# From Individual Ideation to Group Knowledge Co-Construction: Comparison of High- and Low-performing Groups

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**Abstract:** This study compares the high- and low-performing groups' knowledge co-construction process in the context of computer-supported collaborative argumentation from epistemic, argument, and social perspectives. Product analysis, lag sequential analysis, Sankey diagram visualization, and social network analysis were used to analyze groups' written argumentation artefacts, on-screen behaviors, and online interactions. Results show that the high-performing group students demonstrated a higher level of engagement and cognitive elaboration than the low-performing group. The high-performing group was more competent in integrating various argumentation elements than the low-performing group. And the students in the high-performing group tended to contribute equally to their group work. The implications of the findings in designing and implementing knowledge co-construction activities are discussed.

**Keywords:** Knowledge co-construction, collaborative argumentation, computer-supported collaborative learning

## 1. Introduction

Collaborative argumentation is an effective way for students to learn together. It deemphasizes the social interactions that take place when students discuss divergent claims and come to a consensus (Gao et al., 2022; Han et al., 2021). Existing research studies show that collaborative argumentation benefits students' knowledge construction in classroom practice (Asterhan & Schwarz, 2016). Computer-supported collaborative argumentation (CSCA) supports students to practice argumentation simultaneously through writing and discussion (Baker, 1999). In CSCA, students with differing views critically debate a subject. Ideally, they come to an agreement and collaborate to construct argumentative knowledge after comparing, assessing, and synthesizing multiple points of view (Han et al., 2021). In order to learn about argumentation and content knowledge, students generate and co-construct arguments by interacting with their learning partners (Andriessen et al., 2003). Argumentative knowledge co-construction is one of the important competencies for joint problem-solving (Vuopala et al., 2019).

To examine multiple dimensions of the knowledge co-construction process in computer-supported collaborative learning (CSCL), Weinberger and Fischer (2006) proposed a framework that contains the epistemic, argument, and social-mode dimensions. The epistemic dimension describes how learners work on the knowledge construction task (Fischer et al., 2002). This dimension looks into whether students are working on the job at hand (engaged in on-task conversation) or if they are off-task. The argument dimension focuses on how learners construct arguments with regard to defining formal relationships between specific elements of arguments, such as claims, data, and warrants (Fischer et al., 2007). The dimension of social modes indicates how learners interact with each other.

Previous studies attempted to unpack the complex and dynamic process of group students' argumentative knowledge construction. For example, Ouyang et al. (2023) developed an integrated discourse analysis approach to examine how the group's discourse movements, structures, and turn-taking processes evolve over time by analyzing the collaborative argumentation from cognitive, metacognitive, and social perspectives. Lu et al. (2011) explored whether discourse moves, sequences, and participant features were related to two types of justifications (evidence and explanations) during online argumentative discussions. Most of the existing studies attempted to study the group's collaborative argumentation process itself without considering how individual students in the group contribute to the knowledge co-construction of the group. Compared with direct collaboration, adding individual ideation before collaboration may require different epistemic activities, making it worthwhile for a detailed investigation (Valero et al., 2022).

## 2. Literature Review

Knowledge co-construction refers to collaborative processes in which learners interact with one another in order to build new knowledge and enhance the knowledge and understanding of each individual student (Janssen et al., 2009). These productive interactional processes include asking thought-provoking questions, exchanging ideas, negotiating and providing justified arguments in order to build new knowledge (Arvaja et al., 2007; Sawyer, 2006). There is evidence that active participation in knowledge co-construction activities can result in high-quality learning outcomes (Wang, 2009). Previous research has suggested that knowledge co-construction activities can have a positive impact on both group productivity and learning outcomes (Weinberger et al., 2007).

Collaborative argumentation is a group-based exercise in which students work together to construct an integrated group view on a discussion topic (Noroozi et al., 2012). Learners benefit from collaborative argumentation because they obtain new ideas and information while comparing, assessing, and synthesizing different points of view based on evidence and rationale (Han et al., 2021). Furthermore, collaborative argumentation is helpful in the development of competencies for arguing and collaborating with others, both of which are required for working and living in the future society (Noroozi et al., 2012).

Typical collaborative learning processes commence with the group or end at the group level. In fact, participating in individual ideation before collaboration can benefit both individuals and groups. By engaging in individual ideation before intra-group knowledge co-construction, each group member's ability to recall prior knowledge is enhanced, fostering a greater number of ideas that can subsequently contribute to the overall intra-group synergy (Chen et al., 2021). Additionally, individual ideation promotes increased levels of participation, discourages the presence of free-riders, and equalizes the level of collaboration among group members (Isohätälä et al., 2017).

This study analyzes the process of collaborative argumentation of two groups (one high-performing group and one low-performing group) from individual ideation to group knowledge co-construction from epistemic, argument, and social dimensions. To be specific, the research questions are:

RQ1: What are the sequential patterns of epistemic knowledge co-construction behaviors of the high- and low- performing groups in CSCA?

RQ2: How did the high- and low-performing groups' argument structures develop?

RQ3: What are the social interaction networks of high and low-performing groups' argumentative knowledge co-construction?

## 3. Methodology

### *3.1 Context and Participants*

The study took place in a secondary school English class in Singapore. A total of 24 secondary school (15-year-old) students (male =12, female =12) participated in this study. The teacher randomly assigned participants to 6 groups (4 members in each group). The participants in this study possess experience in collaborative learning but lack familiarity with argumentation. The experiment occurred in a blended learning environment; the teacher and students interacted offline in a physical classroom while they engaged in collaborative arguments on an online platform using their personal learning devices (PLDs). The teacher's expertise in computer-supported collaborative learning (CSCL) contributed to the experiment's instructional design. The learning objective is applying English language skills in an argumentation context and improving students' argumentation skills and critical thinking, as highlighted by 21st-century student outcomes. IRB approval has been obtained from the university of the first author before data collection commenced.

### 3.2 Procedure

The participants were asked to collaboratively co-construct an argumentation diagram in Appletree, an online collaborative argumentation platform (see Figure 1. http://www.appletree.sg/ ) (Chen et al., 2013; Tan & Chen, 2022).

The argumentation topic is “AI will make our lives at home more enjoyable. How far do you agree?” selected from the English lesson syllabus. The whole lesson lasted for 1.5 hours which included teachers’ instruction, and students’ collaborative argumentation. The students went through a 5-phase Spiral Model of Collaborative Knowledge Improvement (SMCKI) (Chen, et al., 2021). Phases 3, 4, and 5 are inter-group feedback, intra-group refinement, and individual achievement, which touch on students’ feedback literacy and exceed argumentative knowledge. To better understand argumentative knowledge construction, this study focuses on the first two phases which lasted for 30 minutes in total: 1) Individual ideation (10 minutes): students individually generate ideas and take a position for the augmentative topic; 2) Intra-group synergy (20 minutes). Group members co-constructed an argumentation diagram by integrating all individual ideas through discussion and negotiation.

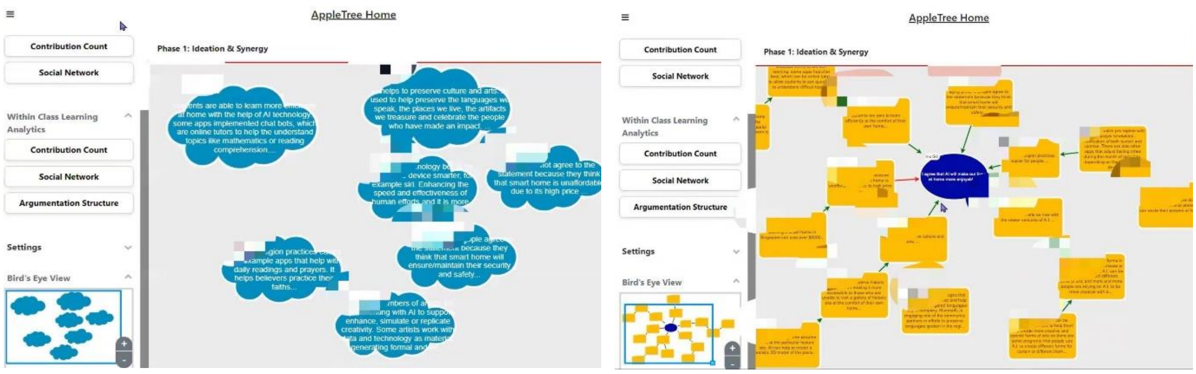



*Figure 1.* Appletree working space. Phase 1 individual ideation (left), blue bubble showcases the idea generated separately by each group member; Phase 2 group synergy (right) shows the argumentation work co-constructed by all group members. The dark blue bubble is the main claim; the green/red represents for/against the relationship between the two bubbles.

### 3.3 Data Collection and Analysis Method

Two types of data were collected: the group's argumentation diagrams (artifacts) in AppleTree, and the computer screen recordings from each group member of the 2 groups. Multiple analytical methods were used to examine the students’ knowledge co-construction. The study used product analysis (PA) (Novak & Cañas, 2008) to assess the quality of all groups’ argumentation diagrams in terms of four dimensions, i.e., clarity, multiple perspectives, selection of evidence, and depth of elaboration (Marzano et al., 2000; Stapleton & Wu, 2015; Tan & Chen, 2022). The unit of analysis is the argumentation diagram of the group. Each dimension is rated on a scale ranging from 0 to 3. Two of the authors scored the argumentation diagrams independently (Cohen's *K* = 0.70). Two groups with the highest and lowest quality of argumentation artefacts were selected in this study to compare the process of knowledge co-construction between the high- and low-performance groups. The high-performance group's score was 8 (clarity = 2, perspective = 2, evidence = 2, elaboration = 2), and the low-performance group's score was 5.5 (clarity = 1.5, perspective =1.5, evidence = 1.5. elaboration = 1).

First, the coding scheme for on-screen behaviors was adapted from Chuy et al. (2011)'s explanation-seeking dialogue framework and the Claim-Evidence-Reasoning (CER) model (Toulmin, 2003). We take one behavior as a unit, for example, student add one subclaim, then we code it as ABC. The explanation-seeking dialogue framework includes five epistemic behaviors: 1) formulating thought-proving questions; 2) theorizing; 3) obtaining evidence; 4) working with evidence; and 5) synthesizing and comparing. This framework was most used in the knowledge building context (e.g., Knowledge Forum online platform). CER is an argumentation pattern including three argumentation elements: "claim", "evidence", and "reasoning". An argument's main goal is to justify a claim with evidence and reasoning (Osborne & Patterson, 2011). The coding scheme is shown in Table 1. The coding process was iterative. The second and third authors coded the screen recordings separately and held multiple meetings to resolve discrepancies. The inter-rater reliability, as measured by kappa coefficient, between the two coders was 0.761.

Table 1. *Coding Scheme for Knowledge Co-construction in Collaboration Argumentation*

| Category | Sub-category | Code |
|---|---|---|
| Contribute | 1. Add a claim or sub-claim | ABC |
| | 2. Add new facts/examples (evidence) to support a claim/sub-claim | ASE |
| | 3. Add new facts/examples (evidence) to oppose a claim/sub-claim | AOE |
| | 4. Provide elaboration to explain evidence/sub-claim | ELA |
| Seeking input | 5. Seek help from discussing with other group members | DIS |
| | 6. Seek input (from internet/discussion) | INP |
| Revising | 7. Copy & paste | C&P |
| | 8. Rephrase/Revising previous work | RE |
| | 9. Delete information | DE |
| | 10. Change link/position | CH |
| | 11. Synthesize available evidence/elaboration (bubble) | SYN |
| Off task | 12. Discuss irrelevant things/play with the system | OFF TASK |

## 4. Results

### *4.1 The Sequential Patterns of Argumentative Knowledge Co-construction*

The results of on-screen behavioural coding consist of a totally 111 and 67 behaviors for the high- and low-performing groups, respectively. The frequency and percentage of each coded behaviour were calculated for the two groups (see Table 2). In the high-performing group, the most frequent on-screen argumentative knowledge co-construction behaviour was seeking input from the internet (INP), whereas and least frequent behaviour was off-tasking (OFFTASK). By contrast, the most frequent on-screen behaviour of the low-performing group was discussing (DIS) while behaviours like synthesizing existing and new information (SYN) and copying and pasting (C&P) were not identified.

Table 2. *Frequencies and Percentages of On-screen Argumentative Behaviors between the High- and Low-performing Groups*

| | INP | DIS | SYN | RE | C&P | ASE | ABC | OFF TASK | DE | ELA |
|---|---|---|---|---|---|---|---|---|---|---|
| High | 27 | 14 | 9 | 17 | 11 | 7 | 5 | 4 | 7 | 10 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (111) | (24.32%) | (12.61%) | (8.11%) | (15.32%) | (9.91%) | (6.31%) | (4.5%) | (3.6%) | (6.31%) | (9.01%) |
| Low<br>(67) | 8<br>(11.94%) | 35<br>(52.24%) | 0<br>(0%) | 1<br>(1.49%) | 0<br>(0%) | 2<br>(2.99%) | 4<br>(5.97%) | 10<br>(14.93%) | 1<br>(1.49%) | 6<br>(8.96%) |

Lag Sequential Analysis (LSA) (Bakeman & Gottman, 1997) was conducted based on the coding results to understand the sequential pattern of students' knowledge co-construction from the epistemic dimension. Lag sequential analysis (Bakeman & Gottman, 1997) examines the occurrence and temporal order between different learning behaviors (Kapur, 2011). The coded knowledge co-construction behaviour sequence was imported into the GSEQ 5.1. The z-score of every transition from one behaviour to another was reported in the LSA results, indicating the significance level of each behaviour sequence (z-score > 1.96, Bakeman & Gottman, 1997). A behavior transition diagram was created to visualize the significant sequences in each group.

Figure 1 visualizes the on-screen behavioral transition patterns in terms of their argumentative knowledge co-construction of the high and low-performing groups. There were 4 and 2 significant behavioral sequences identified in the high and low performing group respectively. Firstly, the predominant patterns of high performing group's argumentation co-construction were "seeking input from the internet or discussion (INP)" → "synthesizing internet information with existing evidence or reasoning (SYN)" and "synthesizing internet information with existing evidence or reasoning (SYN)" → "seeking input from the internet (INP)". The findings show that the high-performing group students searched for information online and then integrated that information into their proposed ideas. They tended to seek information from the internet after synthesizing ideas. Another significant transition pattern for the high-performing group was "seeking input from the internet (INP)" → "adding new evidence to support a claim or sub-claim (ASE)". The high-performing group raised evidence for claims after searching for relevant information. On the contrary, the low-performing group directly proposed claims and sub-claims after seeking information from the Internet without deeper information processing according to the transition pattern "seeking input from the Internet (INP)" → "adding a claim or a sub-claim (ABC)".

In addition, high-performing group students continued to construct knowledge via rephrasing or revising previous ideas after copying and pasting information from the Internet, the team members' work, or from their own individual ideation as demonstrated in the sequence pattern "copy and paste (C&P)" → "rephrase or revise previous work (RE)". One significant sequence of the low-performing group was "OFFTASK" → "discuss the topic (DIS)", which infers that the students tended to discuss irrelevant things or play with the system before discussing the topic.

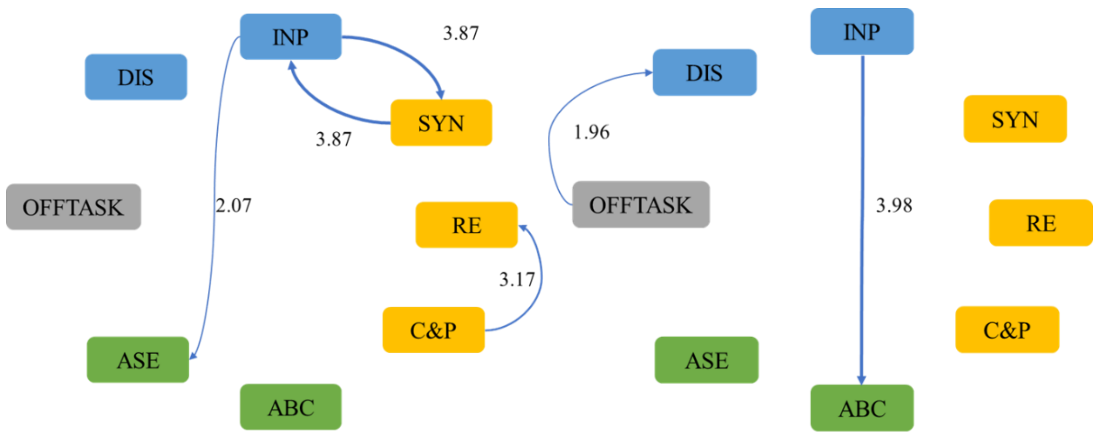



*Figure 1.* Argumentative Knowledge Co-construction Behavior Patterns of High- (left) and Low-performing (right) Groups.

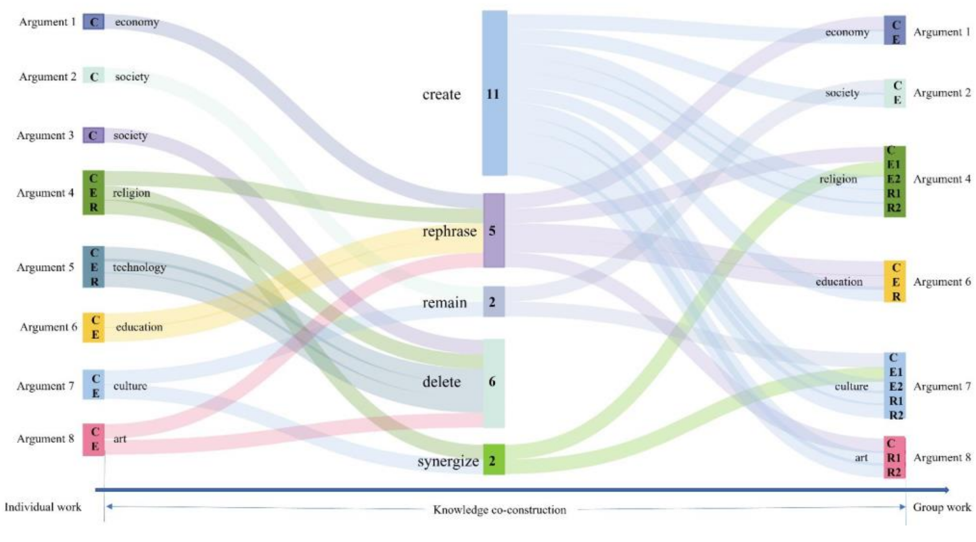
### *4.2 The High- and Low-performing Group's Arguments Development*

To answer the second research question about the development of the high- and low-performing groups' arguments compositions, the Sankey diagram was employed to unpack the knowledge co-construction process to show the reasoning flow to reveal the differences between the two groups. Two Sankey diagrams were derived to visualize the development of students' argument construction (see Figure 2) from the individual ideation phase to the group synergy phase. The left column of the diagrams is the students' individual ideation whereas the right column is the results of group argumentative knowledge co-construction. The middle column illustrates how each idea and argument element developed. For example, the evidence (E) in Argument 4 (left column) became the evidence (E1) in Argument 4 (right column) through synthesizing the original evidence (E) with new ideas from the Internet, the team members' work, or from their own individual ideation.

Figure 2 shows that the high-performing group students constructed eight arguments from seven different perspectives, including only two sound and completed arguments with a "C-E-R" structure (Argument 4 and 5), three arguments consisting of a claim and one piece of evidence (Argument 6, 7 and 8), and three arguments with one claim (Argument 1 and 2). After the knowledge co-construction, there were three arguments with a "C-E-R" structure and two of the three arguments consisted of richer evidence and stronger reasoning (Argument 4 and 7). Additionally, two arguments were made up of a claim and a piece of evidence (Argument 1 and 2), and in Argument 8 there were a claim and two lines of reasoning. The arguments focusing on society and technology appeared in individual ideation passe were deleted after the group knowledge-co-construction.

The low-performing group started with three completed arguments (Argument 1, 3, and 5) from perspective of society, art, and environment; two arguments with one claim (Argument 2 and 4); one argument with a claim and a line of reasoning (Argument 6). Three ideas posted were not considered as arguments by the researchers as they did not correspond to any certain claim. At the end of group co-construction, four fragmented ideas remained and there were only two sound arguments with a "C-E-R" structure (Argument 1 and 3) which was less than their individual ideation work, though Argument 3 added one line of reasoning. Through rephrasing and synergizing, some ideas were still not integrated into an argument well.

The results from the Sankey diagrams show that there were differences in the process of argument development between the high- and low-performing groups. From the behavior point of view, the high-performing group contributed new argument elements via creating reasoning and evidence (N=11) during the argumentative knowledge co-construction, but the low-performing group deleted nine elements and created only one element (R2) and a fragmented idea (idea 6). Second, from the perspective point of view, the high-performing group considered all the perspectives they proposed during the individual phase whereas the low-performing group paid most of their attention to the perspective of art only.



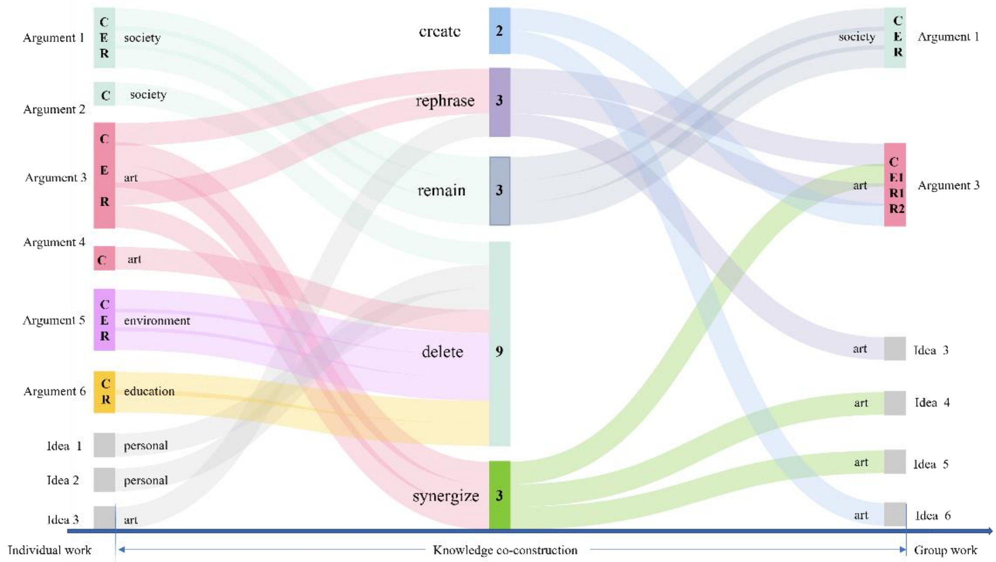



*Figure 2.* Argument Development of High- (above) and Low-performing (below) Groups. Claim (C), Evidence (E), Reasoning (R).

### *4.3 The Social Interaction Network of the High- and Low-performing Group*

Social network analysis (SNA) was used to analyze the social characteristics of group interactions through online collaboration. This study focused on the frequency of interaction, the frequency of built-on work a participant makes to others. The degree centrality and Group centralization to show whether the network is equal or not (Yustiawan et al., 2015); In addition, the density and connectedness of each group were analysed to show the cohesiveness and reachability between group members.

The results show that the high-performance group had higher interaction frequency (freq. = 5, M = 2.5, SD = 1.732) than the low-performance group (freq. = 4, M = 2, SD = 0.816). The high-performance group also has a higher average degree (outdegree=1.25, indegree = 1.25) than the low-performance group (outdegree = 1, indegree = 1). The high-performance group has lower out-centralization (out-centralization = 0.111, in-centralization = 1) than the low-performing group (out-centralization = 0.444, in-centralization = 0.889). On the contrary, the low-performance group has higher density and connectedness (density = 0.333, connectedness = 0.333) than the high-performing group (density = 0.25, connectedness=0.25).

## 5. Conclusions, Discussion, and Limitations

This study explored the high- and low-performing groups' argumentative knowledge co-construction from epistemic, argument, and social perspectives. The findings from LSA, Sankey diagram visualization, and SNA show that the high-performing group possesses a higher level of engagement, cognitive elaboration, and equal relationship, and is more competent in integrating argumentation elements than the low-performing group.

This study yields two findings on the epistemic dimension of collaborative argumentation. First, the high-performing group was more engaged in the learning task than the low-performing group, which echoed the findings from the literature that the more engaged group members are in the ongoing and constant elaboration of collaborative tasks, the higher the quality of learning they achieve (Barron, 2003). Second, the high-performing group tended to process information through rephrasing and synergizing pieces of information from the internet and existing ideas to form higher levels of reasoning.

On the contrary, the low-performing group tended to copy information directly from the internet without deep information processing. A possible reason for this finding is that the less successful groups tend to possess a lower level of cognitive elaboration competence. Cognitive elaboration, a crucial type of cognitive processing with regard to knowledge construction (McNamara et al., 1996), is the enrichment of learning material using additional information taken from or inferred in combination with prior knowledge. Arguments with high quality in terms of argumentative knowledge come with in-depth cognitive elaboration (Stegmann et al., 2007). This finding is consistent with previous research studies which suggested that deep cognitive elaboration of the learning material is causally related to knowledge acquisition (e.g., Stein & Bransford, 1979). Therefore, future pedagogical design that aims to improve students' argumentation skills can pay more attention to students' cognitive processing and elaboration.

There are two findings derived from the analysis of the argument dimension. The argument structure of the high-performing group became stronger and richer, but it was hard for the low-performing group to integrate fragmented reasoning and evidence to support a corresponding claim so that a complete argument could be formed. The findings are consistent with Sampson and Clark's (2011) research results: high-performing triads constructed arguments that included a sufficient and accurate explanation that was well supported by appropriate evidence and reasoning, whereas the low-performing triads produced arguments supported by inappropriate and inadequate justification. A possible reason is that the low-performing group students have difficulties in linking evidence to claims (Osborne et al., 2004; Berland & Reiser, 2009; McNeill, 2011). As Osborne et al. (2004) observed, constructing a good argument is not a simple task for school students, and they need sufficient support and clear guidance to build their sense of what an effective argument is. Walker et al. (2019) also reported that students may need additional guidance when they intend to revise or change their claims and when they use scientific principles in their justification. Researchers and teachers would need to provide additional scaffoldings to guide students to construct effective arguments.

The results of the social interaction show that high-performing group members contributed actively and equally to their group work, while the contribution of low-performing group students was less equal with two students dominating the group work. Borge et al. (2012) reported a similar case that the greatest difference between high and low-performing groups was how dominance shifted by person across activities. For example, in high-performing teams, while one person dominated synthesis-related activities, another person dominated activities involving information interpretation or decision-making. In contrast, a low-performing team would have the same person dominating both activities. This finding can be supported by the previous research studies which showed that an equal and distributed collaborative relationship with minimal hierarchical control could encourage students to engage more in the collaborative process (Zhang et al., 2009). It is necessary to encourage students to build collective responsibility (e.g., shared roles of knowledge builders) and both self- and shared-regulation skills (Park et al., 2019).

This study has some limitations. This study is exploratory in nature with only one high- and low-performing group analyzed. The time duration of the study was short due to the school's curriculum tie constraint. Therefore, the findings may not be generalizable to other groups and contexts. Nevertheless, the study is innovative in its analytical methods and provides interesting insights into the different knowledge co-construction processes between the high- and low- low-performing groups. Future research studies will be conducted with more groups of data included and longer duration and deeper engagement of students' knowledge co-construction are designed and implemented.

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