Striking a balance: socio-emotional processes during argumentation in collaborative learning

interaction

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Introduction

Productive interaction in collaborative learning requires a balance of engaging in deep-level joint thinking, while sustaining a socio-emotional climate that is favorable for collaboration, even during critical discussions (Baker, Andriessen, & Järvelä, 2013). This balance relates to the intertwined nature of the cognitive and socio-emotional processes of collaborative learning, which are reciprocally shaped by one another through social interaction as the collaboration unfolds (Kreijns, Kirschner, & Jochems, 2003; Miyake & Kirschner, 2014). The cognitive processes of collaborative learning encompass the group's efforts to co-construct knowledge and provide the opportunities for collaborators to learn (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006). However, the emergence of high-level cognitive processes, such as elaborating, justifying, negotiating, and reasoning (Baker, 1999; King, 2002; Volet, Summers, & Thurman, 2009) depend on the socio-emotional processes of collaborative learning, namely the group's ability and efforts to sustain cohesive, mutually respectful social interaction (Barron, 2003; Rogat & Adams-Wiggings, 2015).

The equilibrium of engaging in high-level cognitive processes, while sustaining socio-emotional processes that are favourable to this, is particularly precarious when students' interaction involves *argumentation*—that is, critical discussion of divergent claims. On the one hand, argumentation encompasses high-level cognitive processes, such as reasoning, co-elaboration, and negotiation (Asterhan & Schwarz, 2016; Baker, 2009; Osborne, 2010). On the other hand, argumentation is also emotional in nature (Polo, Lund, Plantin, & Niccolai, 2016), being often accompanied by irritation, anxiety, joy, empathy, or other affective feelings (Gilbert, 2004; Martinovski & Mao, 2009; Plantin, 2004). Emotions, thus, are a natural—even fruitful—part of argumentation (Goldberg & Schwarz, 2016; Polo et al., 2016), but intense reactions or insensitivity to others may cause unfavorable socio-emotional tension (Andriessen, Baker, & van der Puil, 2011; Asterhan & Babichenko, 2015) and threaten the face of the participants in the discussion (Brown &

Levinson, 1987; Muntigl & Turnbull, 1998). However, avoiding confrontation and tension does not provide grounds for high-level critical discussion which may lead students to miss opportunities for learning (Andriessen, Pardijs, & Baker, 2013; Baker & Bielaczyc, 1995; Weinberger & Fischer, 2006).

Studies in the interactions paradigm in collaborative learning research (Dillenbourg, Baker, Blaye, & O'Malley, 1995) highlight that it is essential to empirically study the dynamics of productive interaction in order to foster learning in groups (Enyedy & Stevens, 2014). Regardless, the majority of past empirical studies arguing to learn as a group focused on cognitive processes of reasoning; it is only recently that studies have more explicitly addressed the socio-emotional processes that intertwine with cognitive ones (e.g., Andriessen et al., 2013; Asterhan, 2013; Polo et al., 2016). Since the research has yet to thoroughly document or untangle the complexity of collaborative learning interaction, it is necessary to explore how engaging in high-level cognitive processes—namely, argumentation—and sustaining favorable socio-emotional processes occur and intertwine in students' interaction.

Socio-emotional processes in collaborative learning interaction

Different concepts have been used to describe the social and emotional dimensions of collaborative learning, including *social and socio-emotional processes* (Kreijns et al., 2003; Rogat & Adams-Wiggins, 2015), *the relational space* (Barron, 2003; Janssen, Erkens, Kirschner, & Kanselaar, 2010), and *group processes* (Rogat & Linnenbrink-Garcia, 2011). What these concepts essentially try to capture are the learners' abilities and efforts to sustain cohesive, mutually respectful social interaction (Barron, 2003; Rogat & Adams-Wiggings, 2015), including developing trust and fostering safety for collaboration, and building a sense of community with a shared goal (Kreijns et al., 2003; Wegerif, 1998).

Socio-emotional processes in collaborative learning are *social* processes in the sense that they are dynamically created within the interpersonal setting through the social interactions that the learners engage in and also influenced by students' beliefs about the social context (Van den Bossche et al., 2006), which include, for example, students' perceptions of interdependence (Van der Vegt, Emans, & Van de Vliert, 1998), social cohesion (Sargent & Sue-Chan, 2001), group potency (Guzzo, Yost, Campbell, & Shea, 1993), and psychological safety (Edmondson, 1999). Socio-emotional processes are also *emotional* in the sense that learners' perceptions of the social context are related to their emotions as subjective inner appraisals and responses (Frijda, 1988). The emotional appraisals are both expressed in and influenced by learners' social interaction and activities (Cahour, 2013; Pekrun & Linnenbrink-Garcia, 2012). These elements dynamically shape each other during the flow of collaborative learning, which motivates reference to the socio-emotional dimension of collaborative learning as a temporally unfolding *process*.

The present study explores learners' socio-emotional processes in groups' social interaction, revealing how learners engage in collaboration and how they express their emotions and relate to each other during collaboration (Linnenbrink-Garcia, Rogat, & Koskey, 2011). Observing learners' social interactions can shed light on how collaborative processes unfold over the course of collaborative learning (Enyedy & Stevens, 2014), giving insight into the temporal evolution of collaborative learning. Socio-emotional processes can be traced in interaction by observing the degree of joint participation as an indicator of how learners engaged in collaboration, but also the emotional valence of students' communicative exchanges as an indicator of how emotions were expressed and how students related to each other in interaction.

Studies have shown that productive collaborative learning is facilitated by active participation in social, task-focused interaction (Cohen, 1994; Dillenbourg, 1999) and students' mutual engagement in joint discussion (Barron, 2000, 2003). It is known that joint participation is not self-evident when people work together (Miyake & Kirschner, 2014); nevertheless, participation

in social interaction is a prerequisite for students to make use of the affordances of learning as a group (Clark & Brennan, 1991). In interaction, joint participation is manifested as group-level behavioral engagement, where the whole group is focused on a task and each other's contributions and when students actively contribute to the discussion (Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015). A lack of participation, in turn, is manifested as non-engagement and social loafing (Karau & Williams, 1993; Salomon & Globerson, 1989). In collaborative learning situations, it may not be necessary for joint participation to be completely continuous, but activities and attention must regularly converge in order for students to sustain mutual engagement (Barron, 2000; Roschelle & Teasley, 1995).

Socio-emotional processes in collaborative learning are also linked to the emotional valence of students' interaction. Studies have shown that favorable socio-emotional processes are fostered by *positive socio-emotional interaction*, such as encouragement, inclusion of ideas, listening, and conveying group cohesion (Kwon, Liu, & Johnson, 2014; Rogat & Adams-Wiggins, 2014, 2015; Rogat & Linnenbrink-Garcia, 2011). Such exchanges sustain cohesive and mutually respectful social interaction (Barron, 2003; Kreijns et al., 2003). For example, Sinha et al. (2015) reported that a collectively engaged case group of 7th graders showed evidence of soliciting opinions, a respectful and responsive tone in their interaction, and a sense of cohesion through the frequent use of the first person plural pronoun "we." Similarly, Arvaja, Häkkinen, Rausku-Puttonen, & Eteläpelto (2002) observed that a case group of 9th graders was able to reach a high level of collaboration through an open and relaxed atmosphere with the safety to disagree. In other studies, favorable socio-emotional processes have been shown to be impeded by negative socio-emotional interaction, such as overruling, undermining, exclusion, insulting, ignoring, and discouraging participation, which may trigger further negative emotions and lead to non-engagement (Chiu & Khoo, 2003; Linnenbrink-Garcia, Rogat, & Koskey, 2011; Näykki, Järvelä, Kirschner, & Järvenoja, 2014; Rogat & Linnenbrink-Garcia, 2011; Webb, Ing, Kersting, & Nemer, 2006).

In sum, studies have shown that favorable socio-emotional processes for productive collaborative learning are characterized by cohesive, attentive and respectful interaction. However, the more cognitively challenging the interaction becomes, the more challenges it can pose for sustaining favorable socio-emotional processes (Järvenoja & Järvelä, 2009). The tension raised by cognitive challenges in interaction can pose a threat to the group's socio-emotional climate but can also accompany cognitive affordances (Andriessen, Baker, & van der Puil, 2011; Polo et al., 2016). As discussed next, this is particularly the case when the collaborative learning interaction involves interpersonal socio-cognitive conflict, resulting in argumentation.

Argumentation and socio-emotional processes in collaborative learning interaction

It has been shown that, given the right conditions, argumentation can be an effective way of learning as a group (Asterhan & Schwarz, 2009; Clark & Sampson, 2008; Felton, Garcia-Mila, & Gilabert, 2009; Yeh & She, 2010). Argumentation deepens knowledge construction from quick consensus building to conflict-oriented consensus building, where students subject each other's contributions to critique rather than simply accepting them as such (Weinberger & Fischer, 2006). Critical discussion allows learners to mirror opposing opinions and facilitates the recognition of multiple views (Kuhn, Shaw, & Felton, 1997) and discrepancies in one's own and others' understanding (Nussbaum & Sinatra, 2003). Thus, as argued by Baker (2009), argumentation has the potential to broaden, deepen, and refine understanding, as it fosters justification, negotiation of meaning, and opinion change.

Argumentation in collaborative learning can be defined as "verbal communicative interaction in which the dialectical dimension is present" (Baker, 1999, p. 182). The "dialectical dimension" refers to Barth and Krabbe's (1982) theorization of game-like dialogue, where two or more participants—the proponent and the opponent—debate over a thesis with the objective of coming to an agreement on the outcome (i.e., who has won or lost). The debate progresses through

"defenses" and "attacks" that manifest, for example, as justifications and reinforcements or as rebuttals, contradictions, or counterclaims. However, while this definition highlights a competitive setting, scholars have pointed out that arguing for learning should not be driven by dispute or the pursuit of victory. Instead, learners should engage in *collaborative argumentation*, where learners critically reason together to improve their understanding (Andriessen & Baker, 2014). Such argumentation has also been referred to as *deliberative argumentation* (Asterhan & Schwarz, 2016; Felton et al., 2009; Felton, Garcia-Mila, Villarroel, & Gilabert, 2015) and *co-constructive, critical argumentation* (Asterhan, 2013). Researchers in the sociocultural research tradition have also used the term *collective argumentation* (Brown & Renshaw, 2000; Ryu & Lombardi, 2015) and drawn connections with *exploratory talk* (Mercer, 1996).

In recent years, researchers have started reporting empirical findings about more and less collaborative ways of arguing in order to learn in a group setting. Andriessen, Baker, and van der Puil's (2011) study on socio-cognitive tension and its relaxation was among the first studies to analyze excerpts of argumentation with notions of the socio-emotional dimension of learners' interaction. The study included a case example where the group fluctuated between building tension (e.g., questions, counterclaims, persisting, or ignoring) and relaxing tension (e.g., humor, compromising, consideration, and changing focus). In the dialogues, tension arose during argumentation, but occasionally relaxed in order to sustain favorable socio-emotional processes. However, when the social climate was favorable, students could handle a relatively high degree of tension and engage in more deep-level argumentation.

Andriessen, Pardijs, and Baker (2013) continued exploring the development of tension by describing the interaction in a triad of 13-year-old boys during a series of collaborative meetings. The authors found that the boys' interaction included signs of more optimal and less optimal tension moderation. At less optimal moments, the group showed few signs of reasoning or tension increases, but more tension relaxation owing to off-task discussions or enforcing group solidarity

through consensus-building or uncritical agreement. At more optimal moments, the group could engage in high-quality argumentation with a clear sense of trust, but little tension relaxation.

The interpersonal dimension of argumentation was also explored by Asterhan (2013), who proposed that argumentative discourse can be divided roughly into three categories. The first category, consensual discourse, emphasizes consensus-seeking with little critical reasoning. The second, adversarial argumentation, is characterized by criticism and disputational talk (Mercer, 1996), but little collaborative effort or openness to opinions. The third, co-constructive, critical argumentation, involves critical reasoning, but also collaborative activity and an effort to construct understanding together. Asterhan (2013), also proposed markers for analyzing the collaborative features of interaction in online dialogues: actions that reduce face threats during disagreements (e.g., using hypothetical propositions), ego-reducing moves (e.g., hedging (Lakoff, 1972), acknowledging other's contributions, humor), conveying collaborative intent (e.g. first-person plural pronouns), and attempts to maintain positive relationships (e.g., encouragement). This research connects closely with prior research on politeness and face work in learning settings which suggest that politeness strategies are frequently used in collaborative dialogues (e.g. Brummernhenrich, Jucks, Brummernhenrich, & Jucks, 2013; Watson, Wilson, Drew, & Thompson, 2016).

Recently, Polo et al. (2016) proposed a model that specifies the social and cognitive functions of emotions in argumentation. On the social side, emotions come into play through expressed feelings, facework, and a type of group talk that can be consensual, competitive, or constructively critical. On the cognitive side, emotions play a part in the emotional framing or tonality (e.g., positive, negative, strong, or slight) of argumentative claims. In interaction, low-intensity emotional framing may be accompanied by a more consensual type of group talk, whereas high-intensity emotional framing can be associated with a competitive social climate. Thus,

achieving constructively critical social interaction, which is especially beneficial for learning, requires the optimal emotional framing of the activity.

All in all, a growing body of research suggests that optimal argumentation for learning requires a balance of engaging in critical discussion while sustaining favorable socio-emotional processes for productive collaborative learning. However, given that the characteristics of the interaction in argumentation vary in different situations and contexts (Andriessen & Baker, 2014), more empirical evidence is needed about how students attend to socio-emotional processes while engaging in argumentation. Thus far, studies have mostly relied on rather short examples of interaction and have often lacked a clear articulation of the features of interaction that lead to interpretations of socio-emotional processes. Especially the non-verbal features of interaction have often been neglected. The analysis of social interaction with attention to non-verbal cues (e.g. gaze, gestures, sighing, laughter) affords the observing important elements of the socio-emotional processes of collaborative learning, such as joint attention (Allwood, Nivre, & Ahlsén, 1993; Barron, 2003) and expressive behaviors of emotion (Cahour, 2013). Furthermore, the non-verbal modes of social interaction have also been found to be essential elements of arguing (Groarke, 2015; Gilbert, 1994).

Aim

The aim of this study was to investigate how student teachers strike a balance of engaging in argumentation that deepens the topic of discussion, while sustaining socio-emotional processes that are favorable to this, in collaborative learning interaction. The analysis was two-fold: First, we broadly investigated socio-emotional processes and argumentation in the entire dataset; then we micro-analytically examined the socio-emotional processes during the argumentation in a case example. The research questions were as follows. RQ1: What is the quality of the socio-emotional

processes and the frequency of argumentation in groups' collaborative learning interaction? RQ2: How did the case group sustain favorable socio-emotional processes during argumentation?

Method

Context and participants

The study was conducted at a Finnish university in a first-year teacher education course on environmental science. The course was part of the compulsory teacher education studies, but the students' participation in the research was voluntary. The course took place in a classroom-like research space with 360 degree cameras and individual microphones for each participant. During the five-week course, the students (N = 19, M_{age} = 23 years, 12 women) performed five face-to-face collaborative tasks. Students were divided into five mixed-gender groups of three to four students. The groups were formed on the basis of a pre-questionnaire assessing the students' disposition toward collaboration (Wang, 2009). The Likert-scaled items included measures such as "I enjoy exchanging thoughts" and "I am open to all sorts of opinions." Based on their answers, students were divided into three profiles: students who were the most positive toward collaboration, students who were the least positive toward collaboration, and students who were in between. Groups were formed such that each included students from all three profiles so that groups would have similar preconditions for collaborating in terms of students' general attitudes towards collaboration.

Even though the groups were formed by the researchers, the students were not aware of the profiles and the grouping appeared similar to the ordinary grouping method where a teacher randomly assigns students to groups. The grouping was discussed with the teacher of the course who considered that it is common for the students to work in externally assigned groups. Furthermore, students were already familiar with each other, which was considered important because group member familiarity can potentially enhance more critical and exploratory group norms (Janssen, Erkens, Kirschner, & Kanselaar, 2009). As members of the same class with the

10

same curriculum, the participants had spent the last seven months studying together during their first year of teacher education. The participants had previously collaborated with all or some of their group members on various teacher education courses before the data collection. They were also accustomed to the local practices of teacher education which emphasize collaborative learning and the development of scientific reasoning. Given that the students were adult learners who knew each other and had previous experience of collaborative learning, it was considered that all groups had good preconditions for engaging in high-quality collaborative discussions and sustaining favorable socio-emotional processes.

Procedure

The groups were assigned to work on technology-enhanced tasks relating to five environmental science topics: Species, Ecosystems, Maps, Planetary Phenomena, and Climate. In each 90-minute lesson, the groups were asked to discuss a specific topic and collaboratively design various tasks for teaching the topics in an elementary school setting. The students were asked to take advantage of given materials, such as handouts, books, and the elementary school curriculum. The students also had access to laptops and tablets for searching for further information and for sharing their products online with other groups. To give an example of one of the tasks, the following instructions were given for the collaborative task concerning Ecosystems: "Discuss and plan how to teach forest ecosystems to fourth graders. Save your plan to Google Drive. Complete the following steps: (a) Define core content, complementary content, and specialized content in relation to the topic. (b) Read Bloom's revised taxonomy of cognitive domains. Create educational objectives and tasks for activating both high-order and low-order cognitive processes. (c) Share your plan with the other students in the class. Evaluate the plan of another group and give feedback using the Comment tool in Google Drive. Read and discuss the feedback your group has received."

The goal of the tasks was to enhance students' conceptual and pedagogical understanding of given concepts and phenomena in environmental science. The open-ended tasks required students to activate prior knowledge, negotiate their understandings, evaluate the relevance of various environmental science topics for children, and jointly design pedagogical methods for teaching the topics in elementary school. The tasks were not specifically designed to create argumentation through controversial topics or claims (see Goldberg & Schwarz, 2016), but rather the open-ended nature of the tasks included the potential for groups to engage in argumentation in order to reach joint understandings and well-reasoned decisions. It was particularly expected that the tasks would give rise to argumentative negotiations about concepts in environmental science and their relevance as well as about pedagogical decisions regarding the teaching of environmental science in elementary school. The provided technological tools (tablets, computers) with internet access also gave the opportunity to seek for information and use it to ground the discussion of divergent claims. Argumentation was not explicitly prompted or instructed given that we wished to investigate how argumentation emerged spontaneously in the groups' collaborative learning interaction. It was considered that the explicit prompting of argumentation would influence the emergence of argumentation too greatly. Instead, the students' collaborative learning was supported more generally with a collaborative macro-script that facilitated discussion about goals and progress (Näykki, Isohätälä, Järvelä, Pöysä-Tarhonen, & Häkkinen, submitted), but did not advise the students to argue or discuss their interpersonal relations. The brief prompted discussions about planning how to proceed or reflecting on collaboration that took place before and after each group work session and once during the group work. Finally, following the last of the five group work sessions, students individually filled out a Collaborative Learning Experience questionnaire. In the questionnaire, Likert-scaled items were used to evaluate students' individual perceptions of the collaboration in their group.

Data and analysis

Video recordings of the groups' collaborations were the primary source of data for this study. Altogether, 24 lessons were captured on video, but after excluding videos where fewer than 3 students per group were present, 20 videos (22 h 15 min, $M_{duration}$ = 1 h 9 min) were used for the analysis. In addition, students' self-reported perceptions of the collaboration in their groups were analyzed. The data analysis was conducted in two phases.

Phase 1: Socio-emotional processes and argumentation. In the first phase, we broadly examined the quality of the groups' socio-emotional processes and the amount of argumentation in their interaction. Socio-emotional processes were investigated by observing and coding students' interaction during the video-recorded tasks. The video data were analyzed in several stages using QSR International's NVivo 10 software. First, the videos were divided into 30 s segments. The time-based segmentation allowed for creating a temporally unfolding overview of the whole dataset and provided a manageable and consistent unit of analysis (for similar studies, see e.g. Sinha et al., 2015; Sullivan & Wilson, 2015). The 30 s time-frame was chosen because it was long enough to observe several conversational turns in a single episode, but short enough for making rather fine-grained, moment-by-moment observations. Each 30 s segment was briefly annotated with a description of what occurred within the episode, such as "The group finishes planning the hiking trip. Antti shows the map to the others. The group discusses if they have justified their plan sufficiently. Henna suggests that the group moves on to the second task."

The segmented video recordings were analyzed by coding the characteristics of favorable socio-emotional processes. The analysis focused on two characteristics that were selected on the basis of earlier evidence of productive interaction in collaborative learning: *joint participation* and *positive socio-emotional interaction*. Joint participation and positive socio-emotional interaction were chosen as indicators of students' socio-emotional processes as they revealed how learners behaviourally engaged in collaboration and how they expressed their emotions and related to each

13

other during collaboration. Each category included the sub-categories presented in Table 1; however, in this study, we focused only on the main categories, which include all material coded with the given sub-categories. The unit of analysis was one 30 s segment. The segment was coded if it met the criteria for a code. The codes were not mutually exclusive; thus, the same segment could be coded under several categories. The reliability of the analysis was checked by calculating Cohen's kappa value of inter-rater reliability after two independent coders coded 30% of the whole dataset. The kappa value was sufficient for all categories.

Table 1. Coding categories for socio-emotional processes.

Code	Criteria	Cohen's κ
Joint participation		
Joint task focus	The whole group is engaged in on-task behaviors, i.e., performing task-related activities, such as discussing the task, regulating their collaboration, or solving technical problems. None of the students show disengagement (e.g., checking phones, joking with another group).	.72
Active contributing	All group members contribute verbally to the discussion by initiating turns or responding in turns. All group members make at least one verbal contribution, which is more substantial than a simple back-channeling turn.	.79
Active listening	All group members signal attunement, e.g., by nodding, back-channeling turns (e.g., "mm," "yes," "right"), eye contact, and attentive gaze. The group listens to everyone's contributions. The students are attuned during the majority of the episode and are not distracted by other activity.	.69
Positive socio-emotional interaction		
Humor	A student jokes and another shows amusement by laughing or smiling amusedly. Something funny happens or is said and students show amusement by laughing. The humor is good-natured and inoffensive.	.77
Socio-emotional support	A student compliments, praises, or encourages another team member or the group's work (e.g., "We did a great job"). A student expresses the desire to do a favor for someone (e.g., "Should I slow down?"). A student shares positive beliefs about the group's potency or group members' strengths (e.g., "I'd be lost without your help"). A student apologizes, thanks, or expresses sympathy ("I'm sorry, I'm a little tired today"; "Poor you").	.76

The observation data were complemented by self-report data from the Collaborative Learning Experience questionnaire. The questionnaire data provided evidence of students'

individual interpretations of the groups' socio-emotional processes, particularly of group

satisfaction (Chang & Bordia, 2001), cohesion (Sargent & Sue-Chan, 2001), and psychological

safety (Edmondson, 1999). Table 2 presents the scale items and Cronbach's alpha value of each

variable.

Table 2. Questionnaire variables for socio-emotional processes.

Variable	Scale items	Cronbach's α
Group satisfaction	I am satisfied with the performance of our group. I would like to work with this group in the future. As a group we learned a lot.	.83
Cohesion	I liked my group. I felt a sense of belonging to my group. The group was united in trying to reach its performance goals. Group members listened to each other. The group has conflicting aspirations for the group's performance (reversed).	.84
Psychological safety	No one in this group deliberately acted in a way that undermined my efforts. I was safe to take risks in this group. I had the courage to voice out my thoughts.	.80

The analysis continued by identifying the argumentation in the video-recorded interaction.

Our criteria for coding argumentation were based on the minimal conditions proposed by Baker

(1999). Firstly, the interaction had to include an opening phase, where a difference of position or

attitude was verbally expressed against a previously stated claim or suggestion. The opening phase

had to be followed by an argumentation phase, where at least one communicative act was carried

out to argue for the initial claim or suggestion either directly, for example, by justifying or

reformulating the claim, or indirectly, for example, by arguing against the expressed difference of

position or attitude. The unit of analysis was one 30 s segment. However, if the exchange spanned

across two or more episodes (e.g., claim in the first segment, counterclaim in the following

segment), all the segments were coded. The reliability of the analysis was checked after two

independent coders coded 30% of the whole dataset. The analysis suggested that the analysis was conducted reliably ($\kappa = .71$).

After coding argumentation and signs of favorable socio-emotional processes, the durations of the coded content were extracted. Descriptive statistics about the coded content were compiled in order to make interpretations about the quality of the groups' socio-emotional processes and frequency of argumentation. In addition, the quantified results were used to compare whether groups differed in terms of socio-emotional processes and argumentation. First, we compared the proportions of joint participation and positive socio-emotional interaction in the groups' collaboration and students' self-reported evaluations of the collaboration. Next, we compared the proportions of argumentation in the groups' collaboration. The Kruskal-Wallis test was performed to explore if there were significant differences between the groups. A non-parametric test was used because the analysis relied only on the coded content in 20 videos and on the self-reported measures of 19 students in the 5 groups. Based on the results, one of the five groups was selected for the second-phase micro-level case analysis.

Phase 2: Micro-level case analysis. In the second, micro-analytical, phase of the study, we selected a case group on the basis of the results of the first phase of analysis. The results from the prior phase revealed that one group stood out from the rest. Judging by the given evidence, the chosen group sustained favorable socio-emotional processes, but also engaged in the most argumentation. All the episodes of argumentation in the group were viewed, but one illustrative episode was chosen for case analysis. In the episode, the group had to design a task for teaching maps for second graders in elementary school. The particular episode was chosen because it included a lengthy (9 min) piece of argumentation and because the group's final outcome was considered pedagogically creative and well-founded. Specifically, students successfully considered the heterogeneous abilities of elementary school students and could extend their first idea of teaching maps by drawing to the idea of using Legos as a way to illustrate how structures are

perceived from the bird's eye perspective. This new idea emerged from the argumentative dialogue and resolved the different points of view that were debated.

The chosen episode was micro-analytically and inductively examined through qualitative interaction analysis (Jordan & Henderson, 1995). First, the episode was viewed several times and discussed among the co-authors of the study. The contents of the groups' interaction before, during, and after the episode of argumentation were roughly narrated. Next, the students' interaction was transcribed with attention to both the content of the students' speech and the accompanying nonverbal cues (e.g., gaze, gestures) using the Jefferson system of transcription notation (Jefferson, 2004;see Appendix). Transcriptions were used as a tool for analysis to assist in annotating the interaction with qualitative observations and identifying the most crucial features of the interaction. However, transcriptions were not the main focus of the analysis; videos were continuously viewed as well.

The qualitative annotations ultimately created a rich play-by-play description (Derry et al., 2010) of the interaction in the selected episode. The description focused on how the characteristics of discourse evidenced how socio-emotional processes occurred while the group engaged in argumentation. We concentrated especially on how the argumentative process evolved, how attentively and respectfully the students engaged in interaction and put forward their arguments, and how the students expressed emotions while reasoning together. It should be noted that the analysis relied solely on observable, verbal and nonverbal expressions and on the interpretation of the turn-by-turn flow of interaction. The careful analysis of the linguistic and pragmatic features of students' social interaction shed light on the overall nature and evolution of both argumentative processes and the intertwined socio-emotional processes on the group level. After multiple rounds of reviewing the descriptions, the most salient features were synthesized into a summary of findings. An overview of the argumentation process and socio-emotional processes was also illustrated with a

flowchart. Screenshots were chosen to complement the written analysis and the transcripts of the interaction were translated from Finnish to English for reporting.

Results

What is the quality of the socio-emotional processes and frequency of argumentation in the collaborative learning interaction?

The first phase of the analysis focused on the quality of socio-emotional processes and the frequency of argumentation in the collaborative learning interaction of all five groups in all video-recorded sessions. The groups' socio-emotional processes were evaluated by coding signs of *joint participation* (joint task focus and active listening) and *positive socio-emotional interaction* (socio-emotional support and humor) that were exhibited during the video-recorded group work. The analysis revealed evidence of favorable socio-emotional processes: Overall, the groups showed joint participation for most of their collaboration (M = 83%, Std = 14% of the total duration of the collaboration in each session). Additionally, the groups frequently engaged in positive socio-emotional interaction (M = 39%, Std = 10% of the total duration of the collaboration in each session).

Slight differences could be seen between groups (Table 3). For example, group 3 had the lowest mean proportion of joint participation (M = 72%), but a rather high prevalence of positive socio-emotional interaction (M = 41%). In contrast, group 5 showed clearly more joint participation (M = 89%), but the least positive socio-emotional interaction (M = 26%). However, there was also variation within groups in different situations. For example, the amount of positive socio-emotional interaction in group 5 varied between 22% and 33%. Despite situation-specific variations, no group consistently showed the least joint participation or positive socio-emotional interaction. Furthermore, there were no sessions in any group where all the characteristics of favorable socio-emotional processes would have been particularly infrequent. For example, in session 5, group 3

had little joint participation (39%) due to external distractions (children of one of the group members), but the proportion of positive socio-emotional interaction was slightly higher than average (42%).

Table 3. Proportions of joint participation and positive socio-emotional interaction in the collaborative learning interaction.

		Group 1	Group 2	Group 3	Group 4	Group 5
Joint participation	M	95%	82%	72%	82%	89%
	Min.–max.	92–99%	73–92%	39–85%	61–91%	87–91%
Positive socio-emotional interaction	M	34%	43%	41%	43%	26%
	Min.–max.	26–46%	34–52%	42–50%	35–55%	22–33%

The evidence indicated that while the characteristics of interaction varied in different situations, in general, the groups' socio-emotional processes were favorable. The Kruskal-Wallis H test revealed no significant differences between groups. The findings of the video analysis were supported by students' self-reported evaluations of their collaboration. The results from the Collaborative Learning Experience questionnaire showed that, across groups, students were satisfied with the collaboration in their group (Table 4). On average, the students' evaluations of group effectiveness (M = 5.52, Std = 0.54), cohesion (M = 5.72, Std = 0.42), and psychological safety (M = 5.67, Std = 0.51) were high and variation was low. No notable differences were found between groups. This was confirmed by the Kruskal-Wallis H test.

Table 4. Students' evaluations of group effectiveness, cohesion, and psychological safety.

		Group 1	Group 2	Group 3	Group 4	Group 5
Group effectiveness	M	5.75	5.42	5.22	5.44	5.67
Cohesion	M	5.90	5.45	5.67	5.73	5.85
Psychological safety	M	5.75	5.50	5.67	5.44	5.92

The amount of argumentation during the groups' collaborative learning was very scarce. On average, only 4% (Std = 4%) of the total duration of the collaborations involved argumentation (Table 5). Thus, the clear majority of the group interactions included no exchanges that would have fulfilled even the minimum criteria of argumentation. Instead, students mostly accepted each other's claims or suggestions as such or conceded with a divergent claim or suggestion without argumentation. However, some groups were more argumentative than others. In particular, group 3 showed almost no argumentative interaction (0–1%), whereas group 5 engaged in notably critical discussion (8–12%). The proportions of argumentative interaction in groups 1, 2, and 4 varied. For example, group 2 showed no argumentation in the fourth session, whereas the proportion of argumentation was 13% in the second session. A Kruskal-Wallis test confirmed that there was a significant difference between groups (H = 9.972, p = 0.41). Pair-wise comparisons showed a difference (p = .26) between groups 3 (mean rank 4.62) and 5 (mean rank 18.00). In all, the findings suggest that the group members mostly accepted each other's claims and suggestions without critical discussion, but group 5 was able to engage in the most argumentation.

Table 5. Proportions of argumentation in collaborative learning interaction.

		Group 1	Group 2	Group 3	Group 4	Group 5
Argumentation	M %	4%	3%	0%	2%	10%
	Min.–max.	2–7%	0–13%	0–1%	0–5%	8–12%

Overall, the findings showed that most groups did not reach critical discussion, but rather co-constructed and co-elaborated knowledge while sustaining a favorable socio-emotional climate. Even though it can be considered that the groups succeeded in getting along and collaborating, the scarcity of critical discussion suggested that most groups did not achieve an optimal balance between cognitive and socio-emotional processes for deep-level learning. However, one group was more successful in reaching this balance. This group's interaction was examined in detail in the second phase of this study.

How did the case group sustain favorable socio-emotional processes during argumentation?

In the second phase of this study, we conducted a micro-level case analysis of socio-emotional processes during argumentation. Group 5 was selected for the case analysis because, based on the results of the first phase of analysis, the group showed evidence of favorable socio-emotional processes and the most argumentation. Our analysis focused on a nine-minute episode of argumentation in session 3 about teaching maps in elementary school. The episode covered 11% of the total duration (1 h 18 min) of the group's collaboration. Argumentation emerged as the group was preparing a lesson plan for teaching maps. The task instructions asked the group to design a two-hour lesson plan with collaborative tasks about maps for the age group of their choice.

Prior to the episode of argumentation, the group members discussed their perceptions of the task and their pedagogical objectives, agreed to design the lesson for 2nd graders (age 8), and created the first tasks for preparing pupils for more difficult activities. The group also shared ideas about, and experiences of, teaching maps and grounded the episode of argumentation by discussing some key concepts and ideas. For example, the group established that they wanted pupils to understand the bird's eye perspective and collaboratively create a map of a familiar place. Following this discussion, the group continued to argue about what kind of task would be pedagogically reasonable for second graders. Based on a qualitative analysis of the group discussion, the episode of argumentation was divided into seven phases: Proposal, Disagreement, Reformulation, Reasoning, Seeking understanding, Countering, and New proposal. Figure 1 visualizes the process of argumentation during the episode and summarizes the socio-emotional processes intertwined with the cognitive processes. As seen in the flowchart, the episode included a long chain of counterarguments, reformulations, and elaborations. Disagreement emerged especially between Sanni and Minna. However, despite the divergent views, the group maintained a favorable socio-emotional climate, as shown in the following play-by-play description of the group's

interaction. The showcase how attentively and respectfully the students engaged in argumentation and expressed emotions while reasoning together.
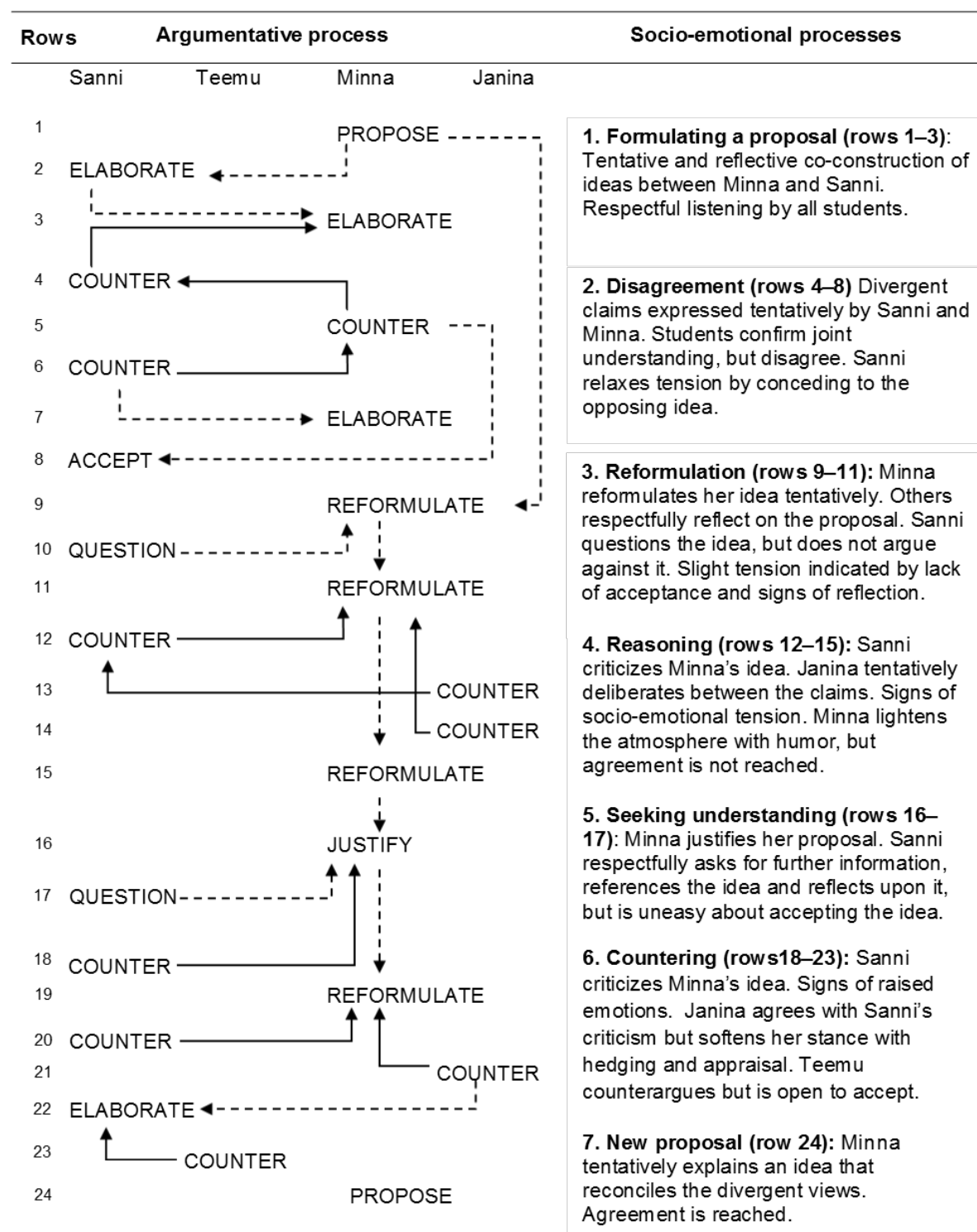

Figure 1. Argumentation and socio-emotional processes in the case example.

Phase 1 (0:56:27–0:57:45): Proposal. In the first phase of the episode, the group formulates

a proposal that becomes the topic of debate. As seen in example A, the students' interaction is

marked by tentative co-construction of ideas. Tentativeness is seen in how Minna hedges her

proposal about drawing a map by formulating it as a question (*should we*) and accompanying it with

signs of hesitation (*is it sensible?*) (A1). Sanni, in turn, presents an alternative suggestion: pupils do

a task before drawing (A2). Sanni also offers her suggestion tentatively by presenting it as an option

(alternative conjunctive *or*), indicating uncertainty (*I don't know*, reflective gaze, quiet voice), and

formulating her suggestion as a question (*could they*, *is it too much*). Minna elaborates her idea with

picture orienteering—that is, taking pictures of places marked on a map (A3). Minna hedges her

elaboration with the conditional mood (*they'd go over*), question format (*should they have*),

discourse markers (*like*, *you know*), and the use of *for example*.
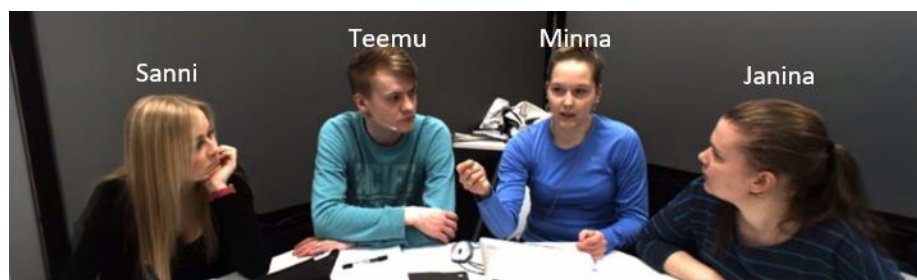
Picture 1. Minna explains her suggestion.

Example A.
A1. Minna: <Should we then have the task where they (.) draw or (.) is it [sensible]> ((gazes at Sanni))
A2. Sanni: [Or would] there be something in between some (1.0) some then (0.4) some task like ((gazes up reflectively)) °Yeah, I don't know° (1.1) ((places her finger on her chin, gazes up)) could they still have interpreted a map? (2.4) ((gazes ahead reflectively)) °some kind of task indoors or is it too much° ((turns her gaze toward the others))
A3. Minna: Well hey (.) if next would be that they'd go for example get famil- erm ((gazes around)), if there's an aerial picture of the school yard (.) ((gazes around, gestures an area with her hands)) a simple [one] (.) map ((glances at Sanni)) (0.6) [and] (0.4) the teacher (.) with the teacher they'd go over what's where on the map (0.4) ((glances at Sanni)) (.) and then, should they have for example a kind of picture-orienteering thing there then like after that they have gone through ((gazes at Sanni, explains using her hands)) the school area (0.8) and [then] they would like have to ((gazes at Sanni, gestures an area))

Phase 2 (0:57:45–0:59:04): Disagreement. Arguing about the proposal begins in phase 2,

showcased in Example B. At first, Sanni challenges Minna's suggestion about drawing a school

yard with a counterproposal: exploring a larger area than the yard. Sanni softens her argument with

23

hedges (question form, conditional mood, discourse markers, e.g., *for example, in my opinion, presumably*) (B1) and shows acknowledgment of Minna's earlier proposal by integrating the idea of picture orienteering (B3, see also A3). However, Minna argues against Sanni: second graders cannot be allowed to leave the school premises (B4). She formulates her argument tentatively as a question and expresses her argument reflectively by squinting and gazing ahead (Picture 2). The group respectfully listens, evidenced by their attentive gaze (Picture 2) and back-channeling (B2, B5, B7, B9). Even Sanni tentatively agrees, but signals the recognition of opposition and possible unease by changing her posture, gazing away and defending her claim (B10). Interestingly, the argumentation turns more consensual: Minna agrees and elaborates Sanni's counterargument (B11), which evidences acknowledgment of divergent claims and eases the potential face threat to Sanni. Sanni continues by clarifying what she meant (B12), suggesting that Sanni tries to correct a possible misunderstanding and reduce the disparity between the suggestions. Minna explicitly assures that she understood what Sanni meant (B13, B15), which signals Minna's will to maintain joint understanding. Janina also indicates that she understands Sanni (B14). However, both Minna and Janina add the adversative conjunction *but* (B14, B17), subtly maintaining tension by suggesting they are against the suggestion. Tension is relaxed by Sanni who agrees to Minna's proposal, explicitly stating that she is fine with the idea and waving her hand as a sign of indifference (B18).
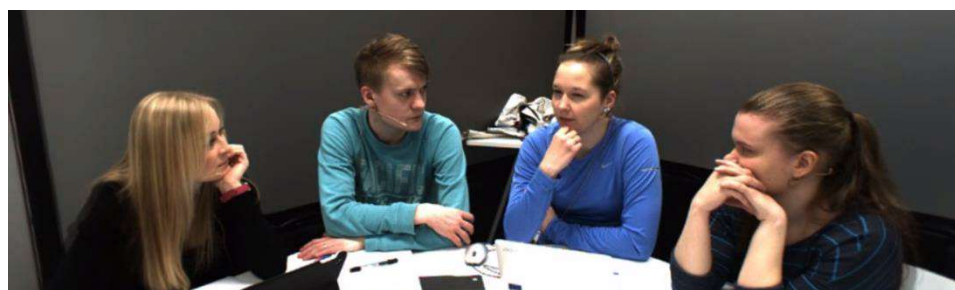
Picture 2. Minna counters Sanni's suggestion.

Example B.

B1. Sanni: So that could it in my opinion be like >in that way that< ((leans forward, gazes ahead)) it could be for
example a larger area than the school yard for example it could have (.) >presumably< somewhere near the school
there is some for example some shop or something else ((gazes ahead, but glances at Minna, gestures a school

area)) so (.) they are given a kind of map where there is the school and that is like drawn from a bird's eye perspective ((gestures a map on the table and points at objects on the map)) and then they get certain spots per group ((gazes at Janina))

B2. Minna: mm ((gazes at Sanni))

B3. Sanni: (.) that they go see and for example exactly with tablets take pictures of them ((gestures toward Minna)) [and mark]

B4. Minna: [But does one dare] to allow children of that age to really leave the school (.) surrounding? ((squints reflectively, rests her chin on her fist, glances at Sanni, Picture 2))

B5. Teemu: Yea:::h ((turns his gaze from Minna to Sanni, grins doubtfully))

B6. Minna: <They are quite small> ((gazes at Sanni)) (1.0) we had at least when I was (.) working like (.) second graders still did picture orienteering ((gazes ahead, but turns her gaze to Sanni))

B7. Janina: Yeah like [(unclear)] ((gazes at Minna))

B8. Minna: [On the third grade] then we only went further ((glances at Janina)) from [like] away from the school gates. ((gazes at Sanni))

B9. Janina: [Yeah] ((glances at Minna))

B10. Sanni: Yeah well I- it depends on what kind of school [it is] ((leans back, turns her gaze away from Minna, looks up reflectively with her chin resting on her hand))

B11. Minna: [Yeah and] (.) of course the group also influences like what kind of [group] it is.

B12. Sanni: [Yeah] (1.2) Of course I don't mean now that really [far] ((smiles subtly, gazes at Janina and Minna))

B13. Minna: [No no like] ((shakes her head))

B14. Janina: [Yeah well yeah but] ((gazes towards Sanni))

B15. Minna: [I did understand] that like near ((leans back and gestures an area))

B16. Sanni: Yeah ((gazes at Minna)

B17. Minna: (0.8) the [near area but] ((gazes down))

B18. Sanni: [Should it then be the nearby surrounding] okay (.) that's fine for example the school surroundings ((waves her hand in indifference)) or [something] there ((gestures an area))

Phase 3 (0:59:04–1:00:35): Reformulation. In the third phase, Minna reformulates her original suggestion and Sanni asks for clarification. Here, the students do not directly argue against each other's ideas; rather, they establish a better understanding of the proposition. As shown in Example C, Minna reformulates her proposal, but does not impose her suggestion, as she hedges the proposal with the conditional mood (*would be given, would draw*) and discourse markers (*for example*) (C1, C3, C5). Sanni, in turn, respectfully expresses attunement (C2), but asks for confirmation of understanding (C6, C8, C11). This indicates that Sanni is willing to understand the proposal better, even though she has previously criticized the idea of drawing. However, the lack of signs of agreement by Sanni and her raised brows (C11, Picture 3) suggest that she is still questioning the idea. Thus, the degree of tension created remains. This is also evidenced by the students' contemplative facial expressions (Picture 3).

Picture 3. Sanni asks Minna for clarification.

Example C.
C1. Minna: they ea- each would be given from that map (.) some place ((gazes around, gestures places on a map))
C2. Sanni: [mm] ((gazing down))
C3. Minna: [which] they draw <with the help of the map> draw the aerial picture ((gazes at Sanni)) (0.9) so then they like (.) they have a ready-made model (0.7) of the bird-eye perspective ((gestures a map, gazes at Sanni))
C4. Sanni: [mm] ((gazes at Minna))
C5. Minna: [But] then they would draw just a certain part from there ((gestures a smaller area, gazes at Sanni)) (1.5) [so they'd divide it] ((explains using her hands))
C6. Sanni: [Which (.) how] a certain part ((gazes at Minna))
C7. Minna: [Well] ((gazes down))
C8. Sanni: [So from the] (0.9) so if for example from the bird's-eye perspective there's the school yard drawn like this ((starts to draw on a piece of paper)) there's the school building then [there's]
C9. Minna: [Yeah] ((gazes at Sanni's drawing))
C10. Janina: [mm] ((gazes at Sanni's drawing))
C11. Sanni: [the yard] then there's a playground ((drawing)) (0.9) and so forth (.) and then if for example that ((refers to an area she has drawn)) is like for one group then do they draw a school? ((moves her gaze from her drawing to Minna and raises her eyebrows, Picture 3))

Phase 4 (1:00:35–1:01:45): Reasoning. In phase 4, the group continues to discuss the idea more critically. Example D illustrates how tension is raised and moderated. Sanni initiates the critique by pointing out that pupils would need to understand scale and reinforces her opposition by making eye contact with Minna and pointing to her (D1). Minna reacts by signaling hesitant agreement after a brief moment of contemplation (D3). Janina, in turn, defends Minna's proposal by countering Sanni's counterargument (D2, D4) and justifying Minna's proposal (D8). Her turns involve strong hedging, such as admitting uncertainty (*I don't know*) and using *if* clauses, the conditional mood and discourse markers (*necessarily, kind of, perhaps, like*), which may lessen the face threat to Sanni. However, Janina changes her stance and tentatively argues against Minna's proposal (D11): some pupils may only have a building to draw. The switch in stance evidences Janina's will to deliberate between options. Minna's reaction to the counterargument may indicate heightened emotion: As she signals agreement, Minna looks away and creases the corner of her

mouth (D12). Subsequently, Janina softens her counterargument by adding "in that sense…" while knitting her brow, gazing at Minna, and gesturing to her in an apologetic manner (D13, Picture 4). Minna sighs, which again suggests evoked emotions (D14). However, Minna persists with her opinion, suggesting that the group considers a schoolyard, where there would be many constructions (D15). Her choice of the markedly colloquial word *shebang* may lessen the seriousness of her suggestion. Minna continues to formulate her suggestion into a question (D17), asking for the group's opinion, indicating a will to find joint agreement. Her laughter makes the suggestion sound jovial. She also elaborates the proposal, accompanying the elaboration with a joking smile (D19). The humor may serve to lighten the atmosphere and help Minna persist with her idea without imposing it. Janina expresses amusement by laughing (D20). However, because Sanni and Teemu do not comply with the proposal or the laughter, a degree of tension remains. This is evidenced by the following moment of silence and Janina's reflective sigh (D22).


Picture 4. Janina criticizes Minna's idea.

Example D.
D1. Sanni: [But then there comes] (.) there comes already the concept of scale then ((leaning back, pointing her index finger toward Minna))
D2. Janina: But I don't know if [it is a problem] necessarily ((gazes ahead reflectively))
D3. Minna: [Yea::h] ((reflectively, turns her gaze away from Sanni, rubs her hands))
D4. Janina: (.) you know like because it doesn't (.) it doesn't of course become <like exactly [the same> size] ((turns her gaze from Sanni to Minna))
D5. Minna: [No it doesn't] ((gazes at Janina and shakes her head))
D6. Janina: (0.6) like in scale [but]
D7. Sanni: [mm] ((turns her gaze away))
D8. Janina: if one thinks so that then it (.) kind of would perhaps allow that pupils wouldn't have to draw like exactly the whole area and kind of perceive it [all] ((explains with her hands, gazes at Sanni))
D9. Teemu: [mm] ((gazes at Janina))
D10. Minna: So they'd like be able to perceive that one area like this ((gestures an area and then gazes at Sanni))

D11. Janina: But then there's of course just that that if there's like the school yard then someone will get just the building ((squints and gazes ahead reflectively)) then they just like draw a kind of building there (.) like on the paper [so] ((gestures a building drawn on a paper))

D12. Minna: [Yeah] ((gazes away from Janina and creases the corner of her mouth))

D13. Janina: in that sense ((gazes at Minna, knits her brow, and gestures apologetically, Picture 4))

D14. ((Minna sighs and continues gazing away from Janina))

D15. Minna: [Well but] let's think that the schoolyard is so that there is all kinds of (.) swinging gear and like all kinds of *shebang* ((gazes around, gestures a yard with many constructions))

D16. Janina: mm ((knits her brow and gazes ahead reflectively, hand covering her mouth))

D17. Minna: Can we thin(h)k lik(h)e s(h)o? ((glances at Janina, but gazes away laughing))

D18. Janina: hahah ((laughs with Minna))

D19. Minna: A dream school where there are some gadgets at every corner ((smiles jokingly))

D20. Janina: hahaha ((Janina laughs))

D21. ((2 s silence. Minna leans on the table and gazes down))

D22. Janina: Hmm ((sighs reflectively, gazes down))

Phase 5 (1:01:45–1:02:48): Seeking understanding. In phase 5, the students do not directly argue against each other's ideas, but try to seek understanding. Example E shows how Minna justifies her proposal and Sanni respectfully shows consideration of divergent claims by trying to understand the idea better. Minna argues for her proposal by pointing out that, according to the handout about teaching maps, pupils should learn to use scale (E1, E3). Interestingly, Minna directs her gaze to Sanni as she mentions "scale," which was previously mentioned by Sanni in her counterargument against Minna's proposal (see D1). This may indicate that Minna acknowledges Sanni's concern while subtly trying to counter it. Sanni, in turn, reflects upon the statement (E4), which shows a willingness to consider Minna's proposal. However, Sanni also admits that she does not fully understand the idea (E6). Sanni is evidently uneasy: she sighs, places her hands on her temple (Picture 5), and takes pauses while speaking. She seeks further confirmation of understanding and refers to details that Minna presented before (e.g., bird's-eye perspective, orienteering, dividing the map into parts) (G6), indicating acknowledgment of Minna's earlier turns. Minna confirms that Sanni has understood correctly (E7), establishing joint understanding that grounds the following phase of argumentation.
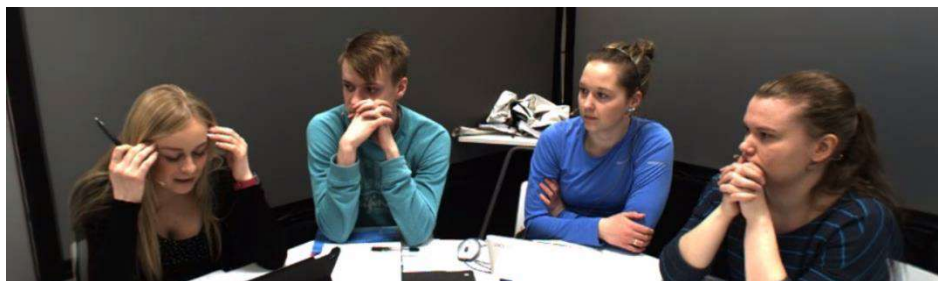
Picture 5. Sanni tries to understand Minna's proposal.

Example E.
E1. Minna: Here is- it says "using scale to evaluate distances between places" ((reads a handout, points at a line))
E2. ((Sanni gazes at the material, trying to find the correct line))
E3. Minna: (1.8) like here at (.) "the goals of teaching maps" ((points at a line on the handout and turns her gaze to Sanni))
E4. Sanni: Yeah using scale so it- so it's a little kind of that map interpretation so ((gazes at the material, arms crossed)) (2.2) ((Sanni leans closer to the material and points at it)) "using scale to evaluate distances between places" ((reads from the material and grabs her pen)) so like you kind of have (0.8) the miniature picture of the map ((sketches something with her pen and turns her gaze to Minna))
E5. Minna: mmm ((nods, gazes at Sanni))
E6. Sanni: °And then the- they orienteer there° I was thinking instead that ((gazes up reflectively)) (1.8) Hhh ((sighs)) (.) or like something in that if they still draw like- draw the like their own part ((gazes around)) (1.0) Somehow I kind of now (1.4) ((places her hands on her temple and gazes down, Picture 5)) I like kind of don't quite understand that- do you think that ((points her hand toward Minna, gazes ahead)) they draw like an aeri- (.) like also from the bird's-eye perspective that [large] part? ((turns her gaze to Minna, gestures a map of an area))
E7. Minna: [Yeah] ((nods and gazes at Sanni))

Phase 6 (1:02:48–1:04:48): Countering. Argumentation deepens again in phase 6. Example F shows how the deliberation of options is intertwined with raised tension as well as respectful tentativeness and acknowledgement of ideas. Sanni continues to argue against Minna's proposal by criticizing the idea of drawing a building (F1). She frames her disagreement as her own opinion (*I think*), evaluates the proposal with the rather informal adjective *funny*, and hedges her turn with discourse markers (*quite, kind of*) and a reflective tempo of speech. However, her facial expression (squinting and wrinkling nose, Picture 6) entail that she finds the idea problematic. Minna raises her brow as she listens to Sanni (Picture 6), which may indicate an emotional reaction. Sanni seeks confirmation of understanding and agreement from others (*Do you understand?*). Minna confirms that Sanni has understood correctly and re-explains her proposal (F3, F5), but her use of hedging (conditional, *in principle*) suggests that the proposal is still negotiable. Sanni, in turn, indicates that she understands Minna's proposal (F4), but goes on to argue that the proposal does not allow the

understanding of scale (F6). Minna signals attunement, but her facial expression (raising brow, wrinkling nose, crumpling mouth) indicates that she is hesitant to accept the counterargument (F7). Janina, in turn, deliberates between the options by appraising Minna's idea, but adding that drawing may be too difficult for second graders (F8), which is elaborated by Sanni (F10, F12, F14). This time Teemu steps in to argue against Janina and Sanni with the help of his own experiences of teacher training (F16, F18). Teemu formulates his counterargument tentatively by explicitly stating that Janina and Sanni are right, but continuing to point out that the task may not be too difficult. Sanni and Janina acknowledge the opinion (F17, F19, F21) even though it opposes their argument. Teemu continues to strongly hedge his claim by raising his shoulders and explicitly stating that he does not mind what the group decides (F22).
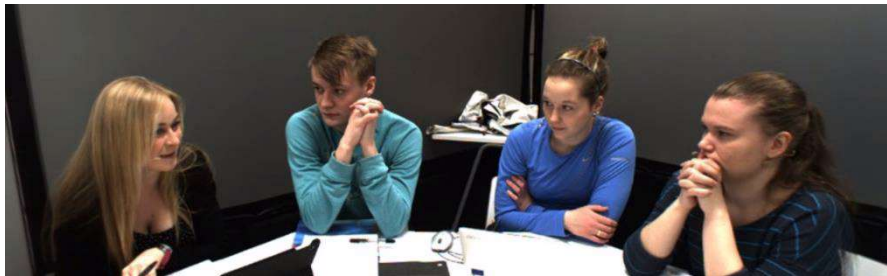

Picture 6. Sanni criticizes Minna's proposal.

Example F.
F1. Sanni: I think it's quite (1.5) ((squints, wrinkles nose, Picture 6)) quite funny that they would then draw some house so it (0.8) kind of (0.9) Do you understand? If it is there on the [small] map already? ((gazes at Minna and Janina))
F2. Janina: [mm] ((gazes at Sanni, squints reflectively))
F3. Minna: Yeah so they in principle duplicate the [same map but bigger] ((gazes at Sanni))
F4. Sanni: [Yeah yeah (.) right]
F5. Minna: So we [would get] it there in the classroo::m ((gestures a big map on a wall, gazes at Sanni)) As a kind o::f (.) bigger ((gazes at Sanni))
F6. Sanni: Yeah well but there's no- the perception of scale then again disappears ((gazes ahead)) in principle because maps are always drawn in a certain scale ((explains using her hands, gazes at Minna and Janina))
F7. Minna: Yea::h ((gazes away, raises her brow, wrinkles her nose, and crumples her mouth))
F8. Janina: I don't know is it kind of so that the drawing would be super good and kind of handy ((gazes ahead reflectively)) but then I'm thinking that is it <kind of like for second-graders if one thinks (.) that (.) in a way> that if they see the yard from this perspective ((gestures a perspective from the side, gazes at Sanni)) that is it just super difficult to perceive then like from the bird's-eye perspective [that] (.) if I see all these ((gestures something in front of her)) then how can I draw it
F9. Minna: [mm] ((gazes at Janina))
F10. Sanni: [Exactly] I was thinking that there would be [no more drawing (.) the drawing would be] taken out now ((gazes at Janina))
F11. Janina [Yeah (.) >yeah yeah that's exactly what I< yeah yeah] ((gazes at Sanni and points to her))

F12. Sanni: [Cause] (0.9) I began to realize that it must be difficult for you to draw ((gazes away reflectively)) if you
        see a building like [this] ((gestures looking at something from the side)) then to start drawing from up in the air
        ((gesturing a view from up above))
F13. Minna: [Yeah] ((gazes at Sanni))
F14. Sanni: [you can't perceive that] (gazes at Janina))
F15. Janina: [True (.) at least second yeah yeah] ((gazes at Sanni))
F16. Teemu: [Yea:h (.) that is true] ((glances at Janina)) (.) but then only that then that kind of that (0.8) how accurate is
        required I was there (.) in the second grade [there] (.) in training ((gazes ahead and then at Janina))
F17. Janina: [Yeah]
F18. Teemu: so they (.) had done sort of their own treasure maps like from their own yard [so] they were just kind of
        really simple ((mostly gazes at Janina))
F19. Janina: Yeah they are ((nods, gazes at Teemu))
F20. ((Minna nods and gazes at Teemu))
F21. Sanni: [Yeah well it can yeah] ((gazes at Teemu))
F22. Teemu: So in fact they like second-graders had drawn their own yard like kind of but (1.2) ((pouts and shrugs his
        shoulders)) it's all the same for me

Phase 7 (1:04:48–1:05:28): New proposal. The debate is resolved through the emergence of

a new proposal. Example G illustrates how the idea is presented. Minna suggests that instead of

drawing a map, the pupils use Legos (G1). Thus, Minna concedes to Sanni's arguments against

drawing, but also integrates her own idea of pupils creating something on their own. Minna

accompanies the proposal with hedging (*for example*, conditional) and explains her idea concretely

by standing up and showing what the pupils would do (G3, Picture 7). She refers to Sanni's and

Janina's earlier concerns about students' ability to perceive something from the side and from the

top (G5, G8). This way, she acknowledges their earlier contributions. Teemu, Sanni, and Janina all

express agreement (G4, G6, G7, G9, G10). In the following minutes, no opposition emerges, as the

new idea accommodates the divergent views that were argued upon earlier. The group continues to

collaboratively co-construct the idea of using Legos.
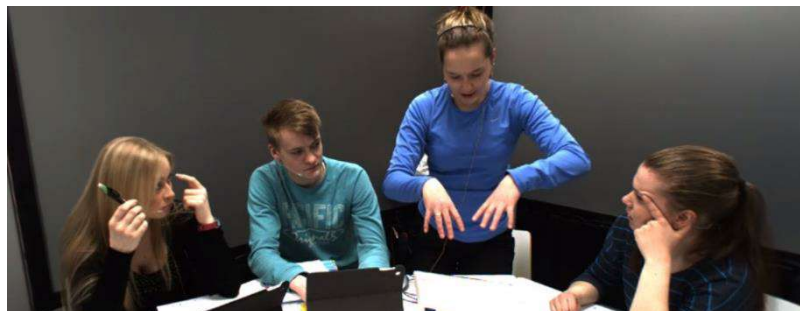
Picture 7. Minna explains her new proposal.

Example G.

G1. Minna: But hey if (.) an idea came that if we now jump from the <u>yard</u> thing to that (0.7) they would (0.7) get to perceive that bird's-eye perspective in that way that they would for example in a group build a thingy with Legos (.) like this ((gazes ahead, gestures an object on the table)) (0.5) some yard they wouldn't be told anything at first (.) it would just be told that build some (0.7) building and a yard ((gestures an area on the table, gazes mostly at Sanni))

G2. Sanni: [mm] ((gazes down))

G3. Minna: (.) [and] then they (0.5) get up ((gets up)) and look from this direction ((points downward with her hands toward an imaginary Lego construction, Picture 7)) and try to (0.5) perceive that <u>construction</u> on paper ((sits down and gazes at Sanni)) (.) so there would come then like

G4. ((Sanni nods))

G5. Minna: (.) that they see it also like this ((gestures a view from the side)) but they can also look at it like this ((gestures a view from up above, turns her gaze to Sanni))

G6. Sanni: Yeah well [yeah] ((gazes at Minna))

G7. Teemu: [Yeah it could]

G8. Minna. So ther- there they could like perceive better (.) in what way it is illustrated for example if there is some building [or something] else ((turns her gaze to Sanni))

G9. Janina: [Yeah] (0.5) True ((gazes at Minna))

G10.   Sanni: Alright ((gazes at Minna))

Summary. Three elements were considered to be of great importance for the group to sustain a favorable socio-emotional climate. First, tentativeness was observed nearly every time the students presented claims. For example, the students hedged their opinions with linguistics markers (conditional, discourse markers), signs of hesitation or reflection (reflective gaze, slowed tempo), or explicitly noting that they were stating a personal opinion. These means allowed the students to keep their claims open for consideration. Second, the students showed consideration of divergent claims. This was seen, for example, in how Minna tried to accommodate the critical feedback given by Sanni and how Sanni tried to seek a better understanding of Minna's proposal. Both Sanni and Minna indicated attunement to one another, though their views were conflicting. Sometimes consideration of divergent claims was shown by explicitly stating a willingness to accept other ideas or by acknowledging a claim before expressing disagreement. These characteristics conveyed respect, but also the ability to deliberate between perspectives. Third, the interaction included elements of occasional tension relaxation, which eased the tension created by the deepening of argumentation. This occurred, for example, in moments when Sanni tried to understand Minna's proposal better, when Sanni conceded to others' views, and when Minna lightened the atmosphere with humor. However, a degree of tension remained as the group did not direct the topic of

discussion away from argumentation or resort to quick consensus seeking. Thus, the group could persistently argue while also attending to the socio-emotional climate.

Discussion

This study examined how Finnish student teachers strike a balance of engaging in high-level cognitive processes—namely argumentation—while sustaining favorable socio-emotional processes in collaborative learning interaction in environmental science. The first phase of the two-fold analysis broadly investigated the frequency of argumentation and the quality of socio-emotional processes among five groups of students. Our findings indicate that the groups sustained favorable socio-emotional processes, but mostly failed to engage in argumentation. Thus, the students generally refrained from critical discussions and accepted each other's claims as such or conceded to divergent claims without argumentation. The findings suggest that spontaneous argumentation can be scarce even when the pedagogical design tasks could have given rise to reasoning and when students are familiar with each other and collaborative learning as a pedagogical practice. The results support studies showing that students tend to shy away from argumentative exchanges (Saab, Van Joolingen, & Van Hout-Wolters, 2005) and settle for quick consensus building (Weinberger & Fischer, 2006). As noted by Andriessen, Pardijs, and Baker (2013), the challenging nature of argumentation may cause students to attend to socio-emotional processes at the expense of cognitive ones. In addition, students may set learning goals for themselves that emphasize task completion, rather than finding the best solution through reasoning (Rogat, Linnenbrink-Garcia, & DiDonato, 2013). As argued by Kuhn (2009, 2010), students may not be inclined to argue, because they do not fully understand or appreciate its value.

The scarcity of argumentation in the corpus of the current study is worrying, since both critical thinking and collaboration are considered 21st century learning skills (Binkley et al., 2012). These skills need to be developed at all levels of education and especially in teacher education so

that future teachers can successfully teach these skills to their pupils (Häkkinen et al., 2017). The results imply that whenever educational objectives seek to induce reasoning, it may be necessary that argumentation is explicitly prompted or instructed (Andriessen & Baker, 2014; Asterhan & Schwarz, 2016; Stegmann, Wecker, Weinberger, & Fischer, 2012; Stegmann, Weinberger, & Fischer, 2007). However, traditional debate settings or simple instructions to argue may not be ideal for learning. Tasks goals that lead to persuasion and dispute rather than deliberation can impede the quality of argumentative discourse and subsequent learning outcomes (Asterhan & Schwarz, 2016; Felton et al., 2009, 2015). Thus, arguing for learning should be aimed at promoting argumentation, which is critical yet collaborative in nature. Such argumentation presupposes that groups strike a balance of engaging in deep-level joint thinking while sustaining a favorable socio-emotional climate for collaboration. To explore how this happens in spontaneously emerging argumentation, the second phase of our two-fold analysis zoomed in on the interaction in a case group that showed evidence of favorable socio-emotional processes, but also the most argumentation. An illustrative episode of argumentation was examined. Three elements were considered the most important for the case group to maintain a favorable socio-emotional climate during argumentation: tentativeness of claims, consideration of others' claims, and moderate tension relaxation.

Tentativeness of claims manifested as frequent uses of hedging (Lakoff, 1972). Hedges were incorporated in argumentative claims with explicit statements of uncertainty, but also in more subtle communicative ways, such as conditional clauses, questions, discourse markers (e.g., *for example*, *quite*, *perhaps*, *kind of*), and reflective gaze or tone. Our observations connect to Conlin's (2012) findings about the use of epistemic distancing in collaborative physics learning. His micro-level discourse analysis of collaborative learning revealed that students distanced themselves from their claims through discursive means, such as hedging. This helped the students manage the cognitive and emotional tensions in their collaboration and made them better able to find a safe space for collaborative sense making. This is in line with the findings of Damsa, Ludvigsen, and

Andriessen (2013), who saw that a case group of higher education students was able to foster an argumentative dialogue through tentativeness of opinions and an informal conversation style. Hedging was also mentioned by Asterhan (2013) as a way for students to reduce ego and preserve face. In the current study, the tentativeness of the students' claims made the students' suggestions open for consideration and preserved the students' face (Brown & Levinson, 1987). This helped the group sustain socio-emotional processes where no student imposed their proposals on the group. Thus, the interaction was negotiable, which is a central feature of collaborative interaction (Dillenbourg, 1999).

Consideration of divergent claims was seen in how students acknowledged and expressed attunement to opposing claims through back-channeling and referencing as well as gesturing, nodding, and an attentive gaze (Allwood et al., 1993; Clark & Schaefer, 1989). Students also conceded to or appraised claims before expressing disagreement, explicitly stated openness to other ideas, tried to seek understanding of others' proposals, and integrated elements of opposing proposals into new reformulations of claims. Similar characteristics were reported in the study of Damsa, Ludvigsen, and Andriessen (2013), who noted that students with high-quality argumentation built on others' suggestions even when they were conflicting with their own ideas. Andriessen, Pardijs, and Baker (2013) also found that the most fruitful reasoning for learning occurred in a group of secondary school boys when the students clearly showed recognition of each other's ideas. This connects to Barron's (2003) and Sampson and Clark's (2011) findings that more successful student groups were more active in responding to and discussing ideas rather than rejecting or ignoring them. In all, the evidence highlights that the students in the case example were capable of deliberation as opposed to dispute or simple consensus seeking. As argued by Felton et al. (2009, 2015), deliberative argumentation necessitates that learners arrive at a shared viewpoint by comparing and evaluating alternatives, rather than trying only to defend their own viewpoint or attacking others' viewpoints. The ability to deliberate, in turn, fostered mutual respect among the

learners and created safety for arguing. The evidence of the present study implies that the case group, unlike most other groups in the dataset, established norms of interaction that emphasized the need to reason, rather than to simply accept claims (Kuhn, Zillmer, Crowell, & Zavala, 2013).

Tension relaxation was evidenced as occasional consensus-seeking, moments of seeking understanding before deepening argumentation, and signs of positive socio-emotional interaction, such as humor and appraisal, which emerged within the group's argumentative dialogue. Tension relaxation during argumentation occurred after moments where a difference of opinion had emerged and, thus, the tension had intensified (evidenced by, e.g., sighing). The moments of tension relaxation, in turn, were accompanied by less critical stances, such as asking a peer for more information instead of arguing against them. This is in line with Andriessen, Baker, and Van der Puil's (2011) suggestion that tension relaxation enables groups to ease tension in order to save face and maintain a collaborative climate while arguing. However, it was also evident that the case group in the present study did not use tension relaxation excessively, which could have inhibited argumentation if the group had avoided critical discussion and simply resorted to consensus-seeking with little tension building elements (Andriessen et al., 2013). Rather, the group's argumentation evidenced the group's ability to keep up an argumentative dialogue while moderating it with positive interactions and brief moments of more consensual agreement seeking and information seeking. The argumentation could be kept up even while relaxing possible tension, for example, when one of the case group members used humor to lighten the atmosphere while still persisting with her idea. Thus, tension relaxation could be embedded within argumentation as a way to continue arguing while sustaining a favorable socio-emotional climate. This reflects Schwartz's and Shahar's (2017) idea of balanced cohabitation of the dialectic and the dialogic characters in classroom talk. The fact that students did not rush into consensus may have been afforded by the group's previous interactions, where a safe social climate had already been established (Arvaja et al., 2002), and norms that fostered reasoning over consensus (Kuhn et al., 2013). Furthermore, the

group members' tentativeness in argumentative claims may have toned down the emotional

positioning of stated arguments (Polo et al., 2016). This was also evidenced by the generally relaxed

tone of voice and few increases in vocal intensity, which indicated that emotions did not overtly

flare (Bachorowski, 1999). Consequently, the group did not need to excessively counterbalance the

intensity of arguments with tension relaxation.

In sum, the interaction in the case episode was characterized by neither consensus-seeking

nor dispute. Instead, students attended to favorable socio-emotional processes during argumentation

with a wide set of communicative means, which allowed students to critique while communicating

their claims as suggestions and acknowledging others' contributions. The students could, thus,

maintain politeness and face by not imposing their claims and by making others feel respected

(Brown & Levinson, 1987; Muntigl & Turnbull, 1998). The interaction opened a space for

exploring options and led to a new idea grounded in the argumentative discussion. Overall, the

group's interaction exemplified deliberative (Asterhan & Schwarz, 2016; Felton et al., 2009, 2015)

and collaborative argumentation (Andriessen & Baker, 2014), which created and maintained a

balanced emotional framing of the debate (Polo et al., 2016). As a result, the group could persist in

arguing and ultimately find a solution that reconciled the divergent opinions.

Conclusions

The results of this study illustrate how both cognitive and socio-emotional processes are

intertwined and interdependently embedded in argumentation. Engaging in high-level cognitive

processes—namely argumentation—and sustaining favorable socio-emotional processes are not

separate elements of productive collaborative learning interaction but indeed intertwined in how

argumentation is expressed in a negotiable and respectful way. However, the scarcity of interaction

where the ability to engage in cohesive and respectful interactions is accompanied with truly critical

reasoning suggests that students may not have the necessary motivation or skills for striking this

balance. It is unlikely that the problem relates only to cognitive processes or capabilities, even though these are typically targeted when studying and promoting argumentation (Asterhan, 2013). Rather, it is likely that the problem is equally rooted in students' ability or will to endure and moderate raised socio-emotional tension that accompanies argumentation; in other words, the ability or will to find the optimal general emotional framing for arguing (Polo et al., 2016).

The results of this study suggest that educators, researchers, and designers of educational tools should pay more attention to the socio-emotional processes of arguing (Andriessen & Baker, 2014). To understand and promote argumentation in collaborative learning as a multidimensional phenomenon, it is not enough to focus on the number or depth of argumentative claims and neglect to examine the socio-emotional climate in collaborative groups, the variety of ways in which claims are expressed, and the functions that students' interactions serve in the social context. Teachers should especially pay attention to the goals of collaborative learning if they wish to promote learning through collaborative argumentation. For example, task instructions and goal setting can guide students to aim for the emergence of mutual understanding through joint reasoning rather than simply directing students to come to an agreement or eliciting competition among the students (Asterhan, 2013; Asterhan & Schwarz, 2016). Furthermore, students' competence in collaborative argumentation could be enhanced by developing pedagogical methods for the explicit teaching and practice of the communicative means of arguing respectfully and politely. In today's digital world, argumentation can be also scripted or prompted with the use of various technologies (e.g. Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2013; Stegmann, Wecker, Weinberger, & Fischer, 2012; Tsovaltzi, Judele, Puhl, & Weinberger, 2017). However, to date, the scripts and prompts for argumentation rarely account for the socio-emotional processes of collaborative learning.

There is more to learn about the role that socio-emotional processes play in the temporal progress, depth, and type of argumentation in collaborative learning. Experimental studies can provide insight into the influence of controlled variables, but studies are also needed from authentic,

"messy" learning situations that depict the complexity of cognitive and socio-emotional processes in collaborative learning. In future studies, outcome measures should be considered to examine how the socio-emotional processes intertwined with argumentation influence learning performance. Future studies are also needed to explore forms of data where evidence does not rely solely on students' or researchers' interpretations. For example, the current study was limited by the fact that the analysis was mostly based on the observational analysis of interaction that is only an overt manifestation of cognitive and socio-emotional processes. Interaction data could be complemented by other data sources, which could reveal more about how learners experienced the collaborative learning interaction. For instance, physiological measures could tell more about the fluctuation of tension and tension relaxation in students' dialogue, and eye-tracking or gesture recognition could provide more detailed information about the multimodal elements of reasoning (Järvelä, Malmberg, Sobocinski, Haataja, & Kirschner, submitted).

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Appendix 1. Used transcription notations based on Jefferson system of transcription.

(.)	A short but noticeable pause
(0.8)	A timed pause (≥ 0.5 s)
[ ]	Overlapping speech
> <	The pace of the speech has quickened
< >	The pace of the speech has slowed down
( )	Unclear speech
(( ))	Contextual information, e.g. gestures.
word	A raise in volume or emphasis
°word°	Quiet voice
wo(h)rd	Laughter within the talk
::	Elongated speech, a stretched sound