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REGULAR ARTICLE

Exploring College English Language Learners' Social Knowledge Construction and Socio-Emotional Interactions During Computer-Supported Collaborative Writing Activities

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Abstract Students' social knowledge construction and socio-emotional interactions in computer-supported collaborative learning (CSCL) are shaped by one another and work together to affect the group's learning performance. However, few studies have combined both social knowledge construction and socio-emotional interactions and examined how they contribute to improved learning performance. This study examines the dynamics of students' social knowledge construction and socio-emotional interactions in the context of computer-supported collaborative writing and compares six high- and six low-performing groups. Quantitative content analysis and sequential analysis were used to reveal the characteristics of groups' behaviour frequencies and patterns. The high-performing groups demonstrated more systematic and meaningful social knowledge construction and socio-emotional interaction patterns, while the low-performing groups only engaged in single repeated behaviours. It is worth noting that memes played different roles in the two groups.

Keywords CSCL · Social interaction · Social knowledge construction · Socio-emotional interaction

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Introduction

Collaborative learning has been widely used in daily teaching practice and is considered a promising learning approach. Effective collaborative learning not only helps promote deep learning and develops critical thinking skills but also provides opportunities for learners to develop their social skills and build social relationships with others (Garrison et al., 2001). Social interaction plays a core role in collaborative learning (Soller et al., 1999). The theory of social constructivism suggests that social knowledge construction, which is realised through social interaction, is a key element of collaborative learning (Driver et al., 2014). Previous studies have proven that active participation in social knowledge construction can positively promote learning outcomes (Wang, 2009). In addition to co-constructing knowledge, students express their emotions and motivation in social contexts, for example, through explicit encouragement or implied ways of communicating that can shape perceptions of individual emotions and a group's socio-emotional climate (Bakhtiar et al., 2018; Isohätälä et al., 2018). Such behaviours are conceptualised as socio-emotional interactions (Kreijns et al., 2003). Some research has indicated that socio-emotional interactions are closely related to learning (Richardson & Swan, 2003). Social knowledge construction and socio-emotional interactions, which are more cognitive or socio-emotional in nature, can be closely interrelated and dynamically affect one another (Isohätälä et al., 2019; Kreijns et al., 2003).

Although many studies have explored and highlighted the importance of social knowledge construction (Hou & Wu, 2011) and socio-emotional interactions (Bakhtiar et al., 2018) in collaborative learning, research considering both aspects has been limited. As these processes are interdependent and collectively impact collaborative

learning, scrutinising both can help us better understand students' learning in CSCL environments. Some researchers have called for studies that measure learning outcomes and examine how they are influenced by socio-emotional and cognitive interactions occurring during CSCL (Isohätälä et al., 2019). Therefore, with the current study, we attempt to provide a more comprehensive account of students' learning during CSCL by exploring how students in high- and low-performing groups participate in social knowledge construction and socio-emotional interactions.

Literature Review

Social Knowledge Construction in CSCL

The theory of social knowledge construction states that knowledge is created through social interactions between individuals who make collaborative efforts and share common goals (Gunawardena et al., 1997). Competence in social knowledge construction can influence how groups negotiate meaning, modify the proposed synthesis and reach a consensus, all of which are highly correlated with the quality of learning (Lin et al., 2016).

Previous studies of social knowledge construction in CSCL environments have shown that groups involved in higher levels of social knowledge construction exhibit successful outcomes (Hou & Wu, 2011; Lin et al., 2016). However, most studies have identified complexities and difficulties associated with students' capacity to engage in higher-level social knowledge construction (Gunawardena et al., 1997; Hou, 2011). Several other studies have examined sequential patterns to analyse social knowledge construction (e.g. Lin et al., 2016; Yang et al., 2018), and high-quality social knowledge interactions have been shown to exhibit systematic patterns and diversity. For example, Lin et al. (2016) compared processes of social knowledge construction among high- and low-performing teams engaged in online collaborative problem solving and found the high-performing teams to first focus on "identifying the different opinions of the participants" and then on "coming to an agreement." In contrast, low-performing teams only engaged in repetitive behaviours of sharing and comparing information. Through their study of online cooperative translation activities, Yang et al. (2018) similarly found low-engagement groups to only share information, while high-engagement groups also tended to negotiate and co-construct knowledge.

Studies on foreign language learners' co-construction of knowledge have been limited. In English language learning and teaching, there has been a call to relate dynamic peer interactions with online writing products to explore factors that affect group performance (Li, 2018). Thus, one focus of the current study is to examine English language learners' participation in social knowledge construction in the context of computer-supported collaborative writing activities.

Socio-Emotional Interactions in Collaborative Learning

When examining students' learning in CSCL environments, restricting our attention to cognitive dimensions limits the scope of analyses (Kreijns et al., 2003). During the process of knowledge construction, students will experience a range of emotions that refers to affectively charged cognitions, feelings, moods, affect, and wellbeing (Boekaerts, 2011, p. 412). In collaborative learning, these emotions collectively contribute to groups' socio-emotional climate (Järvenoja & Järvelä, 2009, 2013). Compared with emotions that are more like an event, the socio-emotional climate is a persistent pattern of shared emotions and behaviours over an extended period (Bakhtiar et al., 2018). Socio-emotional interactions refer to the purposeful interchanges (often communication) among group members that shape perceptions of emotions and socio-emotional climate (Bakhtiar et al., 2018).

Socio-emotional interaction plays an important role in collaborative learning. It shapes group formation, group structures, and group dynamics (Kwon et al., 2014), significantly affecting learning outcomes (Kreijns et al., 2003). Previous studies have shown that positive socio-emotional interactions, including mutual respect, caring, and support, are associated with resolving conflicts and encouraging positive emotions and motivation. Negative socio-emotional interactions, such as overruling, rudeness, exclusion, undermining and insulting, can lead to negative emotions and have serious impacts on the overall quality of learning opportunities (Linnenbrink-Garcia et al., 2011; Näykki et al., 2014).

Due to the dynamic nature of collaborative processes and social interactions, some researchers have examined fluctuations in students' participation in socio-emotional interactions. For example, in comparing two groups reporting positive and negative group dynamics, Bakhtiar et al. (2018) found positive socio-emotional interactions dominated the good climate group's discussions in the initial planning phases and that these interactions were continuously reinforced over time. Kwon et al. (2014) similarly found strong collaborators to facilitate positive socio-emotional interactions in the early stages of collaboration and less skilled collaborators to support fewer socio-emotional interactions during projects. Another study conducted by Isohätälä et al. (2019) found an increase in socio-emotional interactions at key moments of

collaboration, such as during monitoring, when facing challenges, and evaluating group performance.

These process-oriented analyses provide us with a general account of how socio-emotional interactions unfold throughout collaboration. However, an in-depth analysis of behavioural patterns of socio-emotional interactions is lacking. This type of analysis could facilitate better understanding of the features, patterns and limitations of socio-emotional interaction in CSCL environments.

Maintaining Balance Between Social Knowledge Construction and Socio-Emotional Interactions

In collaboration, cognitive and socio-emotional processes are closely intertwined and shaped by one another through social interaction. This suggests that the emergence of high-quality social knowledge construction is inseparable from a positive socio-emotional climate (Andriessen et al., 2011), such as an environment where group members allow divergence and support each other. However, when students are engaged in a high-quality cognitive process such as a critical discussion of divergent viewpoints, intense reactions spurred by cognitive challenges may create socio-emotional pressure (Asterhan & Babichenko, 2015). For example, Andriessen et al. (2011) pointed out that socio-emotional pressure increases when students engage in questioning, counterclaiming, or persisting during argumentation. Besides, high-level cognitive interactions that are emotional (e.g. argumentation; Polo et al., 2016) are sometimes accompanied by anxiety, impulsivity, nervousness or other affective reactions (Martinovski & Mao, 2009).

Ideally, as a natural and even fruitful part of cognitively challenging social knowledge construction, socio-emotional pressure and negative emotions can promote group progress. However, they may also threaten the groups' socio-emotional climate when not handled properly. In some cases, these pressures trigger negative socio-emotional interactions in groups, such as being too critical and impolite rejection, which in turn causes an unfavourable socio-emotional group climate for further social knowledge construction. In contrast, some groups were found to limit reasoning and instead turn to off-task discussions, consensus building, uncritical negotiation (Andriessen et al., 2013) and a de-emphasis of on-task engagement (Näykki et al., 2014) to release pressure and enforce group solidarity. However, avoiding emotional pressure by sidestepping critical discussion and quickly reaching agreement also causes collaborative learning to lose its meaning and learners to miss out on learning opportunities (Andriessen et al., 2013).

Thus, effective collaborative learning requires that students engage in high-quality social knowledge construction and participate in positive socio-emotional interactions. The present work examines high- and low-performing groups' participation in social knowledge construction and socio-emotional interactions in computer-supported collaborative writing activities. This study is guided by the following two research questions:

(1) How do the proportions of social knowledge construction and socio-emotional interactions differ between high- and low-performing groups?
(2) How do the sequential patterns of social knowledge construction and socio-emotional interactions differ between high- and low-performing groups?

Methods

Participants

Participants were undergraduates (19–20 years of age) from a compulsory English course. After being informed about this teaching experiment's process and purpose, 88 students (61 males) volunteered to participate and were divided into 22 groups. We had at least one female in each group (17 groups with 1 female; 5 groups with 2 females). Most of the participants were majoring in computer science, telecommunications, and electronic information science. Before entering the university, the participants in this study had received 6 years of formal English language learning experience in high school guided by a nationally unified curriculum standard. They all shared a similar proficiency level and were enrolled in the same English course at one university. All participants had no experience of online discussions for learning purposes.

Learning Activity and Procedure

This study was carried out in a compulsory English course taught by the English department of a university in Beijing, China. A main objective of this course was to promote students' English essay writing abilities. Students were divided into groups of 3 to 4 members to jointly write an essay on the topic of "Globalisation Threat or Opportunity?" Students needed to consider the following three points in their writing: (a) Analyse the trend of globalisation. (b) Explain what China should do to take advantage of globalisation, and (c) Discuss what college students should do in the context of globalisation. The students were required to use Wikispaces to co-edit their written text and use an instant messenger, Tencent QQ, for brainstorming, negotiating, and discussing ideas during the collaborative writing activity. The final version of their group Wiki page was considered the end product of their collaborative

writing. Before the writing activity, all students were trained in Wiki use and were encouraged to co-edit their writing text on the Wiki group page. The teaching assistant also joined the group chat room to provide them with technical assistance and support.

Students' writing was assessed by two teachers with rich experience of rating English writing assignments on four dimensions: content, structure and cohesion, language use, and writing norms. Each dimension was scored within a range from 1 to 5 (very poor, poor, average, good, excellent). These four dimensions of the rubrics used in this study were adapted from Cohen's (2005) analytic scoring scale (Online Appendix A) and have been widely used for assessing writing in previous studies (e.g. Machili et al., 2019). The rubrics have been useful in providing valid information about test takers' performance in different writing aspects (Cohen & Brooks-Carson, 2010).

Several procedures were used to ensure inter-rater reliability when evaluating student writing. First, test papers were assigned code numbers instead of students' names. The two raters had several meetings where they discussed grading criteria and agreed upon them. Next, the two raters conducted a trial grading and discussed discrepancies in the scores. Then the two raters independently graded 15% of the students' writing. The Spearman coefficient of the scores given by two raters was 0.761 ($p < 0.01$), indicating acceptable reliability in rating (Machili et al., 2019). The two raters discussed the divergence in grading. Finally, one rater completed the remainder of the grading work.

Coding Schemes

Based on the aims of this study, two coding schemes were applied to analyse the online discussion content. The Interaction Analysis Model (Online Appendix B) was used as a coding scheme for social knowledge construction. This model was originally developed by Gunawardena et al. (1997) based on online conference discussions. The model has been widely used in online collaborative learning to analyse learners' social knowledge construction behaviours (e.g. Hou & Wu, 2011; Lin et al., 2016).

The second coding scheme (Online Appendix C) examined the different types of socio-emotional interactions identified in several previous studies (Linnenbrink-Garcia et al., 2011; Näykki et al., 2014; Rogat & Adams-Wiggins, 2015). Text-based chats often involve the use of memes, which cannot be simply categorised as positive or negative socio-emotional interactions due to their rich meanings and contexts. Thus, we used a new code, "M1", to denote memes used in discussions. We adopt Milner's (2012, p.3) definition of the meme as "amateur media artefacts extensively remixed and recirculated by different participants on social media networks".

Data Coding

The unit for coding in this study was basically at the utterance level. For synchronous discussion via instant messaging tools, an utterance from the same student could extend across multiple lines of messages. Such messages were merged and coded as one utterance. These utterances were coded from the perspectives of both "knowledge construction" and "socio-emotional interaction". Social knowledge construction and socio-emotional interactions are not mutually exclusive; both can coexist in parallel, making it possible for codes to overlap. Examples of coding at the utterance level can be seen in Online Appendix D.

Two independent coders completed the coding work. After training, the two coders conducted a trial coding and discussed discrepancies. The two coders then formally coded 15% of the discussion content. Inter-rater reliability was judged by Cohen's Kappa that was computed as 0.92 and 0.81 for social knowledge construction and socio-emotional interactions. These kappa values were acceptable because the variables studied here involve a higher level of inference (Bakeman & Gottman, 1997). Finally, one coder completed the rest of the coding work.

Data Analysis

According to Kelley (1939), setting 27% as the grouping criteria for high/low scoring groups can achieve higher research validity and better discrimination. Many previous studies have adopted this grouping criterion (e.g. Hou, 2015; Su et al., 2018). From 22 groups in this study, there were 6 high-performance groups and 6 low-performance groups. The grades of both high- and low-performing groups' final writing products are reported in Online Appendix E. The Mann Whitney U test and GSEQ 5.1 were used with the high- and low-performing groups to explore differences in the percentages and sequential patterns for social knowledge construction and social-emotional interactions.

Result

Comparison of the Proportions of Social Knowledge Construction and Socio-Emotional Interactions Between the High- and Low-Performing Groups

Table 1 shows frequencies and percentages of students' social knowledge construction and socio-emotional interactions for the high- and low-performing groups.

For social knowledge construction, each individual code occurs more frequently in the high-performing groups.

Table 1 Frequency and percentage of students' social knowledge construction and socio-emotional interactions in high- and low-performing groups

	High-performing groups (N = 6)		Low-performing groups (N = 6)		*P*
	(F)	(%)	(F)	(%)	
Social knowledge construction					
Sharing and comparing information	276	8.47	215	10.39	.699
Discovering and contradictions between opinions	61	1.87	17	0.82	.004**
Meaning negotiation	907	27.83	275	13.29	.015*
Testing and modification of proposed synthesis or co-construction	135	4.14	39	1.88	.065
Agreement statement(s) or application of newly constructed meaning	118	3.62	13	0.63	.002**
Socio-emotional interactions					
Apologies	14	0.43	5	0.24	.041*
Humour/laughs	97	2.98	92	4.45	.485
Encouraging members' participation and motivation	321	9.85	132	6.38	.009**
Promoting trust and cohesion	89	2.73	28	1.35	.065
Total positive socio-emotional interactions	521	15.99	257	12.42	.041*
Combating member participation and motivation	12	0.37	76	3.67	.041*
Low cohesion	1	0.03	34	1.64	.002**
Exerting pressure on others	1	0.03	4	0.19	.240
Total negative socio-emotional interactions	14	0.43	114	5.51	.002**
Memes	134	4.11	164	7.93	.310

*$p < .05$; ** $p < .01$

Mann–Whitney *U* test results show that the high-performing groups engage significantly more in "discovering and analysing inconsistencies and contradictions between opinions" (SKC2), "meaning negotiation" (SKC3) and "agreement statement(s) or the application of newly constructed meanings" (SKC5), indicating that instead of staying at the initial stage of sharing and comparing information, high-performing groups show more high-level social knowledge construction.

Regarding socio-emotional interactions, Mann–Whitney *U* test results indicate that the high-performing groups show significantly higher percentages of total positive socio-emotional interactions and lower percentages of total negative socio-emotional interactions. Specifically, "apologies" (PSE1) and "encouraging members' participation and motivation" (PSE3) are significantly more common among the high-performing groups, while "combating member participation and motivation" (NSE1) and "low cohesion" (NSE2) are significantly more frequent in the low-performing groups. The use of humour/laughter (PSE2) and "memes" (M1) were much more prominent in the low-performing groups.

Table 2 Adjusted residuals (Z scores) for the high- and low-performing groups' social knowledge construction

	High-performing groups					Low-performing groups				
	SKC1	SKC2	SKC3	SKC4	SKC5	SKC1	SKC2	SKC3	SKC4	SKC5
SKC1	6.29*	− 0.43	− 2.23	− 0.46	− 4.16	3.56*	− 0.36	− 2.37	− 1.84	− 0.08
SKC2	− 3.44	0.99	4.29*	− 1.15	− 2.34	1.75	2.13*	− 2.15	− 1.15	0.99
SKC3	− 0.97	0.24	6.31*	− 4.46	− 5.46	− 2.61	− 0.64	5.70*	− 4.67	− 1.88
SKC4	− 2.27	0.22	− 7.36	9.05*	6.79*	− 2.28	− 0.15	− 4.27	12.76*	0.13
SKC5	− 2.42	− 0.78	− 3.6	− 0.05	10.60*	− 1.21	1.29	− 1.86	1.63	5.86*

*$p < .05$

Table 3 Adjusted residuals (Z scores) for the high- and low-performing groups' socio-emotional interactions

	High-performing groups								Low-performing groups							
	PSE1	PSE2	PSE3	PSE4	NSE1	NSE2	NSE3	M1	PSE1	PSE2	PSE3	PSE4	NSE1	NSE2	NSE3	M1
PSE1	− 0.56	− 0.79	− 0.94	0.14	− 0.51	− 0.15	− 0.15	2.14*	− 0.22	0.17	− 0.26	1.52	0.36	− 0.59	− 0.2	− 0.5
PSE2	1.51	4.4*	− 4.02	− 0.16	− 1.44	− 0.41	− 0.41	1.29	− 1.02	4.68*	− 2.32	− 1.38	− 1.01	0.07	− 0.92	0.12
PSE3	0.15	− 2.22	4.75*	− 0.98	0.14	1.04	1.04	− 3.45	1.83	− 2.28	5.43*	1.52	0.34	− 0.17	− 1.15	− 4.3
PSE4	− 1.46	− 0.16	0.38	2.68*	0.38	− 0.39	− 0.39	− 2.11	− 0.53	− 1.45	0.9	2.27*	− 0.57	0.16	− 0.47	− 0.2
NSE1	− 0.51	− 1.44	0.72	− 1.35	6.07*	− 0.14	− 0.14	− 0.3	0.38	− 1.29	− 0.49	0.66	3.99*	0.09	0.62	− 2.09
NSE2	− 0.15	− 0.41	1.04	− 0.39	− 0.14	− 0.04	− 0.04	− 0.5	− 0.58	0.15	− 0.93	− 1.38	− 0.38	5.04*	− 0.52	− 0.78
NSE3	− 0.15	− 0.41	− 0.96	− 0.39	− 0.14	− 0.04	− 0.04	1.99*	− 0.17	− 0.79	− 1	− 0.4	− 0.71	1.91	6.53*	0.12
M1	0.11	− 0.13	− 2.61	− 0.41	− 1.04	− 0.5	− 0.5	4.11*	− 0.53	− 0.01	− 2.54	− 1.42	− 1.99	− 2.87	0.83	6.09*

*$p < .05$

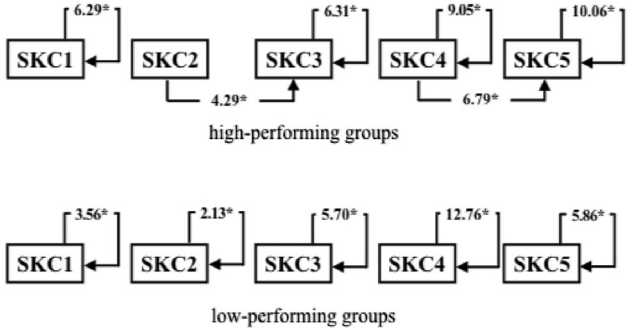

Fig. 1 Behavioural sequence of social knowledge construction of the high- and low-performing groups

Comparison of the Sequential Patterns of Social Knowledge Construction and Socio-Emotional Interactions between the High- and Low-Performing Groups

Z scores were computed to analyse sequential patterns of social knowledge construction and socio-emotional interactions for the high- and low- performing groups (Tables 2 and 3). A Z score of greater than 1.96 denotes that the sequence of a row and column is statistically significant ($p < 0.05$) (Bakeman & Gottman, 1997). Based on the Z scores, behavioural transition diagrams are displayed (Figs. 1, 2), where a single-headed arrow indicates a significant sequential relationship.

As shown in Fig. 1, a behavioural pattern from "Discovering and contradictions between opinions" to "Discovering and contradictions between opinions" (SKC2 → SKC2) (z = 2.13, $p < 0.05$) was found in the low-performing groups, indicating that students in those groups were often lost in repetitive behaviours of expressing and discovering contradictions rather than moving on to further meaning negotiation. The cognitive conflict could have been fruitful, but low-performing students failed to develop a deeper understanding from it. For high-performing groups, contradictions would stimulate them to further meaning negotiation (SKC2 → SKC3) (z = 4.29, $p < 0.05$). An example was when the group discussed examples of cultural globalisation in China. One student proposed that many Chinese students study abroad (e.g. "Going abroad for further study and returning to the country."). Another student disagreed with this point. He tried to seek understanding by asking for more detail, asking: "Is culture equal to knowledge?" He then presented his argument: "To gain knowledge abroad does not mean learning culture. So, I feel that studying abroad is somewhat biased for the topic of cultural globalisation, isn't it?" This illustrates how students in high-performing

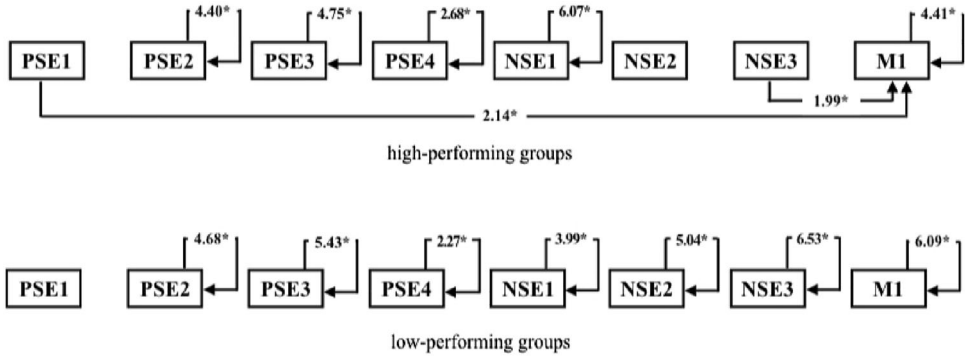

Fig. 2 Behavioural sequence of socio-emotional interactions of the high- and low-performing groups

groups made good use of cognitive conflict to develop deeper thinking.

Another significant behavioural pattern of "Testing and modification of proposed synthesis or co-construction" to "Agreement statement(s) or application of newly constructed meaning" (SKC4 → SKC5) ($z = 6.79$, $p < 0.05$) was identified in the high-performing groups. This pattern indicates that the high-performing students seemed to be more skilful online collaborators who tend to summarise the progress at each stage and try to achieve a phased consensus. For instance, after revising ("We can add one point—that college students cannot worship foreign culture blindly—into the third paragraph"), a student made a summary and sought consensus on the revised content within the group ("So that's all for the third paragraph. Does everyone think it's OK?").

Overall, low-performing groups often became lost in repeated behaviours of expressing and discovering contradictions rather than moving on to further meaning negotiation. In contrast, high-performing groups tended to achieve a phased consensus and move to high-level social knowledge construction.

Figure 2 illustrates the behavioural sequence of socio-emotional interaction of high- and low-performing groups. Two significant behaviour sequences were found in high-performing groups ("Apologies" → "Memes"; "Exerting pressure on others" → "Memes") ($z = 2.14$, $p < 0.05$; $z = 1.99$, $p < 0.05$, respectively). Two significant behaviour sequences in low-performance groups included "Low cohesion" → "Low cohesion" and "Exerting pressure on others" → "Exerting pressure on others") ($z = 5.04$, $p < 0.05$; $z = 6.53$, $p < 0.05$, respectively). These sequences indicate the remarkable differences in behavioural patterns for socio-emotional interactions across the groups.

First, the high-performing groups showed significant behavioural sequences from "Apologies" to "Memes" (PSE1-M1) ($z = 2.20$, $p < 0.05$) and from "Exerting pressure on others" to "Memes" (NSE3-M1) ($z = 2.14$, $p < 0.05$). This indicates that students in high-performing groups use a positive and relaxed way, such as using humourous memes to resolve the apologiser's guilt, ease embarrassment, and ensure negative socio-emotional interactions do not persist. For example, when a student missed the discussion and felt very guilty (e.g. "I'm really sorry, I didn't receive the message notification and I did not know that the discussion had started"), other group members used memes to tell her that it was not a problem, soothe her uneasy feelings and ease the atmosphere.

Next, the significant behavioural path from "Low cohesion" to "Low cohesion" (NSE2 → NSE2) ($z = 5.04$, $p < 0.05$) and from "Exerting pressure on others" to "Exerting pressure on others" ($z = 6.09$, $p < 0.05$) in the low-performing groups indicates that negative socio-emotional interactions persist in groups instead of being regulated and balanced. For instance, a student directly pointed out that another student's point of view was very boring: "But your point of 'college students should improve their self-innovation ability for the country' is so boring." This may have resulted in discouraging student participation. The student's response further implied the disunity of the group: "Fine, I can't catch up with you. Then there is no need to discuss and I'm going to take a break now." This may have adversely impacted the group's socio-emotional climate, ultimately hindering group progress.

Discussion

Our comparison between high- and low-performing groups indicates significant differences between the two groups in social knowledge construction and socio-emotional interactions. The high-performing groups did better than the lower-performing groups in balancing the social knowledge construction and socio-emotional interactions, which may distinguish the quality of the groups' final products.

The comparison of social knowledge construction in the high- and low-performing groups shows that the frequency of each individual code of high-performing groups was higher than that of low-performing groups, corresponding with Hou's (2011) finding that high-performing groups were more motivated to continue each discussion. Besides, high-performing groups outperformed low-performing groups in higher-level social knowledge construction, confirming results of previous studies showing that the higher the level of social knowledge construction achieved, the more likely groups are to be successful (Hou & Wu, 2011; Lin et al., 2016; Wang & Hwang, 2012). The finding of sequential analysis corroborates previous studies that high-performing groups engaged in more meaningful and systematic social knowledge construction (Lin et al., 2016; Yang et al., 2018). For example, among the high-performing groups, further negotiations were carried out when students identified inconsistencies (SKC2-SKC3). In contrast, students in the low-performing groups continued to express different opinions without proceeding to more advanced phases. Ideally, cognitive conflicts during social knowledge construction provide cognitive affordances for students (Andriessen et al., 2011; Polo et al., 2016) and encourage them to engage in deeper thinking and consider more comprehensive solutions (Van Knippenberg et al., 2004). However, low-performing groups lose this opportunity.

Regarding socio-emotional interactions, it was seen that positive socio-emotional interactions were much more frequent than negative socio-emotional interactions in both high- and low-performing groups, which is in line with Bakhtiar et al.'s (2018) results. Previous studies attribute this tendency to the fact that face-to-face work leads students to obey a code of politeness, which to some extent, constrains the development of interactions (Polo et al., 2016). Ayoko et al. (2012) pointed out that virtual teams, just like face-to-face teams, may encounter conflicts about cognition or group organisation. Teams tend to respond to these conflicts by communicating negatively, a finding consistent with our study. We also found negative socio-emotional interactions in the groups, with low-performing groups exhibiting such interactions nearly eight times more than the high-performing groups. Rogat and Linnenbrink-Garcia (2011) found that negative socio-emotional interactions will undermine the potential of regulation to facilitate content understanding and provoke significant off-task behaviour. Their observation may explain the low quality of the writing products of groups with more negative socio-emotional interactions.

Memes played different roles in the two groups. Few researchers have paid attention to memes in online discussions for learning purposes before; however, it is very common for young people to use memes in online communication. As essential speech acts, memes are used predominantly for humour and joking. However, they can also be used to communicate more serious messages, such as expressing opinions, conveying emotion, accusing someone, advancing an argument, apologising, suggesting or questioning (De la Rosa-Carrillo, 2015; Grundlingh, 2018; Milner, 2012). In this study, our content analysis of low-performing groups that used memes in an ongoing way shows that in most cases, funny memes were off-topic and sent for individual pleasure. This is in line with our finding that the low-performing groups engaged in more interactions focussed on "humour/laughter" (PSE2). Some superficial memes that generate individual pleasure inhibit adaptive learning outcomes. Therefore, the use of memes should be considered rationally and contextually.

Conclusions

This study extended previous research by linking both social knowledge construction and socio-emotional interactions to learning performance. Our findings stressed the value of both cognitive and socio-emotional aspects in collaborative learning. However, we cannot provide definite explanations for social knowledge construction and socio-emotional interactions observed among the high- and low-performing groups due to limited data collection. It is unclear, for instance, whether interpersonal factors influenced the students' online interactions. Future research could use more data collection tools such as questionnaires, interviews, eye-tracking technology, and facial expression recognition to better understand students' cognitive and socio-emotional responses. In addition, our relatively small sample of participants may have limited our observations. Future research could expand our sample or conduct studies in different learning settings.

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