially characterized by shifts between domain-focused and metacognitive activities. We found that metacognitive activities, such as monitoring challenges, typically induced socio-emotional interaction, such as encouragement or expressions of frustration, and accompanied increases in participation, unless attention-consuming activities occurred simultaneously. In turn, attention-consuming, domain-focused activities, such as note-taking, oftentimes decreased participation in cognitive interaction, unless active domain-focused interactions were necessary to clarify understandings or start resolving a new task as a group.

Several reasons may influence why participation was generally lower in cognitive than in socio-emotional interactions. It is known that engaging in domain-focused activities in collaborative learning requires cognitive resources (Dillenbourg, 1999), but engaging in social interaction is similarly resource-consuming (Kirschner, Paas, & Kirschner, 2009). Thus, in order to benefit from collaborative learning, learners must balance between engaging in social interaction and having the resources to think and perform domain-focused activities. It may be that the cognitive resources that students need for thinking and performing task activities make the participation during cognitive interaction more disperse. This may be particularly true when the task is mathematical, which can put a strain on the working memory (Raghubar, Barnes, & Hecht, 2010). The case examples presented in the current study support these interpretations: students' participation usually decreased during a transition from socio-emotional interaction to cognitive interaction when they had to focus on checking their calculations, thinking of solutions, or reading instructions.

Earlier studies show that the lower participation in cognitive interaction may also stem from differences in individual students' proficiency, though we did not test participants' achievement levels in the current study. Because low-achieving students tend to show more passivity compared to high-achievers (Mulryan, 1992), it can be that the cognitive abilities needed in cognitive interaction hinder participation in students who are less able or motivated. Rather than actively

contributing in cognitive interaction, these individuals may become disengaged or simply listen to more capable students, especially when the task is difficult. Engin (2017) and Rocksén (2017) suggested that confidence in knowledge can also influence individual learners' willingness to contribute. Engin (2017) added that expectations of roles can affect students' participation as well. Thus, it may be that some individuals are less inclined to contribute to cognitive interaction because they perceive that others should take a stronger role in leading the task performance. In contrast, socio-emotional interaction may be less resource-consuming and demanding, which affords higher participation, also by students with limited proficiency. Thus, students may be able to participate more actively in socio-emotional interaction, such as expressing frustration or discussing motivation, which also gives them the opportunity to voice out their difficulties in performing the task.

Socio-emotional interaction, in turn, may involve higher participation because of the socially engaging nature of emotions. This has been shown in studies focusing on individual students' emotions. As noted by Pekrun et al. (2002, 2012) and Linnenbrink-Garcia et al. (2011), positive emotions especially can reinforce students' learning behaviors; that is, positive feelings, such as excitement, support learners' ability to engage in the task at hand. Similarly, Do and Schallert (2004) found that students' emotions, particularly positive ones, can oftentimes trigger eager listening and contributing in classroom talk. Drawing from the concepts presented by Andriessen et al. (2011, 2013), socio-emotional interaction at the group level may also function as a means to relax tension created by domain-focused activities and cognitive challenges, and thus potentially trigger more active interaction.

Though we did not systematically identify the positive or negative valence of groups' socio-emotional interaction in the current study, the engaging and tension-relaxing nature of positive interactions was seen, for example, in how students' participation increased as they praised each other after successfully solving a task. However, negative interactions could also coincide with

increased participation when, for example, students shared their feelings of frustration with a difficult task. This is in line with Do and Schallert's (2004) conclusion that even though negative emotions may lead to temporary disengagement, they can also induce participation. Similarly, Linnenbrink-Garcia et al. (2011) note that even though individuals' negative affect could oftentimes lead to less active participation, negative group interactions could sometimes spark further positive group interactions. This can be beneficial for collaborative learning, because expressing and talking about emotions may be necessary for recognizing and resolving challenges (Bakhtiar et al., 2017; Järvenoja & Järvelä, 2013; Näykki et al., 2014).

In fact, our results suggest that monitoring progress and challenges commonly coincided with increased participation during a transition from cognitive to socio-emotional interaction. More generally, our findings indicate that groups' metacognitive attention to their learning seemed to coincide with socio-emotional interaction, for example, when students shared feelings about their performance. Unless students' interaction simultaneously involved attention-consuming domain-focused activities, such as taking notes, these metacognitive activities also typically involved increased participation.

This connection between metacognitive activity, socio-emotional interaction and increased participation was not hypothesized in this study, but it does reflect recent studies that have highlighted that metacognitive activities in collaborative learning may involve a heightened socio-emotional tone and participation. Bakhtiar et al. (2017) reported that positive and negative emotional expressions among undergraduate students could arise at challenging moments during collaborative learning. Lajoie et al. (2015) found that socio-emotional interactions among medical students in computer-supported collaborative learning aligned in time with the monitoring of learning. Ucan and Webb (2015) saw evidence of socio-emotional interaction, particularly positive and supportive interactions, as well as mutual participation, in episodes of 12-year-old students' metacognitive regulation of learning.

The connection between more active participation, socio-emotional interaction, and metacognitive activity may boil down to the two-dimensional nature of collaborative learning, consisting of the cognitive and social and socio-emotional processes (Kreijns et al., 2003) or the content space and the relational space of collaborative learning (Barron, 2003; Janssen et al., 2010). It may be that metacognitive activities turn learners' attention from solely the cognitive processes of collaborative learning to the socio-emotional processes as well, which necessitates that students participate in sharing their thoughts and feelings through social interaction in order to create common understandings of how their collaboration is going. The interaction about the collaboration itself, such as evaluating performance, can also induce emotional appraisals or reactions, manifesting as socio-emotional interaction. Thus, in moments of active participation in concurrent socio-emotional interaction and metacognitive activity, the socio-emotional processes of collaborative learning may become more salient and thematic in social interaction, though cognitive processes are nevertheless intertwined (Baker et al., 2013). These moments may allow groups to coordinate and create shared understandings of their learning and foster a positive socio-emotional climate. At other moments, groups can direct their cognitive resources toward the task and content.

However, though this study indicated that increased participation was proportionally more common in socio-emotional interaction, it does not entail that active participation would be less necessary when engaging in cognitive interaction; on the contrary, learners must engage in social interaction in order to co-elaborate knowledge (Baker, 1999; Dillenbourg, 1999). This was also seen in the example from the current study where students started actively recalling and explaining their understanding in order to resolve a challenge they had monitored.

Conclusions

Teachers and learners should be aware of the temporal fluctuations that occur in participation in social interaction and types of interaction during collaborative learning, because

these fluctuations may create patterns of social interaction that influence the progress and outcomes of collaborative learning. Our results show that increases in participation in socio-emotional interactions occurred at important moments of collaboration, including the monitoring and resolving of challenges or the evaluations of performance, which allowed the groups to share perceptions of their learning and voice out their feelings. Afterwards, groups could return to more concentrated cognitive efforts that are necessary for learning to take place. It is possible that pedagogical practices, training or tools could be designed to foster such moments that facilitate groups' progress in collaborative learning. For example, as suggested by Miller and Hadwin (2015), teachers can use scripts to encourage students' monitoring or evaluating discussions, or prompt such discussions using group awareness tools. Scaffolds such as scripts or awareness tools have mostly been used to facilitate cognitive interactions (Bodemer, Janssen & Schnaubert, 2018), but they are also a means to facilitate socio-emotional aspects of learning, for example, by encouraging socio-emotional support or promoting adaptive emotion regulation (Belland, Kim, & Hannafin, 2013; Näykki, Isohätälä, et al., 2017).

However, it should be noted that the consequences for the ultimate success of collaborative learning or individual learning were not measured in the current study. Also, we found no instances of disrespectful negative socio-emotional interaction, such as undermining interactions, which would have led to conflicts and shown how certain patterns of interaction may be detrimental for collaborative learning (Näykki et al., 2014). Future studies should examine how different patterns of participation and types of social interaction actually help or hinder reaching the best outcomes of collaborative learning. Analyses of individual students' participation—including their self-reported experiences and individual differences—could potentially reveal in more detail why students' participation varies in different types of interaction.

The results also have implications for how educational practitioners can monitor the progress of collaborative learning. Based on our results, capturing and analyzing the fluctuation of

participation and types of interactions groups engage in (e.g., detecting the socio-emotional tone of interactions) may help identify different patterns of domain-focused or metacognitive activity in social interaction. This could help develop tools that can provide more targeted support when needed (Wise & Schwarz, 2017). However, the results of this qualitative study need validation and more statistical power before generalizable conclusions can be drawn.

This study was limited with regard to the size of the data, and the results may have been affected by the fact that students' participation fluctuated because of the kind of mathematical tasks that required moments of individual thinking between more active joint discussions. Different tasks and contexts may involve different patterns of participation; thus, different settings could be useful for exploring the findings in more detail. There are many opportunities to broaden the research perspective on collaborative interactions chosen in this study due to increasing interest in technology support and digitalization in interactions (Wise, & Schwartz, 2017). Results regarding participation may differ in chat-based collaboration, where nonverbal behaviors, for example as nodding in agreement, are not available. Thus, one future question to investigate is how the results of this study apply to computer-mediated contexts. For example, do students contribute relatively more in chat-based or video-based communication on a learning platform, when socio-emotional elements appear in the interaction?

Finally, we cannot draw definite conclusions about the causal relations between participation, types of interaction, or activities. As pointed out by Sinha et al. (2015), these intertwine and mutually influence each other in various ways, which further research should clarify in more detail. Further research mapping out the complex dynamics of participation in cognitive and socio-emotional interactions could help educational practitioners monitor and scaffold the flow of collaborative learning processes more accurately with the help of teacher support or technological tools.

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