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The effects of a group awareness tool on knowledge construction in computer-supported collaborative learning

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Abstract

The present study attempts to examine the effects of group awareness on knowledge construction and further surveys in what ways the different group awareness types support the collaboration in CSCL. In this quasi-experimental study, we adopted a self-developed group awareness tool that could display cognitive, social and behavioral group awareness in an authentic semester-long class with 93 undergraduates involved in. Using a mixed research method, we explored the effects of group awareness on knowledge construction by comparing the characteristics and behavioral patterns of knowledge construction between GA (with the GA tool) and NA (without the GA tool) classes and further examined the different role of three group awareness types in supporting collaboration through interviews. The content analysis indicated that GA groups centered their collaboration on negotiating meaning or constructing new knowledge (C3) and conducted more higher-level knowledge construction behaviors (C4 & C5) while in NA groups, sharing and comparing information (C1) appeared to be the most frequent behavior. The sequential analysis showed two distinctive sequential patterns, C4→C5 and C5→C4 in GA class and C2→C4 in NA class. The interview revealed that students thought cognitive and social group awareness played a major role in supporting their collaboration while unexpectedly, the behavioral group awareness was of little use. Finally, pedagogical implications were suggested.

KEYWORDS

computer-supported collaborative learning, group awareness, knowledge construction, learning support and guidance

INTRODUCTION

Knowledge construction refers to a process that emphasizes developing a new knowledge structure by building on each other's ideas (Janssen et al., 2009). Knowledge construction has been recognized as a crucial collaborative process contributing to individuals' learning and to high-productivity collaboration (Yücel & Usluel, 2016). While previous studies have claimed that students moving their collaboration to CSCL environments lack the necessary perception of other members and the group, such as, their presence, actions, task-related activities. Thus, they encounter more difficulties in building knowledge in CSCL environments (Janssen & Bodemer, 2013). Some researchers, therefore, proposed that group awareness may be helpful for students to construct new knowledge (Erkens & Bodemer, 2019). In CSCL, group awareness refers to various information about the group and group members, such as their current locations, activities, knowledge, interests or feelings (Bodemer & Dehler, 2011). Basically, there are three group awareness types being regarded crucial for effective collaboration, including cognitive, social and behavioral group awareness (Dehler et al., 2011). However, there is scarce empirical study examining the effects of group awareness on knowledge construction. Moreover, some researchers also proposed that the three group awareness types are equally important for knowledge construction (Cress & Kimmerle, 2013; Janssen et al., 2011). There is also little study exploring how the three types of group awareness support the knowledge construction differently. The present study attempts to address these issues by utilizing a self-developed group awareness tool that could visualize cognitive, social and behavioral group awareness. Using the quasi-experimental research method, we explore the effects of group awareness on knowledge construction and further survey their different role in supporting the collaborative process.

LITERATURE REVIEW

Knowledge construction in CSCL

Knowledge construction refers to a social and collective process in which learners exchange their own knowledge and build on new knowledge through interaction (Cress & Kimmerle, 2013). There are several models explaining the process of knowledge construction (Fischer et al., 2002; Garrison et al., 2001; Gunawardena et al., 1997). Gunawardena et al. (1997) proposed that there are five levels involved in knowledge construction: (C1) sharing and comparing information, (C2) exploring dissonance among ideals, (C3) negotiating meaning or constructing new knowledge, (C4) testing and modifying the co-construction and (C5) summarizing or applying new knowledge. C1 and C2 are the preliminary stages in which

Practitioner notes

What is already known about this topic

- Successful knowledge construction is regarded essential for both individuals' learning and high-quality collaboration in CSCL.
- Since students collaborating in CSCL environments lack necessary perception of peers and the group, they encounter more difficulties in building new knowledge.
- Some researchers proposed that group awareness might be helpful for students constructing knowledge because it could provide necessary information about group members and the group needed for successful knowledge construction. However, there is little empirical study exploring the effects of group awareness on knowledge construction.

What this paper adds

- Reveal the positive effects of group awareness on knowledge construction by comparing the characteristics and behavior patterns of knowledge construction in GA and NA classes.
- Indicate the distinct role the three group awareness types play in supporting knowledge construction.
- Unpack the mechanism of cognitive and social group awareness supporting the knowledge construction.

Implications for practice and/or policy

- Provide a starting place for adopting group awareness to improve learners' knowledge construction in CSCL.
- Based on the mechanism of group awareness, it might bring new ideas to designers and teachers to develop more kinds of GA tools or to better utilize it in real class.
- Teachers and curriculum designers may need to design and implement instructional programs to guide students pay equal emphasis on self and group members' participation.

students state their opinions, clarify the details, express agreement and explore the inconsistency (Roseli & Umar, 2015). C3 is the discussion, negotiation and formation of the new co-construction, which plays a vital role as a bridge connecting the lower level and higher level of knowledge construction (Yang et al., 2015). C4 and C5 represent the critical analysis of peers' opinions and the summarization or implication of the new knowledge (Roseli & Umar, 2015). Gunawardena et al. (1997) indicated C3, C4 and C5 are the higher level of knowledge construction and also the higher form of mental functions.

Knowledge construction is conceptualized essential for both individual and collaborative learning in CSCL (Wendell et al., 2019). For individual learners, they could expand their knowledge by exchanging, comparing and synthesizing ideas in discussion (Farrokhnia et al., 2019). In addition, learners could also acquire general skills, such as collaborative skills, through sharing and negotiating ideas with peers (Engelmann et al., 2009). For collective learning, researchers revealed that the higher level behaviors and behavioral patterns of knowledge construction are related to the high-engagement and high-quality collaboration (Yang et al., 2018). While students learning in CSCL, unlike face-to-face collaboration, lack necessary awareness of group members as well as the group, such as groups' social cohesion (Pifarré et al., 2014), learners' engagement (Janssen et al., 2011) and group members' knowledge level (Engelmann et al., 2009), they suffer more difficulties in building new knowledge (Pifarré et al., 2014). Therefore, more studies of promoting learners' awareness about group members and the group are needed to facilitate the knowledge construction.

The possibilities of group awareness in supporting knowledge construction

Group awareness is defined as “consciousness and information of various aspects of the group and its members” (Gross et al., 2005, p. 327), such as the group members' current locations, activities and knowledge (Bodemer & Dehler, 2011). Previous researchers have unpacked that group awareness could promote equal participation (Pifarré et al., 2014), support better coordination and regulation of group activities (Janssen et al., 2011) and facilitate better management of the diverse group mates' knowledge for achieving collaborative task (Dehler et al., 2011) in CSCL. Some researchers, therefore, proposed that group awareness could also support the knowledge construction by providing necessary information needed for collaboration (Cress & Kimmerle, 2013). However, there is limited empirical study exploring the effects of group awareness on knowledge construction.

Previous studies have identified three essential group awareness types for effective collaboration in CSCL, namely cognitive, social and behavioral group awareness (Bodemer & Dehler, 2011). For cognitive group awareness, it refers to the knowledge of group members (Engelmann et al., 2009). Cognitive group awareness is needed for knowledge construction because it could externalize learners' knowledge level and information processing while collaboratively solving problems (Cai & Gu, 2019). It could increase cognitive conflicts (Nickerson, 1999), prevent homogenization of ideas (Shin et al., 2018) and promote knowledge exchanging among group members (Engelmann et al., 2009). Social group awareness refers to the presence and social functioning, such as cooperativeness of groups (Bodemer & Dehler, 2011). Social group awareness is also conceptualized important for knowledge construction because it contributes to a better collaborative learning community (Kreijns et al., 2013) and a better social performance (Phielix et al., 2011). Previous research has indicated that students are deeper engaged in community knowledge building while they work in a group with better social cohesion (Hod & Katz, 2020). Behavioral group awareness comprises various learning activities that show learners' participation (Bodemer et al., 2018). Behavioral group awareness is similarly important for knowledge construction because it facilitates equal participation (Janssen et al., 2011) and promotes better coordination and regulation of group activities (Pifarré et al., 2014), which all play a vital role to engage students into constructing new knowledge (Leeuwen et al., 2014). Given the equal significance of the three group awareness types, some researchers claimed that multiple group awareness is needed to support multifaceted aspects of knowledge construction (Cress & Kimmerle, 2013). Nevertheless, there is scarce empirical study incorporating the three group awareness types to examine their effects on knowledge construction and further explore how the three types of group awareness support the knowledge construction differently. Besides, the guidance provided by group awareness is implicit (Bodemer, 2011) and the experimental intervention with the group awareness in previous studies was short, such as one class or 1 hour that may not be enough to make group awareness fully work on collaboration (Dehler et al., 2011).

Therefore, the current research attempts to address the abovementioned research gaps by adopting a self-developed tool that could display cognitive, social and behavioral group awareness to facilitate students' knowledge construction with an experimental period of one semester. This study utilizes a quasi-experimental method to address the following three questions:

1. What are the different characteristics of students' knowledge construction between experimental groups (with the GA tool) and control groups (without the GA tool)?
2. What are the differences in sequential patterns of learners' knowledge construction between experimental groups and control groups?
3. In what ways the three group awareness types support the knowledge construction?

METHODS

Participants and settings

This research involved 93 freshmen (approximately 19 ~ 20 years old) from the same university and they all participated in a semester-long "Information Processing Foundation" course, which was a general education course to cultivate information and scientific literacy of undergraduates of non-computer major. Most of the participants majored in educational technology, biological science, mathematics or physics. They were randomly arranged into the experimental class (GA class) and control class (NA class). A pretest of the domain knowledge level was conducted to all students and the independent sample *t* tests reported there was no significant difference in prior knowledge level between the NA and GA classes ($p = 0.82$, $p > 0.05$). The experimental class consisted of 8 groups of 43 students (Female = 31, Male = 12) and the control class consisted of 10 groups of 50 students (Female = 20, Male = 30), with 5–6 students in each group. Both classes conducted the collaborative discussion on the Moodle platform (Figure 1) while the experimental class was additionally provided a group awareness tool. Both classes were instructed by the same teacher and followed the same material and schedule. Neither class was informed of whether they were the experimental class or the control class.

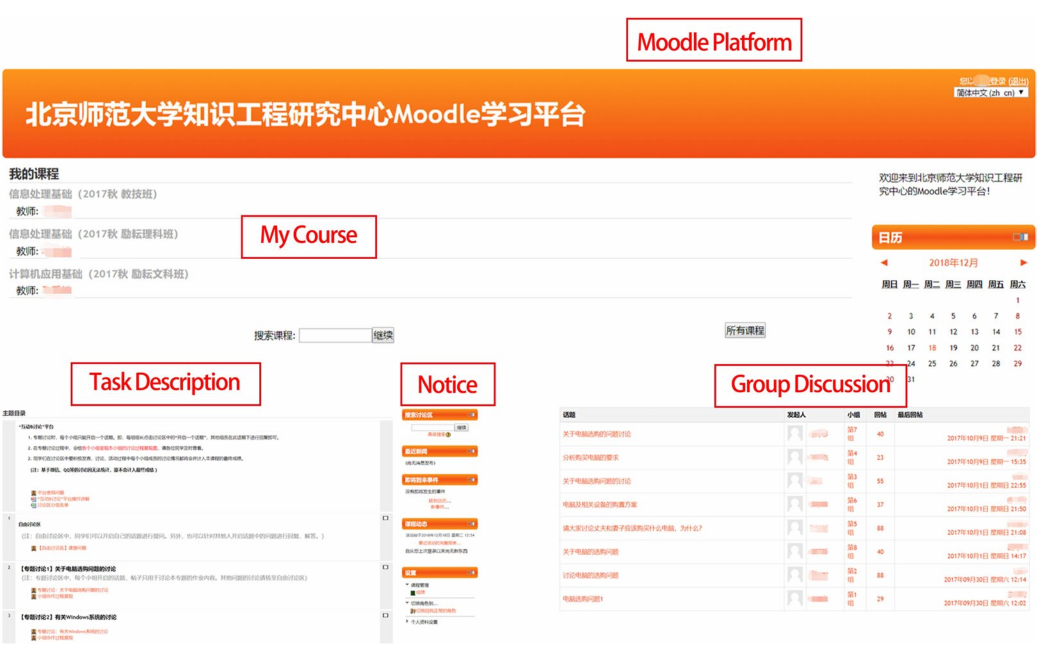


FIGURE 1 Moodle platform

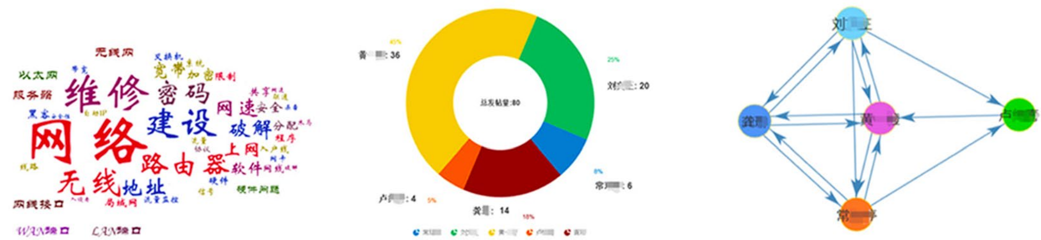
The learning analytics platform and the three types of group awareness

The group awareness tool used in this study is embedded in a self-developed learning analytics platform, which is seamlessly connected with Moodle's database so that we could utilize natural language processing to analyze students' collaborative discourses in the Moodle platform in real-time (Sullivan & Keith, 2019). The learning analytics platform was initially developed for automatically providing a real-time, in-depth understanding of students' mastery of domain knowledge for teachers (see previous research article of our team, Zheng et al., 2018). Afterwards, we continuedly developed the student-oriented group awareness tool, presenting cognitive, social and behavioral awareness information, on this platform. Thus, students in experimental groups (with the GA tool) needed to log in the Moodle platform to join collaborative discussions and meanwhile log in the learning analytics platform to obtain the group awareness information.

The group awareness tool could display the three types of group awareness. Cognitive group awareness was demonstrated by a tag cloud that revealed the high-frequent words mentioned in the collaborative discussions, by which students could explicitly capture the key points that have been discussed and its centrality. Behavioral group awareness was presented as the number and percentage of postings contributed by each member so that students could quickly perceive the participation and engagement of each learner. Social group awareness was illustrated by an interaction diagram that indicated interaction patterns (the student at the end of the arrow replied to the post of the student who started the arrow) and social cohesion within the group (Fincham et al., 2018), through which students could acknowledge the interpersonal and group's social performance (Figure 2). The tool presented group awareness in easy-to-understand graphs, allowing students to perceive the multiple group awareness in real-time and thus, identify their learning problems and adjust the collaboration timely.

Experimental procedure

The course lasted for 16 weeks and was designed for blended learning including weekly face-to-face lectures (sixteen times in all) and three online collaborative discussion activities, including “Computer Shopping,” “Windows System,” and “Computer Network.” Before the experiment, the researchers introduced the collaborative discussion activities to all students and trained them to use the Moodle platforms. Additional guidance for using the group awareness tool was provided to the experimental class. Prior to each activity, the teacher (the first author, with more than 10 years teaching experience) provided the specified



(1)Cognitive awareness information (2)Behavior awareness information (3)Social awareness information

FIGURE 2 Three types of group awareness

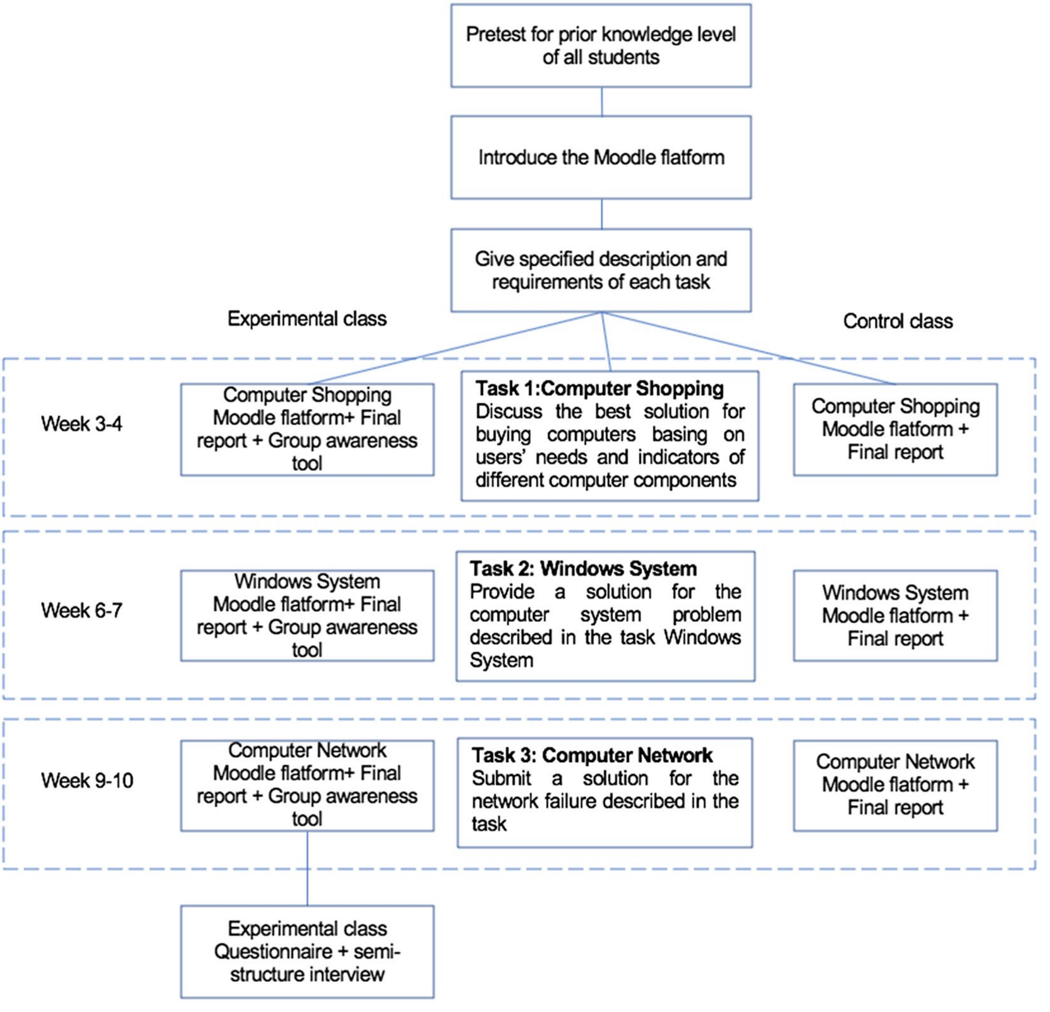


FIGURE 3 Experimental procedure

description and requirements to students and did not intervene afterwards. Students had 2 weeks to work collaboratively and form a final group report for each task. All groups could post ideas, discuss and form the final report on the Moodle platform with no time and space constraints within the 2 weeks. After completing the three activities, all students in GA class volunteered to answer the questionnaire regarding their acceptance of the GA tool. Sixteen students, with two randomly selected from each GA group participated in the semi-structure interview to further explore how the three types of group awareness support their collaboration (Figure 3).

Data collection and analysis

Data for this study came from multiple sources, including logs from the Moodle platform, questionnaires and semi-structure interviews. The questionnaire was originally developed by Davis et al. (1989) and revised for this study incorporating four dimensions, such as usefulness, ease of use, satisfaction and willingness for future use of the GA tool (Appendix A).

In semi-structure interview, students were asked questions, such as their motives for using the tool, how they used the three types of group awareness to improve their collaboration and how they valued the three types of group awareness.

An integration of content analysis and lag-sequential analysis was used to analyze the log data and explore the different characteristics and sequential patterns of knowledge construction between the GA and NA classes. There were 2325 valid logs generated in both classes across the three activities on Moodle. We adopted the Gunawardena et al. (1997) social knowledge construction coding scheme in this study, which is a widely accepted coding scheme for studying knowledge construction (Table 1). The analysis unit was thematic unit that may consist of several logs reflecting students' knowledge construction behaviors (Rourke et al., 1999). All students' logs were coded by two independent coders who received training of applying the coding schemes. After the two coders coded 15% of the logs, the Cohen's kappa coefficient was calculated and it was 0.904.

To further explore the different sequential patterns of knowledge construction between GA and NA classes, all the knowledge construction codes were chronologically arranged and imported into GSEQ 5.1, which has been widely used in many behavioral pattern studies to conduct lag sequential analysis (Su et al., 2018; Yang et al., 2015). In the sequential analysis, the frequency of each knowledge construction code immediately followed by another was calculated into the frequency transition table. Then, the adjusted residuals table (Z-score table) was inferred. According to Bakeman and Gottman (1997), if the Z-value of a sequence is greater than 1.96, the connectivity of this sequence reaches statistical significance ($p < 0.05$).

To further examine how the three group awareness types support students' knowledge construction, the interview transcripts were processed by thematic analysis to identify in students' perception, the core variables of group awareness supporting the knowledge construction.

RESULTS

The different characteristics of students' knowledge construction in GA and NA classes

Table 2 displays the frequency and distribution of each level of knowledge construction during the three activities. The frequency and percentage of C2 (exploring dissonance among ideals, 4.29, 7.75%), C3 (negotiating meaning or constructing new knowledge, 27.58, 49.81%), C4 (testing and modifying the co-construction, 0.50, 0.90%) and C5 (summarizing or applying new knowledge, 2.54, 4.59%) in GA groups are higher than that in NA groups (1.87, 5.62%; 10.20, 30.72%; 0.13, 0.40%; 1.47, 4.42%, respectively). While for C1 (sharing and comparing information), GA class (27.99%) performed much less than NA class (48.29%). These results indicate that GA groups demonstrated more higher-level knowledge construction, as negotiating meaning or constructing new knowledge (C3), testing or modifying the co-construction (C4) as well as summarizing or applying new knowledge (C5) while conducted less low-level behavior as sharing and comparing information (C1) than NA groups. Mann–Whitney U-tests were used to examine the differences between the GA and NA classes. The results indicate there are significant differences in the distribution of C1 ($u = 109.5$, $z = 4.361$, $p = 0.000 < 0.05$), C3 ($u = 111$, $z = 4.338$, $p = 0.000 < 0.05$), C2 ($u = 192.5$, $z = 2.962$, $p = 0.003 < 0.05$) and C4 ($u = 268$, $z = 2.364$, $p = 0.018 < 0.05$) while little differences in C5 ($u = 307.5$, $z = 0.914$, $p = 0.361 > 0.05$) and C6 (others, $u = 336$, $z = 0.421$, $p = 0.674 > 0.05$).

TABLE 1 The coding scheme for knowledge construction

Code	Phase	Description	Example
C1	Sharing/comparing information or proposing similar ideas	A statement of observation or opinion; a statement of agreement between participants	Husband requires a higher configuration of computer. CPU: The bigger the main frequency, the better. The larger the R&D algebra, the better
C2	Discovery and exploration of dissonance or inconsistency among participants	Identifying areas of disagreement; asking and answering questions to clarify disagreement	I agree with you very much, but we still have some problems: They have limited budget as 9,000 yuan to get two computers. How could we keep the balance? The need of wife is the basic text data processing. Is the high performance desktop necessary for her?
C3	Negotiation of meaning or co-construction of knowledge	Negotiating meanings of terms and negotiation of the relative weight to be used for various agreements	Regarding the first question, the different works of wife and husband determine that the requirements of the two computers are different, the price should be more aligned with the husband to ensure that the needs of the two are met to the greatest extent
C4	Testing and modification of proposed synthesis or co-construction	Testing the proposed new knowledge against existing cognitive schema, personal experiences or another source	I just checked out a mistake that the HP Pavilion 550-171on Jindong is ¥ 6629. Considering mistakes… we need to change the plan
C5	Agreement statement(s) or application of newly constructed meaning	Summarizing agreements and metacognitive statements that show new knowledge construction	According to everyone's discussion, our current plan is: The wife is Asus Scitron X205TA3735 costing 1900 yuan and the husband is HP Pavilion 550-171cn costing 6629 yuan
C6	Others	Messages irrelevant to the discussion task	We need to send the question to different posts and then reply separately

TABLE 2 The frequency and distribution of each level of knowledge construction

	GA class			NA class			Mann–Whitney *U*-test (Z)
	Mean	*SD*	Percentage	Mean	*SD*	Percentage	
C1	15.50	7.96	27.99%	16.03	9.69	48.29%	4.361*
C2	4.29	3.93	7.75%	1.87	3.38	5.62%	2.962*
C3	27.58	19.02	49.81%	10.20	13.26	30.72%	4.338*
C4	0.50	0.82	0.90%	0.13	0.50	0.40%	2.364*
C5	2.54	1.61	4.59%	1.47	0.81	4.42%	0.914
C6	4.96	4.25	8.95%	3.50	4.49	10.54%	0.421

*$p < 0.05$.

Moreover, in GA, class C3 (49.81%) is the most frequent behavior and accounts for almost half of all the knowledge construction behaviors. While in NA class C1 (48.29%) appears to be the most common knowledge construction behavior. These results indicate that GA groups' collaboration centered on discussing, negotiating and forming the new knowledge. However, contrast to GA groups, sharing and comparing information was the most frequently used behavior in NA groups.

Figure 4 demonstrates the changes in each level of knowledge construction across the three tasks. Overall, C2, C4, C5 and C6 perform little change. While C1 constantly increases in both classes as NA class (34.78%-57.46%-60.14%) enjoys a more dramatical rise than GA class (24.04%-27.02%-31.56%). For C3, it continually drops from 37.07%, 28.36% to 23.37% in NA class while enjoy an overall rise in GA class (46.15%-56.27%-48.38%). These results suggest that NA groups stayed progressively more in sharing and comparing information and less in negotiating meaning or constructing new knowledge. Contrarily, GA groups have continuously maintained a high proportion of discussion and a low percentage of sharing and comparing information.

The different sequential patterns of knowledge construction in GA and NA classes

The study further explores the differences between GA and NA classes by comparing their sequential patterns. Table 3 shows the frequency of each knowledge construction behavior that is immediately followed by another knowledge construction behavior (eg, in GA class, in row 2 column 1, the number 20 means that "C1 occurs immediately after C2," which happened 20 times). Figure 5 presents all the behavior transitions that are statistically significant in Table 4 (Z-scores > 1.96, $p < 0.05$). There are eight behavioral sequences that are statistically significant in the GA class (C1→C1, C2→C3, C3→C3, C4→C5, C5→C4, C5→C5, C5→C6, C6→C1) and five in the NA class (C1→C1, C2→C3, C2→C4, C3→C3, C5→C5). To explore the different sequential patterns of knowledge construction between GA and NA classes, we compared the statistically significant behavioral sequences between the two classes. The results indicate that both GA and NA classes have the behavioral sequences as C1→C1, C2→C3, C3→C3, C5→C5 and the differences lie in C4→C5, C5→C4, C5→C6, C6→C1 and C2→C4.

First, the significant behavioral path C2→C4 ($z = 3.71$, $p < 0.05$) in NA class indicates that when an inconsistent idea was proposed by a group member, sometimes other teammates may revise the plan or draw a conclusion directly without a necessary response or discussion on the disagreement. For example, "The assembled PC is really good, but the husband

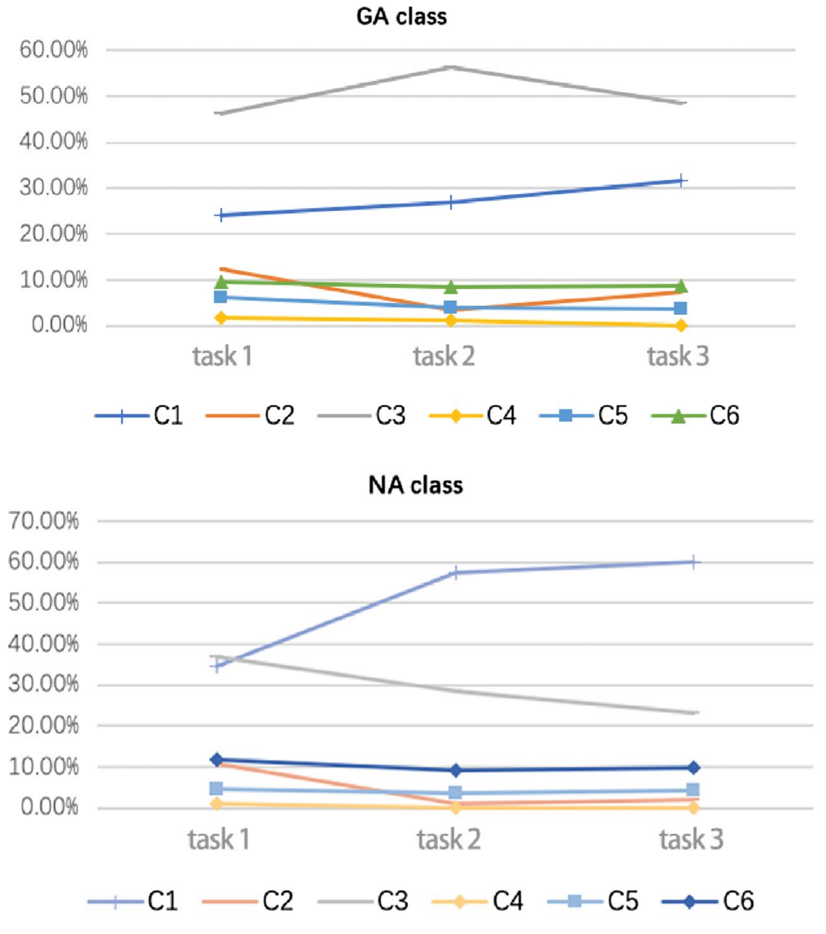


FIGURE 4 Changes in each level of knowledge construction across the three tasks

can't work at home all the time. The notebook is convenient and portable" (C2), while the following post is "Budget is not enough. The plan is revised as follows: Intel i7, 7700, 7700k, Desktop PC, price in Jingdong is 2499 yuan" (C4). It's obvious that there was a lack of negotiation and feedback on different opinions and not every piece of idea received the equal emphasis to contribute to the group. Another distinctive behavioral pattern is a bidirectional transition of modification and summarization (C4→C5 and C5→C4) in GA class. Both C4 and C5 are higher level of knowledge construction and are hard to attain. This path reveals that students in GA groups were more likely to conduct higher level behavior transitions during collaboration and tried to build a new knowledge structure through constant modification and summarization of it. Finally, for the sequential patterns of C5→C6 and C6→C1 in the GA class, we find that C6 mainly incorporates the regulative behaviors. While the transition between the knowledge construction and regulation is not the focus of this study.

In what ways the three types of group awareness facilitate knowledge construction

Thirty-nine valid questionnaires were collected at last and the results showed the majority of students think highly of the tool. Approximately 75% of students agree (strongly agree and agree) that the tool could support group knowledge construction and 89% of students agree that the tool is easy to use. Nearly 95% students are satisfied with the functions of the tool and 74% students hope they can use it in other disciplines.

TABLE 3 Frequency transition table in the GA and NA classes

	GA class						NA class					
	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6
C1	145	31	145	1	9	40	248	23	98	0	24	53
C2	20	7	63	1	6	6	19	6	24	2	1	3
C3	132	58	387	6	31	47	93	18	133	2	10	30
C4	1	0	7	0	2	2	1	0	3	0	0	0
C5	6	1	17	2	8	8	7	1	5	0	3	5
C6	48	6	43	2	5	12	58	7	26	0	5	9

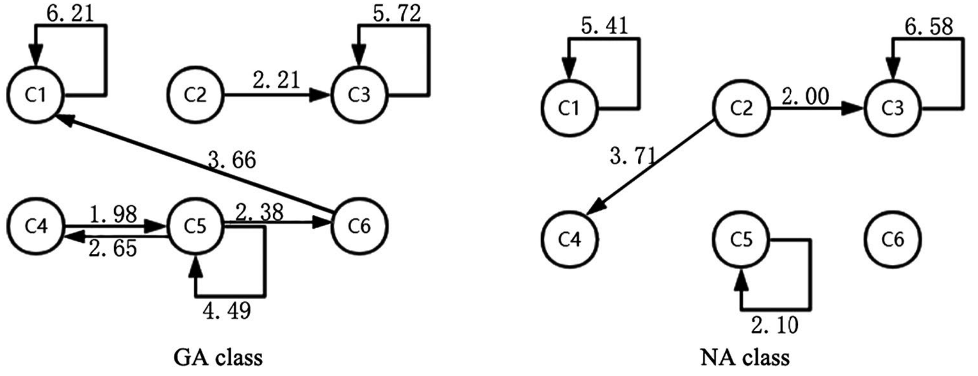


FIGURE 5 The behavioral transition diagram

The interview data give us further information about how the three types of group awareness facilitate knowledge construction (Table 5). Overall, students thought the cognitive and social group awareness were useful for the collaborative discussion, but the behavioral group awareness was of little use. Three themes of cognitive group awareness were identified as keeping the discussion focusing on the topic (student 1,3,15), externalizing the inconsistency and provoking cognitive conflicts or discussion (student 2,5,11) and summarizing the discussion content (student 6,9,11,13,14). Two themes of social group awareness were classified as identifying the opinion leader (student 3) and building more interaction with learners having less communication with (student 6). The behavioral group awareness was of little use because student paid less attention than other two awareness (student 1,2,3,5,6,7,8,10).

DISCUSSION

The purpose of this study is to examine the effects of group awareness on knowledge construction with regard of the different characteristics and behavioral transitions of knowledge construction in GA and NA classes. Further, this study also surveys in what ways the three group awareness types support the process by interviews.

The results reveal some distinctive characteristics of knowledge construction between GA and NA classes. GA groups performed more higher-level knowledge construction behaviors, such as C3, C4 and C5 and less low-level knowledge construction behavior, such as C1. C3 was the most common knowledge construction behavior in GA groups and it

TABLE 4 Results of sequential analysis (*Z*-scores) in the GA and NA classes

	GA class						**NA class**					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
C1	**6.21***	0.39	−5.30	−1.55	−2.43	1.58	**5.41***	−1.04	−6.05	−1.95	0.96	0.92
C2	−1.80	−0.43	**2.21***	0.06	0.58	−1.11	−1.83	1.58	**2.00***	**3.71***	−1.04	−1.34
C3	−5.78	1.20	**5.72***	−0.05	0.03	−2.20	−5.70	0.25	**6.58***	0.81	−1.15	−0.27
C4	−1.46	−1.02	0.53	−0.34	**1.98***	0.96	−0.86	−0.51	1.88	−0.13	−0.44	−0.70
C5	−1.88	−1.35	−1.35	**2.65***	**4.49***	**2.38***	−1.22	−0.24	−0.77	−0.31	**2.1***	1.92
C6	**3.66***	−1.14	−3.08	0.95	−0.19	0.61	1.92	0.31	−1.58	−0.72	0.04	−0.82

*Z-scores > 1.96, $p < 0.05$.

TABLE 5 Themes of how three group awareness types facilitate knowledge construction

Categories	Themes	Examples
Cognitive (tag cloud)	a. Keep the discussion focusing on the topic	Student 1 & 15: "Tag cloud helped me to tell whether we missed some core concepts mentioned in discussion requirements. If so, I will come up with it in my statement."
		Student 3: "Checking the tag cloud helped me to see whether our discussion was off-topic."
	b. Externalize the inconsistency and provoke cognitive conflicts or discussion	Student 2: "Tag cloud helped me to see if other teammates thought of something I didn't think of. And I will go for this point."
		Student 11: "I found some new ideas in the tag cloud, took it into discussion and formed a deeper understanding."
		Student 5: "I read the tag cloud from the big and center words to small words to recall my answers to the questions. I found something I didn't think. I went for the Internet to obtain related knowledge to enrich my knowledge system."
	c. Summarize the discussion content	Students 6, 9, 11&14: "I haven't been a team leader yet, but I think it's useful to sort out the report and better than reading dozens of posts"; "It's like this, I take the overall picture and to see which problem the keywords belong to and put them in the report. I think it's very good."
		Student 13: "When I saw the tag cloud, I recalled what I had discussed and added the different ideas to my own knowledge system."
Social (interaction diagram)	a. Identify the opinion leader	Student 3: "I identified the core person in the interaction diagram because he might be the leader of the discussion. Then, I mainly focused on his posts to obtain the main information of discussion."
	b. Building more interaction with learners having less communication with	Student 6: "Before the discussion, I looked at the interaction diagram to see who I have not discussed with and then focused on his point of view."
Behavioral (distribution of posts)	a. Be of little use	Students 1, 3 & 6: "I don't think this information is important. I pay more attention to the discussion content."
		Student 2, 5, 7, 8 & 10:" If I posted less than others, I would try to post more to make it looks nice."

enjoyed an overall increase during the three tasks. Findings of previous studies indicated that the higher level of knowledge construction plays a significant role in building new knowledge (Hou et al., 2008) and C3 is the vital bridge to connect the lower level and higher level of knowledge construction, through which learns are more likely to achieve C4 and C5 (Yang et al., 2015). These results suggest that GA groups performed better in constructing new knowledge by centering their collaboration on negotiating meaning or constructing new knowledge (C3) and conducting more higher-level knowledge construction behaviors (C4 & C5). While in NA groups, C1 appeared to be the most frequent behavior, which dramatically increased during the three tasks and they conducted less higher level knowledge construction with a constant decrease in C3. This result confirms findings of previous studies that most knowledge construction stagnates at sharing and comparing information (C1) that is the elaboration of existing knowledge rather than building new knowledge (Hou et al., 2008; Yang et al., 2018). Besides, the continuous increase of C1 may lead to the conclusion of knowledge construction at this stage due to no different ideas being proposed (Roseli & Umar, 2015).

The sequential analysis shows two different sequential patterns between GA and NA classes. In GA class, there is an initial finding of sequential patterns as C4→C5 and C5→C4 (Yang et al., 2018). Both C4 and C5 are higher level of knowledge construction and are also the higher form of mental functions (Gunawardena et al., 1997). This pattern suggests that students in GA class inclined to build knowledge via repeated modification and summarization. It has been pointed out in previous study that behaviors in C4, C5 and C4→C5 contribute to effective online collaboration (Yang et al., 2018). This finding reports that GA groups not only produced more higher-level behaviors, but also conducted effective behavioral patterns. The sequential analysis also reveals a distinct sequential pattern in NA class. C2→C4 indicates that sometimes the team straightly revised the plan from an inconsistent idea lacking necessary discussion on the idea within the group. This might be due to the challenge to identify the inconsistent idea among the great number of postings. Some postings might be neglected owing to the nature of asynchronous discussion (Su et al., 2018).

Analysis of the interview data further explains in what ways the three group awareness types supported the knowledge construction. Overall, most students thought the cognitive and social group awareness played a major role in facilitating discussion while unexpectedly, the behavioral group awareness was of little use. For cognitive awareness, students expressed that it helped them keep the discussion focusing on the topic and ensure all core concepts were included. Off-topic discussions or repeatedly checking the core concepts may distract group members' attention and waste more time in preliminary collaboration behaviors, such as clarifying the tasks and stating opinions (Yang et al., 2018). In addition, students also voiced that cognitive group awareness externalized the inconsistency and provoked cognitive conflicts or discussion. In other words, by exposure of what has been discussed in the group, students were easier to acknowledge the different ideas against themselves among the great number of postings and involve in the discussion (Hwang & Chang, 2020; Limón, 2001). Some students further mentioned that the centrality of each key point assisted them in focusing on not only frequently discussed keywords, but also words proposed by a few learners in the group. This is accordance with a previous study that non-consensus idea might be crucial for collaborative discussions (Engelmann et al., 2009). Furthermore, students also regarded the cognitive group awareness as a summarization of the discussion that helped them reflect on their learning and enrich their own knowledge system as well as revise and form the final group report. It is also accordance with suggestion of a previous study that more information of the discussion should be provided to groups to achieve the C5 (Hou et al., 2008), However, there was no sign of applying the new knowledge in this study due to the design of the tasks that only required students to finish a group report rather than using the new knowledge to solve another problem.

Students also thought the social group awareness was valuable for their collaboration by aiding them to identify the opinion leader or those they had less communication with. A previous study has revealed that identifying the opinion leader is important for collaboration because they play a crucial role to convey message for solving web-based collaborative mission and significantly enhance group performance and group cohesion (Cheng & You, 2019). Additionally, being aware of those they had less communication, students could pay more attention to those members' postings and thus, more discussion or group interactions occurred. This finding confirms previous studies that social group awareness is positively related to a better collaborative learning community (Ouyang & Chang, 2019) and a better social performance (Phielix et al., 2011). This study also extends the previous findings by unpacking the mechanism how social group awareness promotes social performance through building more interaction of opinion leader and between those having less communication before.

One unexpected finding in the present study is that students did not think the behavioral group awareness was useful for their collaboration. This finding is contrary to previous researches that indicated the importance of behavioral group awareness on facilitating equal participation (Janssen et al., 2011). The interview data revealed that students were more concerned with the discussion content rather than group members' participation because they thought the discussion content was more critical for the final reports and the number and percentage of postings was only an indicator that they tried to make it look good to teacher or peers. This might be explained by one previous study that the relationship between the object of the intervention and the students' needs is crucial to promote the effectiveness of the educational intervention (Falcao et al., 2018). While, giving the importance of equal participation on learning outcomes (Janssen et al., 2011), this finding should attract teachers' notice and suggests teachers to guide students pay equal attention to self and others' participation.

Pedagogical implications

The present study reveals the positive effects of the group awareness tool on knowledge construction and also provides a positive example of learning analytics intervention effectively supporting collaborative knowledge construction in higher education (Sønderlund et al., 2019; Vieira et al., 2018). Previous studies have claimed that cognitive and social group awareness are positively related to better accuracy of shared knowledge (Shin et al., 2018), the higher level of knowledge construction (Farrokhnia et al., 2019) and a better social performance (Ouyang & Chang, 2019). This study extends the findings by unpacking the mechanism how the cognitive and social group awareness promote the knowledge construction. Besides, one unexpected finding that contrary to previous studies is that the behavioral group awareness was of little use due to the lack of attention of students.

The findings of this study provide a starting place for adopting group awareness in CSCL to improve learners' knowledge construction. This suggests that more emphasis should be placed on incorporating multiple group awareness types by tool developers when they build a CSCL environment that guides and facilitates knowledge construction. Second, giving the mechanism of group awareness, it might inspire new ideas of designers and educational practitioners to develop and utilize the GA tools in diverse learning contexts. Thirdly, teachers and curriculum designers may need to design and implement instructional programs to guide students pay more attention to self and group members' participation. This implementation could be achieved by directly emphasizing the value of equal participation for successful learning or identify a team leader who reminds team members to get really involved in the collaboration.

Limitation and future work

This study has several limitations. First, students needed to log in another platform to view the group awareness information during the discussion, which brought inconvenience to students. Therefore, further development of the group awareness tool should be conducted to be better combined with the Moodle platform. Second, this experiment should include more experimental groups, each group using a different group awareness type to quantitatively examine how the different group awareness types affect knowledge construction. Therefore, further quantitative and qualitative studies with more experimental groups are needed to investigate how different group awareness types support the collaboration and thus, more kinds of group awareness tools fitting diverse learning contexts could be developed.

ETHICS STATEMENT

The participants were protected by hiding their personal information during the research process. They knew that their participation was voluntary and they could withdraw from the study at any time.

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CONFLICT OF INTEREST

There is no potential conflict of interest in this study.

DATA AVAILABILITY STATEMENT

The data can be obtained by sending a request by e-mail to the corresponding author.

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APPENDIX A

Questionnaire on students' acceptance of the group awareness tool

No	Items	Mean	*SD*	Percentage of agreed/ strongly agreed
1	I think the GAT is useful for learning	3.90	0.99	64.1%
2	I think the GAT is useful for supporting online collaborative learning	4.18	0.82	84.6%
3	I think the GAT is useful to share individual thoughts with group members	3.90	0.91	71.8%
4	I think the GAT is useful to organize individual or group knowledge in a group	3.77	0.96	69.2%
5	I think the GAT is useful to organize individual or group interaction in a group	4.00	0.86	79.5%
6	I think the GAT is useful to organize individual or group participation in a group. (the GAT encourages me to participate actively in discussion activities)	4.15	0.71	82.1%
7	I think it was easy for me to learn how to use the GAT	3.97	0.81	76.9%
8	I think Tag-Cloud of the GAT is very easy to understand	4.15	0.87	79.5%
9	I think Interaction graph of the GAT is very easy to read	4.56	0.50	100.0%
10	I think Group posting map of the GAT is very easy to read	4.64	0.49	100.0%
11	I am satisfied with Tag-Cloud of the GAT in terms of group knowledge acquisition	4.33	0.81	84.6%
12	I am satisfied with Interaction graph of the GAT in terms of peer interaction	4.54	0.51	100.0%
13	I am satisfied with Group posting map of the GAT in displaying information of the group	4.56	0.50	100.0%
14	I would like to keep using the GAT in the future	4.26	0.97	76.9%
15	I would like to use the GAT in other courses	4.08	1.01	71.8%