Unpacking Socio-Metacognitive Sense-Making Patterns to Support Collaborative Discourse

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Abstract: This study explores the dynamics between socio-metacognitive communication patterns and collaborative processes, as students engage in collaborative discussions about course concepts. Building upon a series of studies that aimed to design and validate an intervention to help students develop collaborative competencies at the group level, the study aims to map how socio-metacognitive sense-making patterns are associated with the collaboration quality, by comparing the patterns for low, medium, and high performing teams. Discussion and after-discussion reflection transcripts of 12 teams over five sessions were analyzed and assessed, using previously developed collaborative discourse rubric and sense-making coding construct. The results showed a significant correlation between frequency of sense-making acts and the quality of the collaborative discourse.

Introduction

Collaborative competencies are essential sets of skills for society and it is vital to identify strategies and approaches to nurture them in learners. Unfortunately, many learners do not have the opportunities to develop collaborative competencies, which can lead to poor performance outcomes and undesirable group conflicts (Borge & Carroll., 2014; Fischer et al., 2013; Kozlowski & Ilgen, 2006). In addition to individual problems associated with underdeveloped collaborative skills, in CSCL environments, group-level issues such as social loafing, sucker effect (Salomon & Globerson, 1989), lack of non-verbal expressions, and time lag between the interactions can contribute to lower quality collaboration (Kreijns, Kirschner, & Jochems, 2003). This is why helping learners engage in higher quality collaborative processes has been a central concern for CSCL. As such, many CSCL researchers have attempted to help students improve collaborative skills, but few have recognized the complex and nested nature of collaboration (Borge & White, 2016; Borge, Ong Shiou, & Rosé, 2018; Baker et al., 2007; Stahl, 2006).

Prior research has indicated that without any guidance, support, or training, students tend to demonstrate dysfunctional group processes (Borge at al., 2018; Barron, 2003; Hogan, 1999; Webb & Palincsar, 1996). To address this problem, existing studies have designed and evaluated interventions to support group function, including (1) scripting collaborative interactions, (2) helping students improve metacognitive sense-making through reflecting upon individual and group performances and comparing them to the models of competence, (3) supporting students to develop self- and group-regulatory behaviors, and so forth. However, there still are issues that need further investigation, such as what kind of scripting is needed, how to balance the level of scripting, when to fade the external support, and how to help groups internalize the external support (Borge & White, 2016; Hogan, 1999; Kozlowski, Watola, Jensen, Kim, & Botero, 2009).

Building upon the critical role that self-regulation plays in individual's learning (Zimmerman & Schunk, 2001), Borge et al.'s (2018) suggested that metacognitive guidance and regulation at the group level can serve to help students optimize their collaborative experiences. They referred to collective awareness of and the collective ability to monitor and regulate the collaborative process as socio-metacognition. Borge et al.'s (2018) findings were promising, but also highlighted the need for further research on the development of socio-metacognitive expertise. Similarly, the scarcity of research on the interplay between socio-metacognitive process and collaborative discussion necessitates further exploration of their dynamics in CSCL context (Kwon, Liu, & Johnson, 2014; Rogat & Adams-Wiggins, 2015). This paper builds upon this existing literature and aims to extend what is known about collective regulation by identifying critical socio-metacognitive sense-making patterns in process-related dialogue acts in real-world collaborative learning contexts. Thus, we explored the dynamics between socio-metacognitive sense-making patterns and collaborative processes, as students engaged in collaborative discussions about course concepts.

Theoretical framework

Our work is influenced by the theory of group cognition and thus recognizes collaboration as a form of nested cognition that entails intersubjective knowledge construction and collective sense-making that are situated at different levels, including individual, group, and community levels (Stahl, 2006). Collaborative activities offer

sophisticated learning opportunities that might not be available in individual learning activities, which are likely to help learners meet the need in our society for higher collaborative competencies and to succeed in collaborative teams. However, problems often arise in collaborative activities, especially in terms of the collective sense-making processes (Barron, 2003). The collaborative discourse that occur during group interactions has a large influence on the group performance and outcome (Kozlowski & Ilgen, 2006; Stahl, 2006). Thus, the examination of communication patterns can help evaluate the quality of collaborative discourse.

Challenges for group regulation

Literature on self-regulation in individual learning has identified problems that pose barriers for learners to successfully regulate their own learning, such as not being aware of learning problems, misdiagnosing them, etc. (Winne & Nesbit, 2009). In collaborative contexts, these individual regulation problems arise alongside group regulation problems, where may teams fail to identify or accurately assess problematic processes and devise remediation strategies. There are also social and emotional difficulties involved in communicating problems and regulating group behaviors (Järvelä, & Hadwin, 2013). In each stage of regulating collaborative process, there is a requirement on building shared understanding through synthesizing information and idea negotiation (Stahl, 2006). We argue that in order for teams to engage in high-quality collaborative activities, they need to develop socio-metacognitive expertise: the knowledge of and ability to monitor and regulate collective cognitive processes.

Socio-metacognitive sense-making

As collective literature argues, engaging in high quality collaborative discussion is a hard but crucial skill to develop. Despite multiple complexities and interrelated variables to consider, research also suggested that learners can improve the quality of their collaborative activities over time, if they learn how to regulate their collaborative process (Borge et al., 2018; Kozlowski et al., 2009).

Collaborative interactions are the externalized forms of collective thinking, and thus, how teams collectively make sense of, monitor, and regulate these interactions play a central role in collaborative process. Recognizing the role of group regulation in collaborative activities, recent research efforts have been directed toward developing technological tools to support group regulation. As one of the pioneers of these efforts, Järvelä and Hadwin (2013) developed a technological tool to help learners develop awareness and planning strategies for their collaborative activities. However, developing awareness and planning is not sufficient for the regulation process; learners need to develop an understanding for how a high-quality collaborative discussion should be like, compare their process to a model, identify problems in their process, collectively develop or choose appropriate remedial strategies to solve problems, and take action (Nesbit, 2012; Winnie, & Nesbit, 2009). In group contexts, these steps demand both individual and collective efforts, attention, and time, which might be the reason why teams tend to neglect their collaborative process while reserving all the attention to make sense of the content (Kerr & Tindale, 2004). Collective sense-making of the collaborative process requires teams to monitor and reflect on their collaborative activity (Nesbit, 2012). However, research suggested that individuals do not perform well at asking and addressing these questions, and situation gets even intensified when sense-making moves from individual to group cognition (Gabelica et al., 2014).

In our previous work, we addressed problems associated with collective regulation and developed a theoretically informed technological intervention to help students develop their socio-metacognitive expertise. We identified the communication patterns associated with high quality collaborative discussion, proposed two core capacities for collaborative sense-making, and listed concrete patterns of communication associated with more or less optimal collaborative sense-making processes. We then helped students monitor and regulate their collaborative processes by guiding and constraining how they get prepared for discussion and how they engaged in socio-metacognitive sense-making and regulation after the discussion. The intervention succeeded in getting teams to improve the quality of their collaborative activity over time. However, we did not fully examine the dynamics between socio-metacognitive competence, collective sense-making, and the quality of the collaborative discussion. The collection of research on socio-metacognitive sense-making suggests that it is critical to identify how teams engage in socio-metacognitive sense-making and regulation of both course content and team process discourse, and how these interconnected processes may impact each other. To address this need, we aim to identify socio-metacognitive sense-making patterns in collaborative discussions and thus examined how these patterns are associated with team collaborative performance. Our research questions were:

(RQ1) What patterns of socio-metacognitive sense-making (SMS) talk do teams engage in when unpacking course content and thinking about their own discussion processes?

(RQ2) What are the differences in these patterns between low, medium, and high performing teams?

Methods

Course context and participants

The study was conducted in an online 16-week undergraduate course designed to introduce students to information science concepts. As part of the course, students were expected to engage in collaborative reasoning practices and discussion activities. Developing collaborative discussion skills was one main goal of the course. Participants were 34 online students who enrolled in the course (11 females, 33.3%; 22 males ,66.7%). Students' ages ranged from 25 to 44, and the majority of students were part-time students with full-time jobs.

Procedure

Students were assigned to 12 teams of three based on when they were available to meet. Due to two students dropping the class, two teams ended up as dyads. These teams were required to meet synchronously for five sessions to collectively make sense of course concepts. They met every other week for ten weeks. As a pre-discussion activity, the students were required to read the weekly readings and write an individual reflection in response to four higher-order questions about the readings. Then, they were asked to set a meeting time with their teammates to synchronously discuss the questions and readings. Each discussion session was about 90 minutes: 60-minute main discussion, 15-minute individual assessment of team discussion, and 15-minute collective planning discussion. These activities counted towards 25% of students' grades. For the 15-minute individual assessment of the team discussion that followed the 60-minute main discussion, students were provided with a collaborative process rubric detailing how to assess discussion quality, guides containing goals for collaboration, problems that interfered with good collaboration, and strategies for improving collaborative processes. The discussions were held on a computer supported collaborative discussion environment, and saved automatically in the system. After each individual scored their team's collective processes, the entire team was responsible for completing a collective planning session, where they discussed their scores and process weaknesses they identified during individual reflection for the purpose of collectively diagnosing problems and planning out strategies the team could use to improve in future sessions.

Research design and analysis

We implemented explanatory mixed methods (Creswell, 2015). The main discussions, individual reflections, and collective planning sessions were collected and analyzed for 12 teams across five sessions, following the verbal analyses guidelines offered by Chi (1997). We coded a total of 12,755 utterances, 10,764 from content-based discussions and 1,991from team planning sessions. All ethical guidelines were followed in collecting, analyzing, and reporting the study.

Evaluating teams' discourse quality

Building upon previous theoretical frameworks (Borge et al., 2018), teams' discourse quality, when teams work to collectively understand course content, is defined as the extent to which team members provide evidence of engaging in communication patterns associated with high-quality information synthesis and knowledge negotiation (see Table 1). The quality of teams' discussions was assessed by a research assistant with two years of communication analysis training, using a rubric developed by Borge et al., (2018), which measures two core capacities each with three categories of behavior (see Table 1). To score each item, the entire transcript is

Table 1: Summary of core capacities and categories of behavior associated with high quality collaborative communication behaviors from Borge et al. (2018).*

Core Capacities	Categories of Behavior	What is Examined in the Transcript
Information Synthesis	Verbal Equity	To what extent team members contributed equally.
	Developing Joint Understanding	To what extent team members make an effort to ensure that they fully understand the ideas.
	Joint Idea Building	To what extent team members elaborate on others' contributions.
Knowledge Negotiation	Exploration of Different Perspectives	To what extent teams present and discuss alternative perspectives.
	Quality of Claims	To what extent teams provide logical and fact-based evidence to their claim.
	Norms of Evaluation	To what extent teams adhere to social norms.

Note: * Each score ranging from 1 to 5 outlines a set of guidelines indicating what each score means for each category. For example, in Quality of claims, a score of five means "There are at least two examples where claims are supported by references to course readings or online content AND at least one example of weighing of options or examination of different perspectives." (Borge et al., 2018).

examined for specific discourse quality markers (see top of figure 1 for example) and these markers are used as a means to provide evidence for a score from 1 to 5 (see bottom of Figure 1). Scores for the six categories were summed to a single collaborative discussion quality score for each discussion. Once all the five main discussion scores were identified, they were averaged to produce the average collaboration performance of each team. The quality of the collaborative discussion was assessed using only the main discussion transcripts. 20% of the data were double coded by two trained students with extensive communication analysis experience. Significant agreement was reached, $r = .86$, $p < .001$; Kappa = .64, $p < .001$.

Session	Turn	User ID	Entry	Codes
1	29	86	He tries to balance his views with a pro for privacy violations, asserting that it may be used for national security. Do you agree with this implication?	DJU-1, JIB- 1
1	31	85	I apologize for the delay, I've been rereading your post, I'm not sure I understand what you mean. The author is pro privacy violation?	DJU- 1

Criteria	Score	Evidence
Joint Idea Building	4	I could not locate more than one instance [of JIB] where the participants extended or supported the original claim with additional information. The participants seemed to either skip to another subject very quickly or discuss an opinion over one or two turns.
Developing Joint Understanding	5	There are at least two instances where one participant made an effort to ensure s/he understood what the previous participant said. They used the following strategies: (DJU-1) Rewords another member's ideas to make sure s/he understands it; (DJU-2) Asks another member to explain an idea by elaborating further.

Figure 2. Two screenshots depicting how lines of transcript are examined for specific markers for developing joint understanding (DJU-1 represents first instance of DJU) and joint idea building (JIB-1 represents first instance of JIB) (top) and how these markers are used as evidence for discourse quality scores (bottom).

Analysis of socio-metacognitive sense-making (SMS) talk

The transcripts of main discussions and after-discussion collective reflection and planning sessions were analyzed for 12 teams across five sessions, for a total of 60 analyzed discussions. Socio-metacognitive sense-making is a specific type of process talk where students think about their collaborative processes to try to understand or modify them. To identify SMS talk, main discussions and reflection discussions were segmented into chat turns; then each turn was coded as process (P), content (C), or other (O). Inter-rater reliability for 20% initial coding was Kappa = .79, $p < .001$. The total frequency of P acts varied for each team. To compare teams' SMS behaviors, we calculated percentages of SMS talk out of P acts.

We used two versions of a socio-metacognitive sense-making coding scheme originally developed by Borge et al. (2018): the original version was used for reflections about the processes that occurred during their content-based discussion and a second version for the content-based discussion itself. Both original and modified rubrics are presented in Table 2. The original version was designed to code talk that occurred during reflection sessions to identify the extent to which teams engaged in socio-metacognitive sense-making activities during the reflective activity. It included process reporting, monitoring, reflecting, planning, and revising. Two trained coders

Table 2: Examples of SMS patterns by the participants

SMS Pattern	Rubric Version	Example
Reporting (RP)	Both rubrics	"*We sure covered a lot.*" (MD) A student reports her/his opinion about the collaboration quality without referring to concrete events or patterns from discussion or justifying her/his judgment.)
Process Monitoring (MO)	Both rubrics	"*and we also evaluated trade-offs for some while comparing implications."* (MD) (A student demonstrates evidence of paying attention to the ongoing collective process by pointing out a specific activity/requirement that the team has done or needs to do.)
Process Reflection (RF)	Both rubrics	"*I think the problem is that we read 2 different things."* (MD) (A student demonstrates evidence of reflecting on their ongoing collaborative discussion by pointing out a reason for why s/he thinks that particular incident happened.)
Process Planning (PL)	Original rubric	"*To begin, we definitely need to work on time management. Our communication skills are sufficient when it comes to the subject matter, but we definitely need to get tasks done with a sense of urgency.*" (AR) (A student demonstrates evidence of planning by unpacking the problem and proposing new goals.)
Regulation (R)	Modified rubric	"*Let me play devil's advocate, since we need to think about the other side of the coin."* (MD)

	(A student demonstrates evidence of regulating ongoing activity reminding teammates about previously set process goals.)

Note: MD=Main discussion, AR=After-discussion reflection.

coded 23% of the total reflective discussion data using the original construct, with Kappa = .806; p < .001. The coders discussed and resolved disagreements and then one coder re-coded all the reflection data. A second version of the coding construct was created to code SMS talk that occurred during the content-based discussion. This new version included all the previous forms of talk plus a new category: regulation talk. Regulation talk identified socio-metacognitive strategies, including moves such as proposing or using a discussion strategy from guides we provided. Inter-rater reliability was checked on this new version on 24% data with Kappa = .725; $p < .001$. Two coders discussed and resolved disagreements and then one coder re-coded all the main discussion data.

Selection of high, medium, and low performing teams

Average collaborative discussion quality scores were used to assess performance for each team (see Table 3). High, medium, and low performing categories each have four teams.

Table 3: Mean discussion quality scores of the teams (Lowest to Highest)

	Low Quality Discourse Teams				**Medium Quality Discourse Teams**				**High Quality Discourse Teams**			
	T9	T7	T1	T4	T3	T6	T8	T12	T5	T10	T11	T2
M	19.80	20.20	21.40	21.80	23.40	23.40	23.40	23.80	24.00	24.40	24.60	25.40
SD	3.56	4.15	3.36	3.42	2.88	2.51	3.97	2.59	3.32	1.52	3.65	3.21

Comparing team process interactions

We conducted one-way ANOVA to determine whether there was a significant difference in the average means of the amount of socio-metacognitive sense-making talk that occurred in low, medium, and high performing teams. For that, Levene's test for homogeneity of variances was found to be protected for the total percentage of SMS acts ($F(2,9)= 1.23$, $p=.34$). Shapiro-Wilk test was performed to ensure normality, and no significant value was identified; therefore, the normality assumption was met to perform ANOVA.

Findings

(RQ1) Patterns of socio-metacognitive sense-making (SMS) talk

On average, each team created 263.58 process-related turns over five discussion sessions, *SD*=120.75, *Min*=133, *Max*=521. Over half of these process-related turns, 54.54% (*SD*=13.03), were coded as SMS talk. Those that were not coded as SMS focused on sharing information about how they were using technology or other forms of social -off-task talk. All teams engaged in RP, MO, RF, and PL/R acts in at least one discussion session, but only 7 out of 12 teams demonstrated RV act (Table 4).

Table 4: The mean percentages of teams' SMS patterns

	Main Discussions		After-Discussion Reflections		Total	
	M (%) *	SD	M (%) **	SD	M (%) ***	SD
Reporting (RP)	2.65	4.96	18.37	14.65	11.52	5.06
Process Monitoring (MO)	12.27	4.77	8.45	7.34	10.39	4.76
Process Reflection (RF)	0.19	0.45	5.44	2.63	3.45	1.66
Process Planning/Regulation (PL/R)	43.93	11.05	15.14	11.96	28.64	9.71
Process Revising (RV)	0.58	1.15	0.45	0.67	0.54	0.62

Notes: * Mean frequency percentage out of the total P frequency in main discussions for each SMS pattern
** Mean frequency percentage out of the total P frequency in after-discussion reflections for each SMS pattern
*** Mean frequency percentage out of the total P frequency for each SMS pattern

The findings suggested that the teams engaged in PL/R act the most. In the main discussion these acts occur as regulation acts focused on proposing a discussion strategy or new direction for conversation, whereas in the after-discussion reflections these acts are planning acts focused on identifying a strength or weakness, or proposing and evaluating goals and strategies for future discussions. As shown in table 4, the high frequency of PL/R acts are due to the high number of regulation acts that occurred in the main discussions. For example, during the second discussion, a team was discussing whether all members understood the course content. One team member, Bill, stated that the content was new to them so they did not have full understanding of it. Upon hearing that Bill had specific questions, another member, Juan, said: "… we had some questions there, Bill, you can start" (R act in Main Discussion; Team 2, Session 2).

Figuring out how to discuss topics deeply, while keeping to an agreed upon time limit was a common topic discussed during the after-discussion reflection sessions. Team 2 discussed this topic as part of their reflection. Bill said, "Although we got very in depth, I feel like we could get just as in depth if we focus the conversation more and have strict time framing." Another member, Jill, added, "We need to figure out how to keep to the timeframe without cutting off something important" (PL Act, After-Discussion Reflection; Team 2, Session 2,). Juan then proposed a suggestion for improvement, "We can do anything! we will just have to weigh our questions maybe before we start the conversation and start there as a base." Bill responded by saying. "Right maybe ask the longer ones first" (PL Act, After-Discussion Reflection).

(RQ2) Differences between low, medium, and high-quality discourse teams

Looking at the relationship between SMS talks and team performance, when ranking teams by SMS acts, we saw that the frequency of SMS acts was closely tied to the quality of collaborative discourse (see table 5).

Table 5: Frequencies of teams' collaboration patterns (SMS Lowest to Highest for Each Performance Category)

	Low Quality Discourse Teams				**Medium Quality Discourse Teams**				**High Quality Discourse Teams**			
	T4	T7	T9	T1	T6	T8	T12	T3	T11	T5	T10	T2
P	348	365	196	217	142	133	247	200	216	521	166	412
SMS*	25.57	41.10	43.88	50.23	47.89	57.89	61.54	67.00	60.19	65.45	66.27	67.48

Notes: * Total frequency percentage out of the total P frequency for each team
P=Process-related talk, SMS=Socio-metacognitive sense-making talk, T=Teams

Comparing values on Table 5 with those on Table 3 (teams' mean discussion quality scores), we observed that low quality discourse teams tended to engage in least SMS acts while high quality discourse teams tended to engage in most SMS acts. However, as illustrated in Table 5, there were some exceptions. A Pearson correlation analysis on SMS percentage means and mean performances showed a strong positive correlation (r = .749, n = 12, p = .005). Analysis of variance showed a significant difference in the SMS percentage means between different quality discourse teams, $F(2,9)=10.66$, p=.00. Tukey HSD indicated a significant difference in SMS percentage means between low (M=40.20, SD=10.47) and high-quality discourse teams (M=64.85, SD=3.22), and between low (M=40.20, SD=10.47) and medium quality discourse teams (M=58.58, SD=8.05). No significant difference was found between medium and high-quality discourse teams.

We conducted one-way ANOVA to determine whether there is a significant difference in the five SMS patterns (n=5) between the low, medium, and high-quality discourse teams; no significant differences were found. However, descriptive analysis of the percentage values between teams yielded interesting trends. The average percentage of PL/R act increased from low (M=19.76, SD=5.12) to medium performing teams (M=32.09, SD=9.92), and from medium to high performing teams (M=34.09, SD=7.77). In RV act: low-performing teams engaged less (M=0.27, SD=0.31) than medium-performing teams (M=0.52, SD=0.37), who engaged less than high-performing teams (M=0.83, SD=0.98). The average percentage of RF act in low-performing teams was smaller (M=2.86, SD=1.21) than that of medium-performing teams (M=3.62, SD=2.65), which was smaller than that of high-performing teams (M=3.87, SD=0.91). Figure 2 below summarizes the distribution of the SMS acts by performance categories.

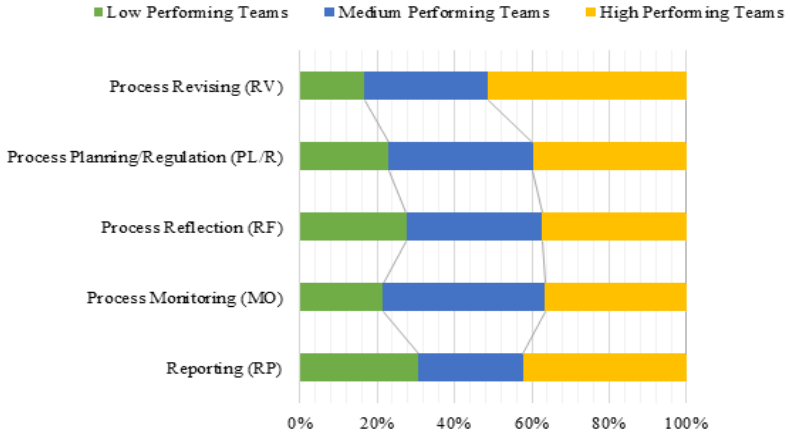

Figure 2. SMS percentage means of the teams by performance categories.

Discussion

In this paper we examined teams' sense-making patterns in the main content-based discussions and during after-discussion reflections, where teams made sense of their collaborative process. We also examined the relationship between sense-making patterns and collaborative discourse quality. Our findings showed that all the teams engaged in collective socio-metacognitive sensemaking (SMS) talk during content-based discussions and after-discussion reflections. Further supporting the design of the original intervention, which aimed at pushing students to engage in SMS talk as part of reflections for the purpose of getting them to figure out regulate activity during content-based talk and then actually regulate activity. We also found a strong positive correlation between the frequency of socio-metacognitive sense-making talk and the quality of collaborative activity.

These findings add to the growing body of research that indicate that supporting collective regulation of group interactions may be the key to enhancing the quality of collaborative processes (Kwon, Liu, & Johnson, 2014; Rogat & Adams-Wiggins, 2015). Prior research has suggested that students do not have the ability to monitor and regulate individual and collaborative activities (Borge & White, 2016; Kwon, Liu, & Johnson, 2014; Gabelica et al., 2014; Winne & Nesbit, 2009), and if not provided with sufficient amount of guidance, they will likely to develop dysfunctional collaborative habits (Borge et al., 2018; Kozlowski & Ilgen, 2006; Webb & Palincsar, 1996). The current study suggests that guiding students to develop sense-making skills to monitor and reflect their ongoing/past collaborative processes can help teams to developing sophisticated collaborative competencies. What is more, this work suggests it is possible to enhance collaborative processes without over-scripting collaboration as it occurs or creating inauthentic collaborative environments (Dillenbourg, 2002; Fischer et al., 2013). As such, this paper also extends what is known about the impacts of socio-metacognition on teams' ability to improve the quality of collaborative discussion processes.

Our findings imply that scripting socio-metacognitive sense-making activities before and after collaborative activity can help teams to regulate that ongoing collaborative activity, thereby developing socio-metacognitive competence and optimizing their ongoing collaborative activities. However, it also underlines the need for a more blended approach to scripting that supports collaborative process both during and after they occur. Nonetheless, it is crucial to note that further research is needed to support these findings and to explore how after-discussion reflection impact students' sense-making of their collaborative process, their socio-metacognitive development, and collaborative process improvement.

One limitation of this study is the low number of the groups for each quality discourse category. Further studies are needed to see if the patterns observed in the study remain once the number of observations increases. Furthermore, the focus of this study did not fully address impacts of emotions on social interactions, which were also prevalent forms of process-based talk. Building on our theoretical framework, collaboration emerges as a product of interactions among individuals (Stahl, 2006), which entails the exchange of ideas, knowledge, emotions, and feelings (Järvenoja & Järvelä, 2009). Thus, further research is needed to examine the dynamics between socio-metacognitive expertise, socio-emotional interactions, and the quality of collaborative discourse.

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