Deepening Students' Understanding of Socio-Scientific Issues Through Graph-Oriented Computer Supported Collaborative Argumentation: An Exploratory Study

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Abstract: Engaging students in the process of argumentation is a productive way to help them deeper the understanding of socio-scientific issues (SSI). This study examined the effect of computer supported collaborative argumentation (CSCA) on Secondary school students' SSI learning and the behavioral patterns of students' CSCA. 122 secondary school students participated in this study. They were randomly divided into 29 groups. Through statistical analysis and epistemic network analysis, results showed that CSCA was effective in supporting secondary school students' evidence-based argumentation skills on socio-scientific issues. The implications of this study are discussed.

Introduction

Argumentation is considered as a vital type of thinking and writing activity that has been studies by researchers for many years (e.g., Chen et al., 2021; Sampson et al., 2011a; Schwarz, 2009). Many effective argumentation activities happen between multiple participants who engage in evaluation, reflection, reasoning and decision making through arguments and counterarguments in relation to specific topic (Scheuer et al., 2014). However effective collaborative argumentation (CA) rarely takes place in school classrooms. According to previous studies in K-12 contexts, students usually have difficulties in providing sufficient and logical evidence to support their arguments (Kuhn et al., 2008; Walton, 1996). They often provide more reasons to support their own position and fail to consider other perspectives (Crowell & Kuhn, 2014). Researchers have used multiple approaches to help students develop argumentation skills (Kuhn et al., 2010). One of the promising approaches is graph-oriented computer-supported collaborative argumentation (CSCA) which was effective in improving students' content knowledge and developing their argumentation skills (Hsu et al., 2015).

Even though research on graph-based CSCA has substantiated many benefits including better conceptual grasping (Wang, 2014) and better development of cognitive and metacognitive abilities (Chen et al., 2019), it rarely occurs in classrooms for the learning of socio-scientific issues (SSI). The learning and teaching of SSI have emerged as an effective way for students to expand critical and civic engagement (Damico et al., 2020). Deeply rooted in everyday lives, SSI can serve as meaningful contexts for meaning making as SSI situates learners to solve critical real-life problems as they manifest both globally and locally in an integrated manner (Owens & Sadler, 2020; Zeidler, 2014). How to integrate SSI teaching and learning into literacy classrooms where argumentation is an important competence to achieve is challenging. Traditional pedagogical approaches with relatively fixed goals and routines were not effective for learning complex issues such as SSI (Tal & Kedmi, 2006). Researchers have proposed to use collaborative argumentation (CA) approach (Tal & Hochberg, 2002) to encourage divergent thinking, student-centered discussions on SSI, and development of scientific knowledge.

This study used graph-oriented CSCA to deepen students' understanding of SSI. CSCA was implemented in secondary school English language classrooms for the development of evidence-based argumentation skills on socio-scientific issues, with more attention paid to group writing performance and writing behavior patterns. The purpose of this exploratory study was to examine whether students improved their evidence-based argumentation skills and SSI reasoning throughout the CSCA learning design and how they engaged in the CSCA. The research questions addressed in this study are as follows:

1. Does a graph-based CSCA approach support the development of secondary school students' evidence-based argumentation skills and socio-scientific issues (SSI) literacy in English language classrooms?
2. What are the behavioral patterns of students' CSCA for learning SSI?

Literature review

Computer-supported collaborative argumentation

In recent years, CSCA has been adopted to facilitate interdisciplinary learning with its effectiveness of facilitating multidisciplinary knowledge integration and meaning making (Noroozi et al., 2013; Noroozi et al., 2012). Argumentation plays a key role in solving the ill-structured problems in the real world, which usually requires observational data collection, rules of formal logic, and rational resolving of different opinions in critical discussions (Jonassen & Kim, 2010). According to Walton et al. (2008), argumentation is a goal-oriented dialog in which different participants collectively reason to prove or disprove certain presumptions until reaching an advanced argument. Similarly, van Eemeren et al. (1987) defined argumentation as a reasonable verbal, social, and rational activity that involves a constellation of separate propositions to justify the acceptability of one standpoint. The common characteristic of different definitions of argumentation is its purpose for rationally resolve differences of issues, opinions, and questions in critical discussions (Jonassen & Kim, 2010).

Argumentation could be a vehicle for collaborative learning processes such as meaning-making and knowledge construction, with an interactive and collaborative nature (Baker, 2003). Researchers have turned their attention to what happens when collaborative argumentation is integrated into classroom contexts, portraying it as a fruitful and engaging process for students (Kanselaar et al., 2003; Stegmann et al., 2012; Wang, 2014). Much of this work illuminates students' improvement on reasoning (e.g. Kuhn et al., 1997; Reznitskya, 2002), co-elaboration of new knowledge (e.g., Schwarz & De Groot, 2007), conceptual learning (e.g. Asterhan & Schwarz, 2007), and critical thinking and problem solving (Cho & Jonassen, 2002). Across contexts, research substantiates the potential for collaborative argumentation as a meaningful learning approach (Noroozi et al., 2012; Sampson et al., 2011; Van Eemeren et al., 2015; Wolfe, 2011).

Following the shift from page to screen, various computer-supported systems with unique learning affordances-such as representational guidance tools (Hsu et al., 2016), micro-scripting or macro-scripting (Noroozi et al., 2018; Noroozi et al., 2013), digital dialogue games (Ravenscroft et al., 2010), and graphical representation of argumentation structure using visualizations (Scheuer & McLaren, 2013; Scheuer et al., 2013) have been developed to facilitate collaborative argumentation processes. The innovative learning approach termed CSCA aims at scaffolding in-depth and productive argumentative learning by supporting sharing, constructing, and representing arguments in multiple formats (Kirschner et al., 2012). Research that closely examined CSCA illustrates its impact on argumentation skills development (Hsu et al., 2016; Lu & Zhang, 2013; Wang et al., 2011), critical and elaborative discussions (Scheuer et al., 2014), domain-specific knowledge (Stegmann et al., 2012).

Existing studies have developed graph-based computer application tools such as Virtual Collaborative Research Institute (van Drie et al., 2005) which help students develop argumentation skills and knowledge. The typical feature of these tools is the use of nodes or shapes to represent argument elements, and use the links and arrows to represent the relationship between these argument elements. In nodes or shapes, users can insert, edit, and modify argument content. In the graph-based argumentation, students find it easier to find points of view and support relationships between claims and evidence. One important affordance of graph-based CSCA is the graphical representations of argumentation structure in the form of schematic representation (Schwarz & De Groot, 2007), tables (Suthers & Hundhausen, 2003), or visualizations (Scheuer et al., 2013). In particular, the diagram-based representation tools own the advantage of non-linear display of argument elements and argumentative relations in a two-dimensional space. This space allows multiple relations between different argument elements by connecting boxes with multiple arrows. This makes argumentation structure more visible for learners, thus promoting productive collaboration and argumentation quality. Empirical studies have examined the positive impact of CSCA, especially argument diagramming on students' argumentation quality, cognitive elaboration depth as well as domain-specific knowledge acquisition (Hsu et al., 2015; Hsu et al., 2016; Scheuer et al., 2014; Stegmann et al., 2012)

Socio-scientific issues and its inclusion in literacy classrooms

Socio-scientific Issues (SSI) have been termed by Sadler (2004), emerging from the connection of science and society. SSI are controversial social issues related to science (Zeidler & Keefer, 2003) which are open-ended problems with multiple solutions, such as climate change, cloning, and genetically modified organism (GMO) (Sadler, 2004). Synthesizing research, scholars (Sadler, 2004) describe that SSI:

- are mediated and complicated by multiple elements including socio-economic, political, geographical, cultural, and contextual factors
- involve multiple stakeholders (e.g., governors, experts, educators, communities) with various positions, contradictions, or conflicts
- require ongoing investigation with multiple solutions of the issues

There has been increased attention on integrating SSI in literacy classrooms as literacy educators are positioned to help students navigate the world they live in (Damico et al., 2020). Deeply rooted in everyday lives, SSI can serve as meaningful contexts for meaning-making as SSI situates learners to solve critical life-wide problems in an integrated manner (Owens & Sadler, 2020; Zeidler, 2014). The investigation and argumentation of SSI can push learners to contemplate contemporary and complex issues as they manifest both globally and locally, which can be a productive way to develop 21st century competencies (e.g., critical thinking, civic engagement, global awareness, etc.) while fostering purposeful language use through engaging in argumentation, interdisciplinary learning, and real-world problem-solving.

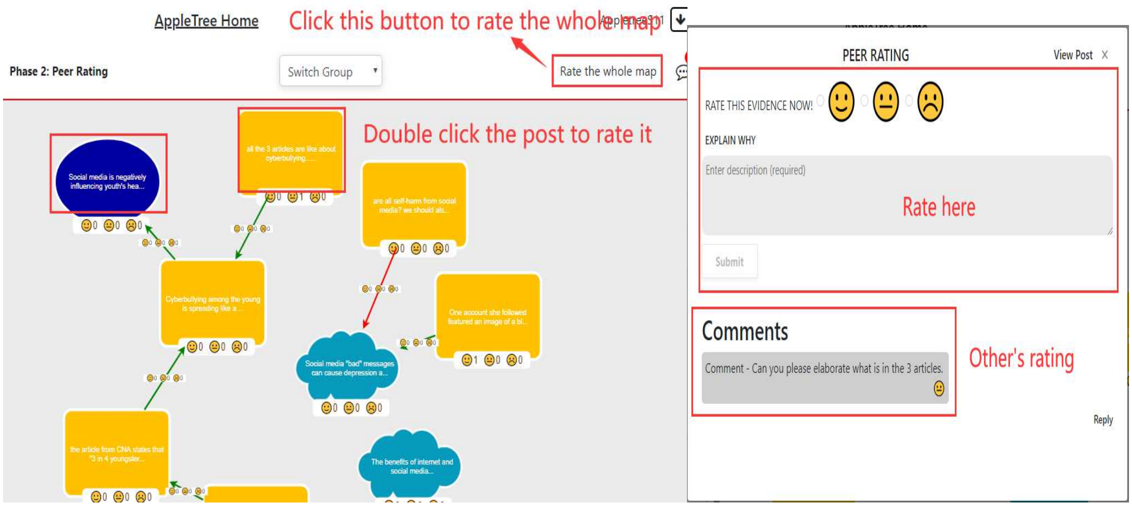
Whereas calls for pedagogical initiatives that target SSI in literacy classrooms continue to increase (Damico et al., 2020), empirical research remains scarce. As literacy teachers work to help students engage with the word and the world more meaningfully, it is important to gain a better understanding of what may happen when SSI are integrated into literacy classrooms to support the efforts of educators and render pedagogical implications. Therefore, this study aims to explore the effectiveness of a CSCA approach in English literacy classrooms on SSI.

Methods

CSCA system

The CSCA system was AppleTree, which was designed for supporting generalized coordination of collaborative argumentation among students and the teacher in the following three aspects: (1) argumentation: developing graph-based argumentation to represent argument elements, and relationships between them, which a cloud represents an idea, an ellipse represents a claim, and a rectangle represents an evidence; (2) collaboration: scaffolding student's continuous knowledge improvement through a phased collaboration; (3) peer critique: supporting intra-group peer assessment and critique by quantitative rating and qualitative feedback. Figure 1 shows the user interphase of AppleTree. The AppleTree system is a graph-based technological platform that allows users to externalize their thought processes in a mind map structure.

Figure 1.
Appletree user interface (collaborative argumentation, and peer assessment)



Research context, participants, and intervention

Three English literacy classes at a Singapore secondary school participated in this study. All the students were in their Grade 9, aged between 14 to 15 at the time of this study. Both Class A and Class C had 42 students. Class B had 38 students. The students within each class were divided into groups of four or five members randomly by the teachers. The teachers were experienced English teachers and had been teaching the class for four months before the research intervention. The students in each class knew each other and had prior group learning experiences but not in the same group settings as in this study. In this argumentation on SSI lesson, students worked in groups to brainstorm ideas for the SSI question "Some people say that Singapore is not doing enough to fight climate change. Do you agree?" in the AppleTree system. The students were taught the approach to answer argumentative questions for the first time in their Grade 9. Instead of approaching this skill with the traditional teacher-centered instructional approach, the CSCA approach was adopted.

The students went through 3-phase collaboration argumentation. 1) Within-group ideation and synergy: 2) between-group peer assessment, and 3) within-group refinement. In phase 1, students tapped upon their prior knowledge during the previous lesson and shared with their group members at the collaborative workspace.

Data collection

Data collected for analysis included the online artifacts generated from the AppleTree system in the three collaboration phases. To answer the first research question on the effect of CSCA on students' argumentation skills and SSI literacy, both students generated artefacts and their online behaviors in CSCA were examined. When it comes to assessing argumentation, researchers have argued for a more comprehensive approach that considers multiple aspects such as argumentation knowledge and argumentation sequences (Haro et al., 2020).

Findings

Effect of CSCA on students' argumentation skills and SSI literacy

To answer the first research question, content analysis was conducted to code the quality of student-generated artifacts. The unit of analysis was each group's argumentation graph. All the students' group argumentative artifacts (graph-based mind maps) were assessed based on the intersection of key argumentation skills and SSI literacy adapted from the previous literature. The coding rubric considers five important dimensions related to both argumentation and SSI literacy. The first dimension is logical reasoning which looks into the logical strength represented in students' group mind map. Logical reasoning is a critical element in SSI literacy (Tal & Kedmi, 2006) and this essential argumentation skill represents meaningful use of language for higher order thinking. Being able to take multiple stakeholders' positions into consideration indicates a better understanding of SSI and a more reliable argument. The second dimension is multiple perspectives which investigates whether students were able to consider and evaluate different perspectives/viewpoints of an SSI. Being able to examine multiple perspectives is an important argumentation skill that can improve the credibility of an argument (Felton & Herko, 2004). In addition, as SSI are normally controversial issues with multiple perspectives, this dimension can also examine students' SSI literacy. The third dimension is elaboration which focuses on the quality of meaning-making (Marzano et al., 2000) of student-generated artifacts. We considered this dimension to be assessed to align with our English literacy classroom's context and learning outcome expectations provided by the teachers. In addition, being able to make meanings in a clear and detailed way lays the foundation for both argumentation and SSI literacy. Two coders were trained to code the mind maps using the coding rubric. The inter-rater reliability for the five dimensions were (Cohen's weighted kappa) 0.70 for 'Logical reasoning', 0.78 for 'Multiple perspectives', and 0.71 for 'Elaboration', respectively.

A paired sample t-test (see Table 1) indicated that there was significant improvement in 'Logical reasoning' in the refinement phase ($M=1.69$, $SD=0.76$) compared to in the synergy phase ($M=1.48$, $SD=0.69$), $t(28)= 2.70$, $p<.05$. There was a significant improvement in 'Elaboration' in the refinement phase ($M=1.97$, $SD=0.68$) compared to in the synergy phase ($M=1.52$, $SD=0.63$), $t(28)= 4.77$, $p<.001$. There was a significant improvement in 'Multiple perspectives' in the refinement phase ($M=2.14$) compared to in the synergy phase ($M=2.03$, $SD=0.63$), $t(28)= 1.80$, $p<.05$. The findings revealing that students improved significantly in these three dimensions during CSCA. Improvement was not statistically obvious in the dimensions of 'Variety of stakeholders', 'Multiple perspectives', and 'Reliability of sources.'

Table 1

Results of paired sample t-test

	Mean		t
	Phase 1 (Synergy)	Phase 3 (refinement)	
Logical reasoning	1.48	1.69	2.70*
Multiple perspectives	2.03	2.14	1.80*
Elaboration	1.52	1.97	4.77**

**p<.05, ** p <.01*

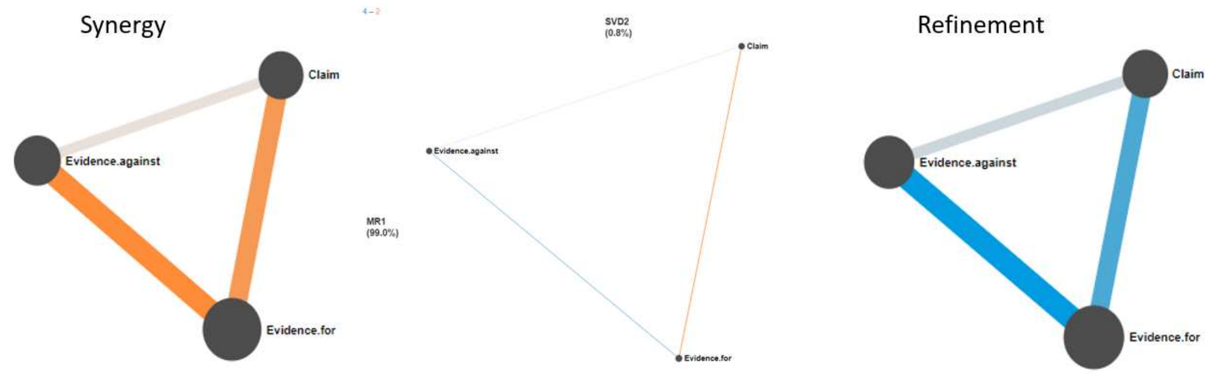
Behavioral patterns of argumentation

The study investigated students' actual sequential argumentation behavior during the process through the Epistemic Network Analysis (ENA) to identify connections and changes between student's CA behaviors. ENA is a learning analytic method that can identify connections among elements in coded data through quantifying the co-occurrence of the codes (Shaffer et al., 2016; Shaffer & Ruis, 2017). ENA measures the co-occurrence of coded elements using adjacency matrices within certain temporal context and then visualizes the patterns of connections in a network graph. ENA has been applied to analyze collaborative learning and discourse (Bressler et al., 2019). Originally developed to model cognitive networks, ENA can be employed to model patterns of associations in any system with a dynamic fixed set of elements (Shaffer & Ruis, 2017), including behavior patterns such as gaze coordination (Andrist et al., 2018). In this study, ENA was adopted to investigate the relationships between argumentation patterns mediated by the CSCA environment AppleTree and compare the behavior patterns in two different phases-synergy (before peer assessment) and refinement (after peer assessment). The data used for ENA was students' online argumentation with temporal sequence. The size of the stanza was set to four, meaning that ENA calculated the co-occurrence of the codes in every four argumentative behaviors.

These data were analyzed and visualized using the ENA web tool version 3.0 (http://www.epistemicnetwork.org/) to provide insight into dynamic learning behavioral patterns and complement the traditional statistical analysis to answer the first research question from a different angle. The ENA results are summarized in Figure 2 which presents a mean CSCA network for the synergy phase 1 (left, orange), the refinement phase 3 (right, blue), and a difference network graph (center) that compares the two phases. The ENA results illustrated how the argumentation behavioral patterns of the synergy phase and the refinement phase in CSCA differed. At the synergy phase, students in each group had stronger connections between 'claim' and 'evidence for'. It meant that students tended to focus more on adding evidence to support their claims, resulting in 'claim' co-occurred more with 'evidence for'. At the refinement phase, students in each group made stronger connections between 'evidence against' and 'evidence for', and 'evidence against' and 'claim'. It meant that students tended to focus more on adding opposing evidence to their claims to acknowledge the different perspectives, resulting in 'evidence against' co-occurred more with 'claim' and 'evidence for'.

These results indicated an improvement in the 'Multiple perspectives' dimension in terms of argumentation behaviors. The change in behaviors of the two phases suggested that students became more aware of different and opposing viewpoints and were actively integrating opposing evidence and perspectives into their argumentation mind map during CSCA. Interpreted from an argumentation aspect, such behavioral change revealed that students were learning to consider different perspectives to establish the credibility of the argument. Interpreted from an SSI literacy aspect, such behavioral change showed that students were learning to acknowledge and analyze the complexity of SSI.

Figure 2
CSCA behavioral network for the synergy (Phase 1) and refinement phases (Phase 3)



Discussion and conclusion

This study examines the effect of CSCA on secondary school students' SSI learning and the online argumentation patterns of CSCA in English language classrooms in Singapore. The results confirmed the beneficial effects of CSCA for innovative teaching initiatives such as SSI in literacy classrooms. Being a study conducted in authentic learning contexts, the findings have more ecological validity than lab-based experiments. The findings of this study corroborate with the past findings that a CSCA learning approach can help with the development of argumentation skills and content knowledge (Chen et al., 2021; Hsu et al., 2015; Wang, 2014).

In response to the efforts of helping students to consider multiple perspectives in composing argumentation (Crowell & Kuhn, 2014), the findings from this study have revealed that the graph-oriented CSCA provides opportunities for students to respect and appreciate each other's multiple perspectives. It is noted that students have certain knowledge about argumentation and SSI, and can help each other improve even without teachers' explicit instructions. The findings highlight the affordance of exchanging ideas in the shared working space enabled by the graph-based CSCA environment. Such affordance can enable students to see other ways and ideas of approaching an SSI topic, thus empowering students to analyze an issue from the perspectives of different stakeholders—an important competence in the learning of SSI (Zeidler et al., 2019).

There are several limitations of this study. The first limitation is that there was no control group in the study when examining the effect of CSCA on students SSI learning because of the authentic context in classroom. Future research can be done by using experimental design to establish more conclusive findings on the effect of CSCA on SSI learning, The second limitation was the relatively short time for students to refine their group argumentation artifacts. Students from all the classes only had less than 10 minutes to refine their group work. In order to draw a better conclusion in the future, a longer intervention over a period of time might be needed. Apart from the relatively small sample size, the current data analysis only focused on students' group products and argumentation behaviours. Future studies can be conducted to encompass student's perspectives and self-report data for a more holistic understanding on students' engagement of CSCA.

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