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“You really brought all your feelings out” – Scaffolding students to identify the socio-emotional and socio-cognitive challenges in collaborative learning

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ABSTRACT

The aim of this study is to explore how students experience and describe socio-cognitive and socio-emotional challenges in collaborative learning. The participants ($N = 20$) were teacher education students whose collaborative learning was supported with a designed regulation macro script during a six-week mathematics course. The purpose of the script was to provide structured phases during the collaborative learning tasks for the group members to plan, monitor, and evaluate their workings. The video data of groups' face-to-face work was collected and analysed by focusing on the different types of challenges the groups experienced and the types of challenges they described during the scripted interaction. The results indicate that the groups experienced more socio-cognitive challenges than socio-emotional challenges. The script provided them a moment to verbalize their emotional experiences, name the emotions (i.e. frustration), and attribute the challenges and emotions more precisely than during their mathematical task. The intertwining characteristics of socio-cognitive and socio-emotional challenges were observable. Collaborative learning can be challenging for groups, and thus, the knowledge of and the ability to implement practices for becoming aware of challenges can provide a direction for students to progress towards more productive collaboration.

1. Introduction

Productive collaborative learning and working is a multifaceted interaction process that integrates cognitive, motivational, and emotional components as a core of collaboration (Baker, Andriessen, & Järvelä, 2013; Barron, 2003; Borge, Ong, & Rosé, 2018; Isohätälä, Näykki, & Järvelä, 2019). In theory, collaborative learning requires group members to be aware of and to coordinate their cognitive, metacognitive, motivational, and emotional resources and processes (Hadwin, Järvelä, & Miller, 2018; Järvelä, Järvenoja, & Malmberg, 2019). In practice, this involves students sharing their thinking and understanding, as well as showing verbally and behaviourally their commitment and motivation to the task and the group (Järvenoja, Järvelä, & Malmberg, 2017). Prior research has shown that successful collaborative learning can be confronted by various challenges related to insufficient or discrepant understandings of the task or each other's points of view at the cognitive level (Khosa & Volet, 2014). Challenges can also be related to disruptive affective reactions within the group at the emotional level (Barron, 2003; Chiu & Khoo, 2003; Zschocke, Wosnitza, &

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Bürger, 2016), or to motivational challenges of not having energy for or interest in working in cognitively and socially demanding task settings (Järvenoja, Malmberg, Järvelä, Näykki, & Kontturi, 2019).

Challenges are not necessarily detrimental to the success of group learning, per se, but what is important is what the group members do because of such challenges. Whether they resolve or highlight the challenges, or withdraw from the group and its activities is what counts (Näykki, Järvelä, Kirschner, & Järvenoja, 2014). Some challenges can even be beneficial for increasing learning opportunities; they make the group members' different (and sometimes incorrect) understandings more visible (Engelmann, Dehler, Bodemer, & Buder, 2009; Khosa & Volet, 2014; Kimmel & Volet, 2010). Challenges can also make group members' possible negative hidden emotions more transparent (Eligio, Ainsworth, & Crook, 2012; Kreijns, Kirschner, & Vermeulen, 2013; Van Kleef, De Dreu, & Manstead, 2010) and, thus, offer opportunities for group members to discuss and negotiate over them (Rogat & Linnenbrink-Garcia, 2011). Malmberg, Järvelä, Järvenoja, and Panadero (2015) highlight that, to collaborate successfully, group members need to recognize the challenges that might hinder their collaboration and to develop appropriate strategies to overcome these challenges. Challenges in group interaction can therefore be regarded as opportunities to regulate learning and interaction so that work on meaningful tasks can be continued and enhanced (Hadwin, Järvelä, et al., 2018). This means that what matters in the success of collaborative learning is group members' efforts and ability to become aware of how the different challenges they face are affecting group work (Fransen, Kirschner, & Erkens, 2011; Hadwin, Bakhtiar, & Miller, 2018; Järvenoja, Näykki, & Törmänen, 2019; Miller & Hadwin, 2015; Schnaubert & Bodemer, 2017). However, research has shown that groups do not often identify reasons for challenging learning situations and the needed focus for regulation (DiDonato, 2013; Järvelä, Järvenoja, & Näykki, 2013; Järvelä, Malmberg, & Koivuniemi, 2016; Näykki et al., 2014). This restricts group members' activation of strategic adaptation in those situations (Rogat & Adams-Wiggins, 2015), and thus, they need to be alerted to this need and supported in productively recognizing challenges in interaction.

Despite the growing interest in collaborative learning in authentic learning situations, research on what kind of on-task socio-cognitive and socio-emotional challenges group members experience during collaborative learning process is rare. Understanding situated challenges, how group members act in these situations and how they reflect the confronted challenges would help to understand process of collaborative learning. Prior studies have explored either group interaction in detail based on, for example, video observations, or students' own interpretations of their collaborative learning based on student interviews (Burdett, 2003; Cantwell & Andrews, 2002), but they have not combined the approaches of observation and reflection. Therefore, the aim of this study was to observe the emerging challenges within group interaction and to combine this information with knowledge of how the group members, themselves, interpret and describe the challenges they are experiencing to each others during scripted collaborative learning in a student teachers' mathematics course.

1.1. Macro scripts as a support for collaborative learning

Students often need scaffolding to engage in and progress with an active and effective collaborative learning (Belland, Kim, & Hannafin, 2013; Kirschner, Sweller, & Clark, 2006). Collaborative learning scripts are developed to support learners in engaging in the collaborative learning process. Scripts are tools for stimulating group processes that can lead to successful learning outcomes in terms of domain knowledge, but particularly in terms of collaboration skills (Hämäläinen & Häkkinen, 2010; Vogel, Wecker, Kollar, & Fischer, 2016; Vuopala, Näykki, Isohäätä, & Järvelä, 2019; Wang, Kollar, & Stegmann, 2017). Scripts have been implemented in collaborative learning, particularly as a support for arguing, explaining, and question asking (Fischer, Kollar, Stegmann, Wecker, & Zottmann, 2013; Scheuer, McLaren, Weinberger, & Niebuhr, 2014; Weinberger, Stegmann, & Fischer, 2007).

Research on collaborative learning scripts broadly distinguishes between two types of scripts, micro and macro scripts, on the basis of the level of granularity at which they support learning. Specifically, micro scripts consist of, for example, sentence openers that prompt learners to contribute domain knowledge to group discussions by extending the presented ideas, questioning one another's contributions, or debating and justifying one's own perspectives and lines of reasoning (e.g. Weinberger, Ertl, Fischer, & Mandl, 2005). Macro scripts are designed to support collaboration more broadly, for example, by scaffolding the activities and processes expected to enhance collaborative learning. Macro-level scripts do not typically provide detailed support on how to enact the specific activities, and the learners/groups can themselves decide how carefully they follow the assigned script (Dillenbourg & Hong, 2008; Dillenbourg & Tchounikine, 2007; Hämäläinen & Häkkinen, 2010; Näykki, Isohäätä, Järvelä, Pöysä-Tarhonen, & Häkkinen, 2017; Vuopala et al., 2019). However, the main goal of the scripts at the micro and macro levels is similar: to raise students' awareness of high-level collaborative processes by supporting the activities that learners are expected to engage in during collaborative learning tasks (Dillenbourg, 2002; Kollar, Wecker, & Fischer, 2018). The logic behind the scripting approach is that students incrementally internalize the behaviours embodied in the script and transfer these behaviours to situations in which no script support is available (Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2013).

Lately, extending the cognitive scripting approach to stimulate socio-emotional interaction has drawn increasing research interest. This is mainly because it provides an opportunity for group members to negotiate their emotional experiences and possibly make changes in how a task is approached, how the roles within the group are distributed, and how communicative actions function (Hadwin, Bakhtiar, et al., 2018; Miller & Hadwin, 2015; Näykki, Järvenoja, Järvelä, & Kirschner, 2017). Socio-emotional scripting approach have acknowledged the need for supporting groups' learning simultaneously at the cognitive level (i.e. task and content understanding) and at the emotional and motivational levels (i.e. increasing the awareness of goals, interests, and emotional states) while working with authentic group tasks. Our own earlier research, along with work by colleagues, has shown that collaborative learning is not spontaneous, and to be successful, it needs to be supported. In our previous study (Näykki, Isohäätä, et al., 2017), we designed a regulation macro script for supporting monitoring in collaborative learning. The study showed that, in the groups in which the macro script was used more actively, the students also provided more socio-emotional support to one another during their non-

scripted task work. In this study, we will continue to explore how students used the script to identify the different types of challenges they were experiencing and how they used the scripted discussion as an opportunity to reflect the reasons for their challenges and plan their tasks.

1.2. Increasing awareness of socio-cognitive challenges in group interaction

Previous studies have shown that socio-cognitive challenges in collaborative learning indicate different understandings at the interpersonal level, and thus provide an opportunity to learn by allowing the elaboration of one another's understanding in greater detail (Jeong & Chi, 2007; Miyake & Kirschner, 2014; Roscoe & Chi, 2008). Foundational research on socio-cognitive conflict in small group interaction (Doise & Mugny, 1979, 1984; Doise, Mugny, & Perret-Clermont, 1975) has shown that confrontations in terms of socio-cognitive conflict can benefit learning when the confrontation leads to conflict regulation in an epistemic (not a relational) manner (Buchs & Butera, 2004). Monitoring as a metacognitive activity contributes to a process of becoming aware of the possible socio-cognitive conflicts or challenges to be faced (De Backer, Van Keer, & Valcke, 2015; Goos, Galbraith, & Renshaw, 2002). Through metacognitive monitoring, group members are engaged in evaluating and judging their own and one another's understanding, cognitive functioning, and progress during a group task (De Backer et al., 2015; Goos et al., 2002; Khosa & Volet, 2014). Empirical research has shown that groups in which learners monitor their own and their peers' thinking and understanding also engage in deeper-level learning processes compared with groups in which understanding is not actively monitored (Goos et al., 2002; Iiskala et al., 2011; Lee, O'Donnell, & Rogat, 2014; Näykki, Järvenoja, et al., 2017; Roscoe & Chi, 2008).

The basic assumption with regard to how scripting can support the awareness of socio-cognitive challenges in collaborative learning is that it guides students in becoming more aware of the group's task and, thus, performing meaningful and beneficial learning activities (Dillenbourg & Hong, 2008; Dillenbourg & Tchounikine, 2007). This socio-cognitive awareness may result in more positive learning outcomes with respect to domain-specific knowledge and collaboration skills (Fischer et al., 2013; King, 2007; Vogel et al., 2016). The ability to monitor challenges in group interaction can therefore be regarded as a central collaborative learning skill that requires a conscious evaluation of how we as a group understand one another, whether we are on the right track to accomplish positive learning results, and whether we support one another to understand the content at hand (Näykki, Järvenoja, et al., 2017). Scripting could be implemented to target the awareness of how the group is doing. This is particularly relevant for the purpose of prompting group members to discuss whether or not challenges are occurring and the possibility that something needs to be changed in terms of work or interaction within the group.

1.3. Increasing possibilities to discuss socio-emotional challenges in group interaction

In addition to cognitive group processes, collaborative learning is built up through the emotional interpretations and emotional expressions that arise before and during the group tasks, and how these are interpreted in group interaction (Jones, Volet, & Pino-Pasternak, 2020; Linnenbrink-Garcia, Kempler Rogat, & Koskey, 2011; Mänty, Järvenoja, & Törmänen, 2020; Van Kleef & Fischer, 2016; Zschocke et al., 2016). Barsade and Knight (2015) in their review of group affect highlighted a need to explore how affect functions in moment-to-moment interaction in groups and teams. Hess and Hareli (2019) argued that emotion expression and recognition research has progressed from samples of facial recognition to their conceptualization as socially embedded processes, which are characterized by both the immediate context of occurrence, but also interpreted within broader sociocultural contexts. These arguments are in-line with socio-dynamic model of emotions proposed by Mesquita and Boiger (2014), which is based on the premise that emotions are typically derived from social encounters and have a functional role towards cultivating the cohesion of the sociocultural context in which they occur. The central consideration what we wish to contribute to this line of thinking is to characterize how students' awareness of their socio-emotional challenges and the meaning of the following emotional reactions can be enhanced (Baker et al., 2013; Barron, 2003). Both negative and positive emotional reactions are caused by a variety of factors—from personality differences to the dynamics and processes created within the collaborative group (Bakhtiar, Webster, & Hadwin, 2017; Linnenbrink-Garcia et al., 2011). Recent research on group emotions has shown that students can monitor and even direct their interpretations of the experienced socio-emotional challenges (Järvenoja et al., 2017; Järvenoja, Malmberg, et al., 2019). Socio-emotional monitoring is one of the main activities in this process (Kwon, Liu, & Johnson, 2014; Lajoie et al., 2015; Rogat & Linnenbrink-Garcia, 2011; Ucan & Webb, 2015). In fact, socio-emotional monitoring can be seen as a part of emotion regulation strategies that influence which emotions students are experiencing, when and how the emotions are experienced, and how emotions are communicated within group interaction (Ben-Eliyahu & Linnenbrink-Garcia, 2013). The increased awareness of socio-emotional challenges can activate emotion regulation, which, in turn, refers to the process involved in controlling emotions to modify or temper aspects of emotional experiences, particularly when they interfere with the group's cognitive or social goals or with social interaction (Boekaerts, 2011; Thompson, Martin, Richards, & Branson, 2003; Wolters, 2003; Wolters & Benzon, 2013).

Monitoring and the use of diverse control processes do not mean that socio-emotional challenges should not be experienced or that experienced emotions should not be expressed verbally within group interaction. In fact, the expression of emotions may signal socio-emotional engagement within a group and can function towards effective collaborative interaction and challenge or conflict resolution (Rimé, 2007; Van Kleef & Fischer, 2016). This means that the number of experienced socio-emotional challenges, or even the cause of the emotional reactions, is not detrimental to group success, per se. What counts for a well-functioning group interaction is how group members identify with and interpret their socio-emotional experiences (Bakhtiar et al., 2017). Mänty et al. (2020) showed that students' negative emotional experiences related to the task prior to collaborative working increased the group's emotion regulation during the collaboration and negative group interactions negatively affected students' emotional experiences after the task. When

socio-emotional challenges and emotional reactions emerge, their interpretation can be positive and, thus, lead to increased engagement and efforts in group activities; alternatively, it can be negative and lead to disengagement and withdrawal from the group and its activities (Linnenbrink-Garcia et al., 2011; Näykki et al., 2014). In sum, considering whether or not the students will allow their emotions to direct their work or whether they can direct their emotions so that they can continue their task is important.

What is missing in collaborative learning research is how to enhance possibilities to discuss emotional experiences during group tasks. This could potentially increase group members' awareness of socio-emotional challenges. There is little effort for helping group members making their feelings and intentions externalized or "visible" so that the group members could reflect more explicitly on their emotional experiences during the progress of group learning processes. Discussing emotional experiences could modify student's learning and group working processes to solve the emotional challenges that implicitly but clearly negatively affect group interaction and learning (Linnenbrink-Garcia et al., 2011; Näykki et al., 2014; Van Kleef, Heerdink, & Homan, 2017).

2. Aim

The aim of this study is to examine how students experience and describe both socio-cognitive and socio-emotional challenges in collaborative learning. The research questions are: 1) What type of challenges are observed in groups' interaction during mathematics problem-solving tasks? and 2) How do students in groups identify and describe the challenges during scripted interaction?

3. Methods

3.1. Context and participants

The study was conducted in a first-year teacher education course on mathematics education. During the six-week course, students ($N = 20$, $M_{\text{age}} = 22$ years, 5 men and 15 women) worked on three face-to-face collaborative tasks. The mixed-gender groups of three to four students were formed based on pre-questionnaire responses that assessed the students' dispositions towards collaboration (Wang, 2009). The Likert-scale items included measures such as, "I enjoy exchanging thoughts with others," and "I am open to all sorts of opinions." On the basis of their answers, the students were divided into three profiles: the most positive towards collaboration, the least positive towards collaboration, and those who were in between. The groups were formed in such a way that each group included students from all three profiles. This was for balancing the group compositions so that any group would not include only the type of participants that would either greatly value the group workings or dislike the group working overall. The groups worked on tasks about three mathematics topics: Base 10 blocks for arithmetic algorithm, fraction cakes for fractions counting, and cubes and paper grids for spatial thinking. The overall goal of the tasks was to enhance student teachers' conceptual and pedagogical understanding of the given concepts and tools in mathematics education.

3.2. A macro script for regulated learning

The work in the student groups was supported with a regulation macro script that divided the group work into different phases. It started with the *orienting phase*, in which the groups set goals and plans for their learning prior to beginning their task. It continued with the *intermediate phase*, in which the groups discussed and evaluated their progress with the task, and it ended with the *reflection phase*, in which the groups evaluated their learning process and overall performance as a group. In addition to the division of group work into phases, specific questions were used to prompt the groups' work (see Table 1). The prompting questions were delivered to the students through tablet computers, which each group had in use during the task. The question prompts instructed the groups to focus and reflect on their thoughts and feelings and to consider the efficiency of their group interaction. These question prompts were designed by considering the findings on the processes that characterize effective collaborative learning (Hadwin et al., 2018). At the beginning of the session, teacher gave instructions on how to use the prompts in the tablets and noted when the students could focus on them. During the sessions, the teacher also guided the groups in specific time points for the use of script.

3.3. Data collection and analysis

The study was conducted in a classroom-like research space (*the link to the research facilities will be added*). Data collection implemented video tracks with a spherical 360-degree point of view. The setting enabled the recording of all groups at once, and videos captured the students' discussions, movements, and gestures.

A multi-step analysis schema was developed and used to explore when and how challenges occurred during the group tasks and

Table 1
The script questions in the three phases.

Orientation Phase	Intermediate Phase	Reflection Phase
What is the purpose of the task?	How has your work progressed?	How would you evaluate your work as a group?
What kinds of feelings does the task arouse?	What kinds of feelings does your work arouse?	How did you reach your result(s)?
What kinds of strengths does your group have?	What kinds of challenges are you currently facing?	What helped or hindered you from reaching your goals?
How do you plan to work?	How will you proceed from here?	How did you overcome possible challenges?

how the student groups discussed these challenges during the scripted interaction. QSR International nVivo 12 data analysis software was used to code the 15 h of videos with time-logged codes. First, the video data were segmented into 30-second events. The time-based segmentation of events gave a structured and consistent unit for the analysis and allowed a temporal unfolding overview of the group situations (Miles & Huberman, 1994; Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015). Each 30-second segment was annotated with a description of what happens within the event, such as, “The group finishes its first task. The group discusses whether it has justified its task sufficiently.” These annotations created a rough content log of each video. Second, each 30-second event was observed to determine whether or not the group members’ interaction showed socio-cognitive or socio-emotional challenges (see Table 2). The implemented coding categories were not mutually exclusive; instead, it was assumed that different challenges could exist parallel to one another, and, thus, the same 30-second event could be coded under more than one category. One example of such overlapping coding is when the groups expressed negative emotions whilst they discussed their cognitive challenges in content understanding.

The coding protocol included the following categories: 1) socio-cognitive challenges (subcategories: content understanding challenges, task understanding challenges, cognitive task progress challenges, and cognitive task difficulty challenges), and 2) socio-emotional challenges (subcategories: frustration, agitation, annoyance, challenge in controlling one’s feelings, lack of interest and energy, and physical discomfort). These challenges reflected how the group members in different task phases and situations dealt verbally and non-verbally with the challenges in the group interaction (Järvenoja & Järvelä, 2009; Näykki et al., 2014). The reliability of the coding was ensured by selecting 25% of the raw video data to be classified by an independent coder. Cohen’s Kappa showed strong reliability of the coding, as the inter-coder reliability score was 0.66 for socio-cognitive challenges and 0.65 for socio-emotional challenges. According to Landis and Koch (1997), a Kappa value above 0.61 indicates substantial agreement.

Further analysis explored how the group members described the challenges during the script discussions (i.e. the orientation, intermediate, and reflection phases). In other words, this focused on how the group members described the challenges they experienced during the previous task phase. The groups self-determined how thoroughly they discussed the provided prompt questions and decided when they were ready to continue with their mathematical tasks. Therefore, the group situations differed in terms of duration of the script discussions, as well as the focus and the quality of the discussions. Based on differences in the experienced and described challenges during group work, we selected one group for closer analysis. A case example was selected among the all group sessions to show how the group experienced challenges and actively described their challenges. As presented in Results, the selected group experienced a relatively large number of socio-cognitive and socio-emotional challenges, and it described and elaborated on its experienced challenges during the scripted discussion. With this case example, we will illustrate how socio-cognitive and socio-emotional challenges emerged in the group’s interaction and the types of discussions about the challenges that were activated with the script in a group.

4. Results

4.1. What types of challenges are observed in student groups’ interactions during mathematics problem-solving tasks?

Overall, we observed 93 events of socio-cognitive and 32 events of socio-emotional challenge situations (see Table 3). The average number of observed challenges per group session was six socio-cognitive challenges (variation 0–12) and two socio-emotional challenges (variation 0–8). Overall, groups 1, 2, and 3 experienced more socio-cognitive challenges during their task work ($f = 22, f = 23,$ and $f = 23,$ respectively) than groups 4 and 5 did ($f = 10$ and $f = 15,$ respectively). Groups 1 and 2 also experienced more socio-emotional challenges ($f = 16$ and $f = 10,$ respectively) than did groups 3, 4, and 5 ($f = 2, f = 2,$ and $f = 2,$ respectively). In sum, the groups experienced more socio-cognitive than socio-emotional challenges during their group tasks. We observed some situational variation between sessions in the number of experienced challenges, but differences between groups were more prominent.

4.2. How do the groups use script phases to discuss their challenges?

The script discussions were explored in detail to understand how the groups responded to the script stimulus in order to discuss and describe the socio-cognitive or socio-emotional challenges they had experienced during their group task or were currently experiencing. Overall, we found 54 situations in which the group members described and discussed the challenges they experienced during

Table 2
Coding categories and Kappa coefficient values.

Challenge	Subcodes of challenges	k
Socio-cognitive	Content understanding challenges Task understanding challenges Cognitive task progress challenges Cognitive task difficulty challenges	Socio-cognitive challenge $k = 0.66$
Socio-emotional	Expressing frustration, agitation, annoyance, Challenge to control one’s own feelings Lack of energy Lack of interest Physical discomfort	Socio-emotional challenge $k = 0.65$

Table 3
Frequency of the observed challenges.

	Socio-cognitive challenges (<i>f</i>)	Socio-emotional challenges (<i>f</i>)	Total (<i>f</i>)
Group 1	22	16	38
Group 2	23	10	33
Group 3	23	2	25
Group 4	10	2	12
Group 5	15	2	17
Total	93	32	125

the scripted phases (see Table 4). Socio-cognitive challenges were described more often ($f = 34$) than socio-emotional challenges were ($f = 20$), reflecting the fact that socio-cognitive challenges were more commonly observed in the groups' interaction. However, relative to the number of experienced socio-emotional and socio-cognitive challenges, the groups described proportionally more socio-emotional challenges (62.5% of the observed socio-emotional challenges) than socio-cognitive challenges (36.6% of the observed socio-cognitive challenges) during their scripted discussions.

Next, we compared the number of challenges that researchers observed in the interaction stage with the number of challenges that students described during the script discussions across different groups. We noticed that some of the groups were more active than others in describing and discussing their challenges during the scripted interaction (see Table 5). The groups with more observed socio-cognitive challenges during their task work (groups 1, 2, and 3) also described more socio-cognitive challenges during the scripted discussion than did the groups with fewer observed socio-cognitive challenges. Group 3 was particularly active in describing their socio-cognitive challenges during the scripted discussion. Groups with more observed socio-emotional challenges (groups 1 and 2) differed in how they described these. Group 1 was the most active in describing the socio-emotional challenges it encountered during the scripted discussion, whilst group 2 described socio-emotional challenges only twice. However, group 4 actually described more socio-emotional challenges during the scripted discussion than were observed during their task work. Thus, the groups appropriated the script in different ways and highlighted different aspects of their experiences in their scripted interactions. The macro script did not require the students to discuss all challenges but gave the students the opportunity to describe and discuss the challenges that they found especially salient or meaningful.

Based on the analysis of differences between groups, we decided to select group 1 for the case analysis. Group 1 experienced a relatively large number of socio-cognitive ($f = 22$) and socio-emotional challenges ($f = 16$), and it described and elaborated on its experienced challenges during the scripted discussion. The case analysis was used for exploring in more detail how the challenges emerged during group interaction and how the case group used scripted discussions to elaborate on their challenges; we also examined whether or not they were thinking about possible challenge resolutions during their discussions. Therefore, a representative case example of *high challenge task* and *active challenge description situation* in the case group was selected. The case example explains in greater detail the observed challenges and the groups' discussions of the challenges. The transcribed examples from the group 1 interaction processes will illustrate the situation in which the case group is discussing the orientation-, intermediate-, and reflection-phase script questions that prompted its members to evaluate the challenges they experienced or were currently experiencing.

4.3. The results of the case group analysis during the first task

In the third part of this study, we conducted a micro-level case analysis of challenges encountered during task work and students' discussions of challenges during the script phases. Our case analysis focused on the case groups' work during the first task because this task involved the most socio-cognitive and socio-emotional challenges in the case group, and because the group was especially active in describing the challenges they experienced. The task instruction asked students to complete arithmetic algorithms and illustrate them using base ten blocks. The groups had to complete several calculations and were asked to discuss how they would teach the arithmetic algorithms to elementary school children using the base ten blocks.

In this case analysis, we describe the progress of the task in four phases: phase 1 illustrates a challenge encountered during work at the beginning of the class; phase 2 showcases how challenges were described during the scripted interaction at the midpoint of the session; phase 3 illustrates another challenge during work on the task; and phase 4 shows how the group described their challenges at the end of the session. Fig. 1 indicates when socio-cognitive and socio-emotional challenges emerged during task work and when they were described during the scripted discussions.

Table 4
Observed and described socio-cognitive and socio-emotional challenges.

	Observed challenges during task working (<i>f</i>)	Described challenges during the scripted interaction (<i>f</i>)	%
Socio-cognitive challenges	93	34	36.6%
Socio-emotional challenges	32	20	62.5%
Total	125	54	43.2%

Table 5
Observed and described challenges in different groups.

Group	Type of challenge	Observed (f)	Described (f)
Group 1	Socio-cognitive	22	9
	Socio-emotional	16	9
	Total	38	18
Group 2	Socio-cognitive	23	7
	Socio-emotional	10	2
	Total	33	9
Group 3	Socio-cognitive	23	15
	Socio-emotional	2	1
	Total	25	16
Group 4	Socio-cognitive	10	2
	Socio-emotional	2	5
	total	12	7
Group 5	Socio-cognitive	15	1
	Socio-emotional	2	3
	Total	17	4
	Total	125	54

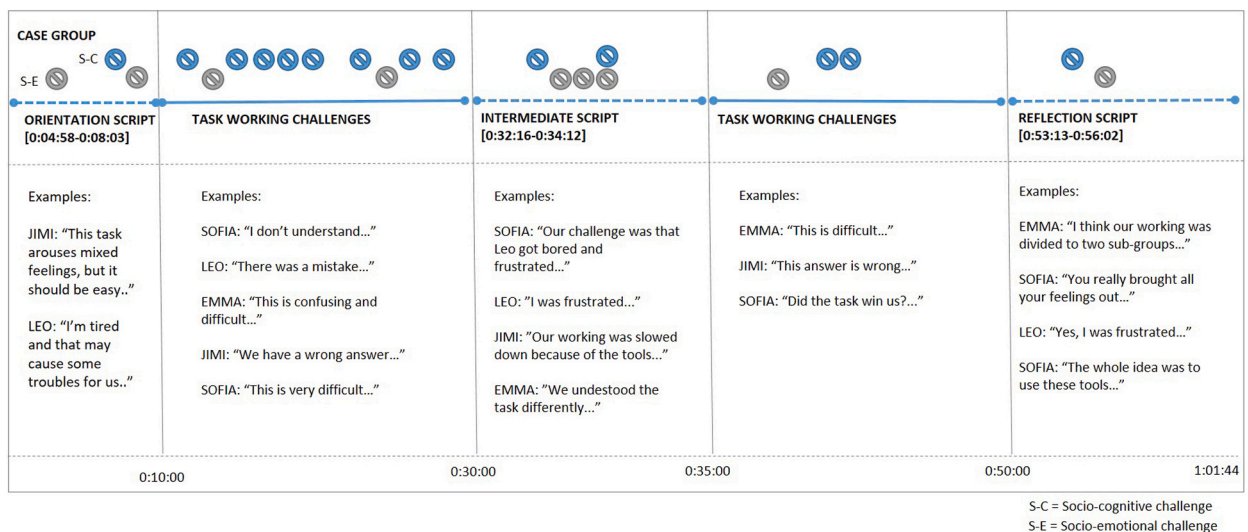


Fig. 1. Overview of the case group's challenges.

4.4. Phase 1 (0:24:00–0:26:24): Mathematical challenges emerge in task work

At the beginning of the task, the group is progressing well. They have easy tasks where they are using the base ten system to count numbers together. However, when the tasks get more difficult, the group starts to have challenges with using the base ten system as a tool in their mathematical thinking. Example A illustrates an episode where group members face a socio-cognitive challenge related to a subtraction calculation with numbers bigger than any they have used before. The challenge arises as Leo suggests skipping a step in breaking a large, one thousand block into smaller units (A1).

Example A

- A1 Leo: When we take ten from here, it should be three, but I won't take that now to its pieces (thousand block). Let's just consider that we have ten of those in here.
- A2 Sofia: But we need those here again.
- A3 Emma: This is only making it more complicated!
- A4 Sofia: But if here, if here is ... where we are? Are we doing the task B?
- A5 Emma: So why do we have a thousand in here?
- A6 Sofia: No, we are not there, we are in a Task C.
- [Jimi is laughing.]
- A7: Sofia: No, you can't take a hundred from here, you should borrow.

A8 Leo: Yes, we need to borrow, I was just thinking about how to make this easier. We are not going to break these in pieces, but you can do it if you want, yeah you just do it [laughs and looks at Jimi]. I was just going to count that in my head [turns himself towards Jimi and hides his face while whispering something to Jimi].

A9 Sofia: Wait, we need from here, hmmm, two, don't we?

A10 Leo: Yeah, this is just that I was not planning to break this, because we would need all of these and even more. [laughs].

A11 Sofia: Is it now nine hundred ... ninety?

A12 Emma: ... ninety ...

A13 Leo: No, it's not nine hundred, no [laughing and shaking his head].

A14 Sofia: This task went over my head.

A15 Emma: Yeah, same for me [laughing].

A16 Leo: See here, when you have here eleven hundreds, then you have one thousand and one hundred, and then you take three hundred away and that leaves eight hundred to you.

A17 Emma: Ahh, right, now I see it, so it is eight hundred.

A18 Sofia: I'm sorry that I didn't get it.

A19 Leo: It is all right, I didn't know how to explain this to you since you were so caught with a thousand block [laughs].

A20 Jimi: This is now more complicated when we go to bigger numbers.

This example shows how group members encountered challenges and had disagreement on how to solve the task. Emma and Sofia expressed confusion (A3), which further leads Sofia to question whether or not they were doing the same calculation (A4, A6). Jimi's laughter indicated that he was amused by the situation and Leo was also visibly amused by the confusion but also expressed frustration by shaking his head (A13). Sofia and Emma both explicitly expressed that they were having troubles with the task (A14, A15). As Leo noticed their troubles, he clarified the calculation by explaining it verbally and illustrating the calculation with the base ten blocks. After the explanation, Emma and Sofia both indicated that they finally understood (A17, A18). At the end of the episode Sofia apologized for not understanding the calculation (A18). This suggests that the experienced socio-cognitive challenge also may have triggered socio-emotional discomfort. Leo further explained that he had trouble explaining the calculation because they focused on different aspects of the task (A19). Jimi admitted that the calculations became more complicated when they needed to work with bigger numbers (A20). Overall, this situation was marked by a socio-cognitive challenge, which induced expressions of emotion but which the group was able to resolve.

4.4.1. Phase 2 (0:32:16–0:34:12): Group discusses its challenges in script phase

The intermediate script phase prompted the group to consider how they have progressed with the task and what challenges they have been experiencing. The discussion shows how they evaluated each other's emotional states, thus recalling socio-emotional challenges that were connected to socio-cognitive challenges.

Example B

B1 Sofia: We got our tasks done, but our challenge was that Leo got bored and became frustrated.

B2 Leo: Yes, I admit that. I was frustrated with these.

B3 Jimi: Our working was slowed down as we did not know how to use these tools appropriately, and that made us frustrated.

B4 Emma: The first tasks were easier, but then it got more complicated.

B5 Leo: Yes, when we needed to borrow and the numbers were bigger. I think we got frustrated with these tools. It was somehow like when you know the results by counting in your mind and it is so much faster, and you still need to use these, so it only slows you down.

B6 Emma: It is different when that process is already automatic, so you need to think about it differently. I think we did not really know how to use these tools in the beginning.

The episode in Example B began with Sofia saying that their group's challenge was that Leo was bored and frustrated (B1). Leo was not offended by this, but instead he admitted that Sofia interpreted his emotional state correctly (B2). When describing these socio-emotional challenges, the group then recalled challenges with using the tools, reflecting the socio-cognitive challenge illustrated in Example A. Emma remembered that the task kept becoming more complicated (B4), which Jimi also mentioned in Example A. Leo continued by explaining that the reason for his becoming frustrated was the use of tools as counting in his head was much faster strategy (B5). Leo seems to refer especially to Example A by noting that he became frustrated because he considered that mental calculations were a faster method of solving the calculations than using the tools, which slowed them down. Emma further elaborated that the base ten system tools necessitated that they not only use automatic processes of calculation, but also think differently (B6). Yet, she argued that they did not really know how to use the tools in the beginning (B6). Overall, this episode shows that the script discussion allowed the group to think back to their previous socio-cognitive challenge. However, new perspectives were added in the scripted discussion. First, Leo explicitly stated that he was frustrated by the challenge they experienced. He had not explicated this emotion previously, but it had become so apparent in his nonverbal behaviour that Sofia had been able to recognize the emotion (B1). Second, the group could reflect more explicitly on the reasons for their emotions and the socio-cognitive challenge. Thus, they could give more explicit attributions to the challenge they experienced.

4.4.2. Phase 3 (0:45:19–0:48:15): Challenges emerge in task work

In the third phase, the group's task challenges continue. They again encounter a socio-cognitive challenge related to mathematics and the tools used, as they try to solve a division calculation using the base ten blocks. The example shows how the socio-cognitive challenge also triggers emotional expressions.

Example C

C1 Emma: How is it then counted with this?

C2 Sofia: Yeah, I was also thinking that could you show how to use this.

C3 Leo: So, in the same way, we start here.

C4 Sofia: But where? Show it in here.

C5 Leo: Let's take 112, so you start from here and then ... [Leo looks at the paper where he had counted the task].

C6 Sofia: But look here, you can't do it in the same way like you counted there [on a piece of paper].

C7 Leo: See, when you divide this into three same-size groups and then this one is left over. And then [organizes blocks and shakes his head] then we have here ... totally wrong answer. Is it? No, yes it is [hits the table with his fist], I don't know [shakes his hands and raises his voice].

C8 Jimi [writes on a piece of paper]: No, but here you can take that zero [Jimi and Leo start to count again on the paper].

C9 Sofia: That is what I was trying to say, that this should not stay in here but should these be in different ways [re-organizes the blocks].

C10 Emma: I don't get this.

C11 Sofia: I don't know, this was difficult. Maybe it can't be done with these at all.

C12 Leo: Yeah, it is very difficult with these if you don't want to break these into very small pieces.

C13 Sofia: So it would be the same to do it with numbers then.

C14 Leo: Mmm-hmm.

C15 Sofia: Did the task beat us or did we beat the task?

C16 Leo: We did beat the task when counting on the paper but not with these tools.

C17 Jimi: This was challenging.

Example C started with Emma and Sofia asking Leo and Jimi to show them how to use the mathematical tool in their task (C1, C2, C4). The setup was similar as in Example A, where Leo helped Emma and Sofia to understand how to complete the calculation using the mathematical tool. Leo started explaining the calculation, referring also to the algorithmic way of solving the task (C5). However, Sofia pointed out that this method does not work with the blocks (C6). As Leo continued explaining, he also noticed that he is not reaching the correct answer and did not know how the task should be done (C7). Leo expressed emotional agitation by shaking his head and hands, hitting the table with his fist, and raising his voice (C7). Jimi and Sofia tried to help resolve the issue (C8, C9). Emma, Sofia, and Leo agreed that the task was challenging (C10, C11, C12). Sofia argued that they might as well use the algorithmic method (C13), and Leo agreed (C14). Thus, they did not complete the task with the tools, but reflected on their performance spontaneously. Sofia asked whether the task beat them or they beat the task (C15). Leo argued that they won on paper but not by using the tools (C16). Jimi emphasized that the task was challenging (C17). This episode, thus, highlights a socio-cognitive challenge that the group was not able to resolve completely. The episode involves several occasions of explicit metacognitive monitoring and evaluating. At the same time, the challenges triggered observable emotional reactions, especially in Leo.

4.4.3. Phase 4 (0:53:13–0:56:02): Group discusses its challenges in evaluation script phase

In the evaluation phase, the group members evaluated their group processes with the help of the script. The group members replied to a prompt question of "what helped or hindered your working" in the following ways.

Example D

D1 Emma: I think our working was divided to two sub-groups.

D2 Sofia [says to Leo]: And you really brought all your feelings out.

D3 Leo: Yes, I was frustrated at the time. I think our working styles were different, us boys, we wanted to have the correct solutions right away.

D4 Sofia: We tested the tools and made mistakes [referring to herself and Emma].

D5 Leo: In that end of the table, you tried things, trying and making mistakes. And here, we wanted to have a correct solution right away, we had to have the answers.

D6 Sofia: You counted the tasks on a paper before we even tried this board.

D7 Leo: For me it is so simple, I only need to see the numbers and I automatically have the solutions.

D8 Sofia: Mmm.

D9 Emma: I didn't even start to think of counting them in my mind.

D10 Sofia: I didn't either, I also just started with these.

D11 Leo: That is the reason why you had so many challenges.

D12 Sofia: Yeah, but the whole idea was to use these tools, and you were counting the tasks on the paper. We were asked to use the tools so that we could experience the same possible challenges that children could encounter when using these.

D13 Jimi: Yeah, we were slowed down because of these blocks [laughs].

D14 Sofia: Yes, we were not used to using these.

D15 Leo: We had to think very hard.

First, Emma reflected that their work was divided into two sub-groups (D1), which refers to the fact that the men in the group wanted to reach the correct solution faster and did not use the mathematical tools in the same way as the women in the group. Similar to the previous script discussion (Example B), where Sofia pointed out that Leo was bored and frustrated, here Sofia said to Leo that he really brought all his feelings out, possibly referring to the strong, observable emotional reactions made by Leo in Example C. Again, Leo admitted that Sofia is correctly interpreting his emotional expressions (D3). Leo attributed his frustration to their different working styles, stating that the men wanted to reach the correct solutions faster than counting with the mathematical tools would allow them (D3). Here, Leo referred to Example C. Sofia elaborated that she and Emma tested the tools (D4). Leo agreed and described how he and Jimi were looking for answers right away (D5). Sofia explained her point of view by referring to the task instructions that stated that they were expected to use the tools and to encounter challenges with them, not to rule them out by using paper and pen as tools (D12).

To sum up, Example D illustrates how the script prompted the group to discuss the reasons behind the challenge they faced in Example C. In the beginning of the episode, the group recalled the emotions that Leo expressed. Again, the script allowed Leo to explicitly state that he was feeling frustrated and reflect on the possible reasons for that emotion. The scripted discussion also allowed the group to reconsider their task understandings. While Leo mentioned the will to reach the correct answers, Sofia highlighted that the task was also pedagogical: understanding what challenges children might face using the tools. Thus, the group was able to create a more profound joint understanding of the discrepancies in task understanding and the ways of working that caused their challenges and provoked their emotions.

4.5. Summary of the case example

The case examples show that the group was experiencing challenges during their mathematical task. Leo's emotional reactions to challenges became especially apparent throughout the task and were reflected in the group's scripted discussions. Furthermore, the scripted interactions showed that the group was aware that it was experiencing some troubles and discrepancies in using the base ten blocks. The script provided them the opportunity to bring up the socio-cognitive and socio-emotional challenges and to create the group's shared understanding of the challenges. During the script discussion, the group members used the opportunity to verbalize their challenges, name the emotions they experienced, and attribute those challenges and emotions differently than during the task work. The group, for example, named the experienced emotions (i.e. frustration) during the script, while during their task work, they were merely expressing the emotions. The group also named different working strategies during the scripted interaction. This was visible in the way they described that some of the group members wanted to find the correct task solutions quickly, whereas others wanted to learn how to use the mathematical tools. Furthermore, the intertwining of socio-cognitive and socio-emotional challenges was apparent in the given examples. Thus, it is necessary to acknowledge that socio-cognitive and socio-emotional challenges are not strictly separate or mutually exclusive.

5. Discussion

This study observed how students experienced both socio-cognitive and socio-emotional challenges in authentic collaborative learning interactions. It also explored how the group members, themselves, described and reflected their challenges in the scripted discussions. The results indicate that, overall, the groups experienced more socio-cognitive challenges than socio-emotional challenges. In other words, socio-cognitive challenges were observable not only during the task work, but also during the scripted discussions when the students were monitoring and evaluating their group work. We selected a case group as an example of a group that not only experienced more challenges than the others, but also explained their challenges in the scripted discussion. The case analysis illustrated in detail how the script prompted discussion of the experienced challenges. The scripted interactions showed that the group was aware that it was experiencing troubles and discrepancies in their group task. Furthermore, by observing their interactions, it became apparent that the script provided them a moment to verbalize their emotional experiences, name the emotions (i.e. frustration), and attribute the challenges and emotions more precisely than during their mathematical task. The group also acknowledged that the members were using different working strategies, and the script provided them an opportunity to explicate their actions and orientations more deeply than during the task work. They, for example, described that some of the group members wanted to find the correct task solutions quickly, while others wanted to use the time to learn how to apply the mathematical tools and thereby enhance their pedagogical thinking of how to support mathematics learning. The intertwining characteristics of socio-cognitive and socio-emotional challenges were observable in the given case examples. Thus, this study highlights that cognitive and emotional challenges in collaborative interactions are not strictly separate or mutually exclusive.

Our observation of socio-cognitive and socio-emotional challenges supports prior research that has argued that studies need to consider emotions as a part of a socio-dynamic interaction processes (Mesquita & Boiger, 2014) and ongoing cognitive efforts (Barsade & Knight, 2015). This study continues the line of thinking that argues that it is important to make participants aware of how learning is affected by various emotional encounters (Ben-Eliyahu & Linnenbrink-Garcia, 2013; Järvenoja, Näykki, et al., 2019; Näykki, Isohäätä, et al., 2017; Polo, Lund, Plantin, & Niccolai, 2016). In this study, we have highlighted an intertwined nature of socio-cognitive and socio-emotional learning processes. One example of this is that the socio-emotional interaction can, at its best, create a space for

cognitive interactions towards problem solving (Lajoie et al., 2015; Rogat & Linnenbrink-Garcia, 2011). This means that positive socio-emotional encounters may provide support needed for engaging in shared learning processes (Isohäätä, Näykki, & Järvelä, 2020; Näykki, Järvenoja, et al., 2017). Challenge situations, which were evidenced also in this study, may bring socio-cognitive and socio-emotional interactions together. In challenge situations students' cognitive monitoring identify whether the situation evokes emotional reactions, how relevant the situation is to learners' individual and group needs (Jiang, Vauras, Volet, & Wang, 2016), and how they could proactively and adaptively regulate their learning and interaction instead of boiling over when challenges emerge (Boekaerts, 2011; Fried & Chapman, 2012; Näykki et al., 2014). Thus, we explain that in collaborative learning socioemotional interactions create conditions, which invite for regulation. While self-regulated learning theory is explicit explaining the role of cognition, motivation, and emotion in successful learning process (e.g., Schunk & Greene, 2018), a concept of socially shared regulation (Hadwin et al., 2018) characterizes intertwined nature of socio-cognitive and socio-emotional learning processes (Isohäätä et al., 2020; Järvelä et al., 2019). Socially shared regulation in a group learning context is particularly enacted through monitoring and controlling processes in which learners strategically view their progress towards shared goals and make strategic changes when needed (Hadwin et al., 2018). We conclude that socio-cognitive and socio-emotional interactions are evident part of successful collaborative learning. When the target of monitoring is emotional experience and interpretation, the focus of regulation is to identify and name emotions that are experienced and to modify or temper of how emotional experiences are shared among group members (Ben-Eliyahu & Linnenbrink-Garcia, 2013; Järvenoja et al., 2017; Järvenoja, Näykki, et al., 2019; Lajoie et al., 2015).

In general, the results indicate that the construct of *challenge* is demanding. In particular, it is important to differentiate when a challenge increases the learning opportunities available (positive challenge) and when it becomes a possible hindrance to achieving collaborative learning success (negative challenge). To coordinate their work through challenge situations, students need to identify the actual source of the challenges (Malmberg et al., 2015). The necessary activities are naturally different if the cause of the challenge is, for example, different goals among the group members (motivational challenge); incompatible strategies or task perceptions (cognitive); internal constraints, such as lack of energy (emotional); or external constraints, such as time (time management; Järvenoja & Järvelä, 2009; Näykki et al., 2014). An awareness of these challenges can be regarded as a supporting element in learning by making group members more aware of one another's thoughts and feelings, and thus, can make even negative challenges to work for advancing group's progress in building a shared understanding and proceeding with the task work.

5.1. Limitations

In this study, we implemented an analytical approach where results of group's interaction analysis and group members' own interpretations and reflection of their shared learning processes were combined. This captured an on-going group process, but also simultaneously acknowledged the importance of group members' subjective appraisals over it. This methodological approach afforded us a micro-analytical orientation (Cleary, 2011; Cleary, Callan, & Zimmerman, 2012) and an in-depth understanding of the group process; particularly it created a new understanding of how socio-cognitive and socio-emotional challenges occurred and intertwined in interaction and how group members responded to the challenges. During the analysis process, we identified and categorized socio-cognitive and socio-emotional challenges separately. This made it possible for us to view the challenge episodes in-depth in the context of collaborative learning. The case analysis made the intertwining characteristics of cognitive and emotional processes more visible. One can question, what would be the optimal unit of analysis and the level of description when analysing intertwined learning processes. Is it feasible to separate different processes? We argue that sometimes it is needed to separate the processes, consider how they are layered in order to understand how the complex phenomena is build up. However, as pointed out also by Sinha et al. (2015), processes in group interaction intertwine and mutually influence each other in various ways. This could be captured in more details in future studies. We also argue that the group situations are always unique constitutions of their members' prior experiences and situational characteristics (Enyedy & Stevens, 2014; Järvelä et al., 2013). Whilst observational methods enable the exploration of the details and context specificity of collaborative learning processes (Jones et al., 2020), the possibility of drawing general conclusions on how, for example, socio-cognitive and socio-emotional challenges generally appear is limited.

A limitation in this study is that it did not apply information about the group members' prior experiences or individual situational characteristic. It is acknowledged that more research is needed that could combine, for example, individual characteristics and group level processes (Mänty et al., 2020). As members collaborate, they encode, interpret, and recall information together, and in so doing, they create knowledge that becomes embedded in the group's structures and processes (Miyake & Kirschner, 2014). At the same time, this can also be regarded as a limitation in this study. As group members construct understanding and make meanings together, they may also construct emotional experiences in a such a way that they would not do individually or without explicit focus on the topic. It is still unclear, what is an emotional interpretation that is related to the actual learning process and what is it related to group members' discussion over it.

Through the observed challenges and learners' subjective appraisals of them, researchers can understand the reasons for specific group processes, for example, why and how regulation is enacted in groups (Järvelä et al., 2019; Järvenoja, Malmberg, et al., 2019). More research is needed to distinguish between positive and negative challenges from the ongoing group interaction as a part of evolving group processes. Further studies are needed to explore when (in time) challenges occur and if there are differences in different time points how the challenges are reflected and responded. Temporal perspective can capture emotions' continually evolving nature (Butler, 2017). This, so called temporal interpersonal system unfolds within interaction partners simultaneously responding to myriad ongoing stimulus (Butler, 2017).

Furthermore, the contextual characteristics of challenging situations call for further analysis for understanding how the group members try to resolve the challenges. If not, why is that the case? Did the challenges that the group encountered lead them into

higher- or lower-level learning and interaction? It can be concluded, that confronting challenges in collaborative learning creates learning opportunities for students. However, it is still not known how these challenging situations can be made into adaptive learning situations for collaborative learning progress, rather than consequencing maladaptive learning, which may terminate collaborative efforts. We agree with Cress, Rosé, Law, and Ludvigsen (2019) that putting effort on collaborative learning designs can support, facilitate, and structure how cognition and emotions play out in collaborative efforts, but only after in-depth and contextual understanding of group processes targeted scaffolding for learners' support can be developed.

6. Conclusion

This study explored emerging socio-cognitive and socio-emotional challenges in group interaction. Our claim is that successful collaborative learning includes learners' meta-level knowledge about cognition, motivation, and emotion, as well as the possible challenges related to these at the group level. More evidence and research is needed how this information can be translated to script tools and support for the quality of collaborative learning (Isohäätä, Näykki, Järvelä, Baker, & Lund, 2021). These results contribute to the collaborative learning research; they illustrate how research should value groups as collective small ecosystems creating their own working cultures and norms, and that no situation is entirely replicable to another. Methodological approach in the group interaction analysis is unique since information can be gained without controlling group interactions excessively. Collaborative learning can be challenging for groups, and, thus, the knowledge of and the ability to implement practices for becoming aware of challenges can provide a direction for students to progress towards more productive collaboration.

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