Wong, L.-H. et al. (Eds.) (2013). Proceedings of the 21st International Conference on Computers in Education. Indonesia: Asia-Pacific Society for Computers in Education

Empowering argumentation in the science classroom with a complex CSCL environment

Wenli CHEN[a*], Chee-Kit LOOI[b], WentingXIE[c] & Yun WEN[d]
National Institute of Education, Singapore
*wenli.chen@nie.edu.sg

Abstract: Understanding the significance of argumentation in the learning and doing of science, the community of computer-supported collaborative learning has developed an increasing interest in argumentation. To empower the teaching and learning of science in real classrooms, a collaborative argumentation tool (called AppleTree) embedding three scaffolding mechanisms, namely, dual representational and interactional spaces, automated assessment for learning, and staged-based collaboration scripts, has been designed and developed using a design research approach. This paper presents the design rationale of the system and its realized prototype. A pilot study in a secondary science grade 1class is also reported. Preliminary data analysis results point towards validation of the effectiveness of the system on empowering learning and its usability.

Keywords: Collaborative argumentation, science learning, assessment for learning

1. Introduction

Engaging argumentation in science teaching and learning has long been stressed. The recognition that argumentation deserves a place in the pedagogy of science (Lin, Hong, Wang, & Lee, 2011), from the cognitive perspective, is based on the substantiatedclaim that argumentation is an effective process through which students improve conceptual learning and process skills (Noroozi et al., 2013). From the socio-cultural perspective, argumentation is the “core epistemic practice” in science (Bricker & Bell, 2009), and as a structural element of the language of science, argumentation is essential in doing and communicating science, and instrumental to the growth of scientific knowledge (Lemke, 1990). Thus science learning could be framed as the appropriation of argumentation practices(Osborne, Erduran, & Simon, 2004).

Being cognizant of the paramount value ofargumentation to science learning, the computer-supported collaborative learning (CSCL) community expressed an increasing interest in argumentation (Bouyias&Demetriadis, 2012) and developed a good number of technology-enhanced learning environments(Scheuer et al., 2010) that promote the teaching and learning of argumentation and provide students with new and rich opportunities for complex collaborative learning through argumentation. In these environments, the representation, construction and sharing of arguments within and between learner groups are facilitated (Noroozi, et al., 2013). Yet problems also arise as students may engage only in low level argumentation (Bell, 2004) and not elaborate and reflect on knowledge (Barron, 2003), thus do not improve in knowledge as expected (Fischer, Bruhn, Gräsel, &Mandl, 2002). These make it clear that argumentation does not necessary lead to improved learning and external support is needed to induce productive argumentation-based peer interaction (Bouyias&Demetriadis, 2012).

Motivated by the progress achieved and problems encountered in the computer supported collaborative argumentation (CSCA) studies, we aim to develop AppleTree, a complex CSCL environment with multiple mechanisms to scaffold collaborative argumentation to empower learning in the science classroom using the design research approach. This paper focuses on introducing the design rationale and the prototype of the system and its piloting in a secondary science class. The pilot study is conducted to examine the effectiveness of the system on empowering learning and its usability.

2. Literature Review

The section reviews the relevant literature to identify the key design components

2.1 Representational and Interactional Space

In the online environment, equal participation can be enhanced as the slow-paced, shy or weaker students are allowed more time for argument construction and for contributing to the group discussion, which may otherwise be interrupted or dominated by outspoken or aggressive students in the face to face environment (Veerman, Andriessen, &Kanselaar, 2000; Nussbaum & Jacobson, 2004). The provision of representations of argumentation also benefits students as it encourages them to make their opinions and arguments explicit, to negotiate and elaborate to come to a shared understanding, to focus on the task, and to maintain the consistency andplausibility the argumentation (Munneke, van Amelsvoort, &Andriessen, 2003; Suthers, 2003). This raises the question of how representational and interaction spaces should be designed to facilitate online argumentation.
Existing CSCA tools have used different types of representations of argumentation (Suthers, 2003). In general, there are two types of tools, namely discussion-based tools and knowledge representation tools (Van Bruggen&Kirschner, 2003). In discussion-based tools (e.g., “CSILE”, Scardamalia, Bereiter, &Lamon, 1994), the environment offers students the opportunity to exchange arguments, yet the structure of argumentation is not explicitly represented. In knowledge representation tools (e.g., “Belvedere”, Paolucci, Suthers, & Weiner, 1995) the structure of argumentation is explicitly represented. Investigations have been made to compare the effects of different types of representations on the construction and communication of arguments. Relatively more research advocates that graphic representation is more beneficial than the linear texts as diagrams can clarify relations (Suthers, 2003), represent structure (Schwarz, Neuman, Gil, &Ilya, 2000), provide overviews (Larkin& Simon, 1987), maintain focus (Veerman, 2000), and enhance reflection on alternative perspectives (Kolodner&Guzdial, 1996). Nevertheless, this issue remains controversial as the evidence gained is still far from being sufficient (Amelsvoort, Andriessen, &Kanselaar, 2007). Kanselaar et al (2002) argue that a combination of structured and unstructured interaction modes can support argumentative processes. In the task window, students are required to construct argumentative diagrams. This may encourage them to attend to multiple perspectives and to elaborate arguments. In the communication window/chat boxes, combining free text entry and well-designed argument moves/sentence openers stimulates students to critically check the information.

2.2 Assessment For Learning

To foster productive collaboration, Jermann and Dillenbourg (2008) proposed the regulation approach, that is, taking actions “on the fly” when unexpected events occur during interaction, as an effective way to structure collaboration. Regulation is a complex skill that requires a quick assessment of the current interaction situation and its compatibility with the desired (Jermann&Dillengourg, 2008). This is consistent with “assessment for learning” which occurs during the teaching and learning process rather than after it, and has as its primary focus on the ongoing improvement of learning with the provision of descriptive feedback (Chappuis&Stiggins, 2002). However, with current technologies, assessing the cognitive aspect of collaborative learning automatically is indeed difficult. The established automated assessments are mainly focused on the social aspect (e.g., Janssen, Erkens, Kanselaar, & Jaspers, 2007). One possible way to address this issue is to engage peer assessment that students critically assess each other’s contributions and provide focused feedbacks (King, 1999; Veerman, et al., 2000). Besides enabling assessment, peer assessment is also a learning mechanism as prompting students to rate contributions may encourage reflection (Rummel&Spada, 2005) and requesting students to give explanations may enhance knowledge construction (Wecker& Fisher, 2006). With computer support and peer assessment, timely and richly provision of information of the learning processes can be attained. Yet as computer supported assessment is syntactic not semantic, to realize assessment for learning, students themselves can and should be the evaluator and interpreter of their learning and thus they can manage theirlearning accordingly--know how they learn best, where they are in relation to the learning goals and plan next moves (Chappuis&Stiggins, 2002).

2.3 *Scripts For Learning*

In CSCL research, the role of collaboration scripts has been extensively discussed. The use of scripts can be an effective technique to assist students to understand and participate in argumentative discourse and facilitate argumentative knowledge construction (Bouyias, Demetriadis, &Tsoukalas, 2007). Different process categories of argumentative knowledge construction (e.g., the construction of a single argument, the construction of argumentation sequences) are distinguished and various forms of collaboration scripts have been designed to facilitate these particular processes (Noroozi et al., 2013). Communication-oriented scripts are composed to facilitate interaction and social modes of co-construction (e.g., Rummel&Spada, 2005). With the recognition of students' difficulties in doing collaborative argumentation as aforementioned and teachers' challenges in designing and implementing collaborative argumentation activities, a CSCA tool embedding a stage-based collaboration script with a focus on guiding argumentation sequences and communication is needed.

3. AppleTree Instantiation

The motivation for the design of AppleTree stems from a literature review that identified key design components of CSCA tools and current approaches to improving learning in CSCL. AppleTree is envisaged as a multiuser tool embedding three mechanisms, namely dual representational and interactional spaces, automated assessment for learning, and a stage-based collaboration script, to scaffold collaborative argumentation.

3.1 *Dual Representational and Interactional Spaces*

Considering the respective advantages of graphic and linear representations and the different preference of interaction medium by different students, both graphic representations (on a public working space) and linear texts (in the chat box) are used in AppleTree (see Figure 1). The chatting tool also supports coordinating and regulating group work. On graph-based argumentation space, an argument is an organized set of argument elements represented by nodes and/or directed links. The specific types of argument elements designed are in accordance with Toulmin's Argumentation Pattern (TAP) (1958). For pragmatic considerations (e.g., understandability oflower secondary school students) (Scheuer, et al., 2010), the original TAP model is simplified. Three argument elements, namely claim, evidence for and evidence against are identified as the essential components of an ideal argument. These three elements are indicated by: 1) the type of Node: Claim vs Evidence and/or; 2) the type of directed Link: For vsAgainst. To encourage brainstorming and pooling of ideas, a bubble node with an undirected link as the "placeholder" for initial ideas is provided (see Figure 1).

The AppleTree chat box incorporates the basic features of a chat room. Besides, the chat can be linked with any post on the board with a drag and drop gesture. The post dragged and dropped will be attached to the end of that chat and represented by an attachment icon. When the user clicks the icon, the post will be highlighted on the group argumentation graph and the content of the post will below the chat room (see Figure 1).

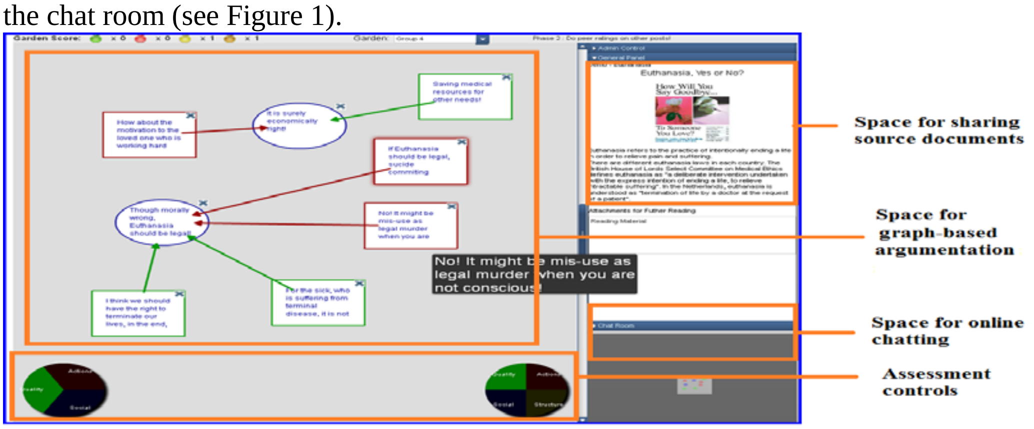


Figure 1. Interface of the AppleTree System

3.2 Assessment For Learning

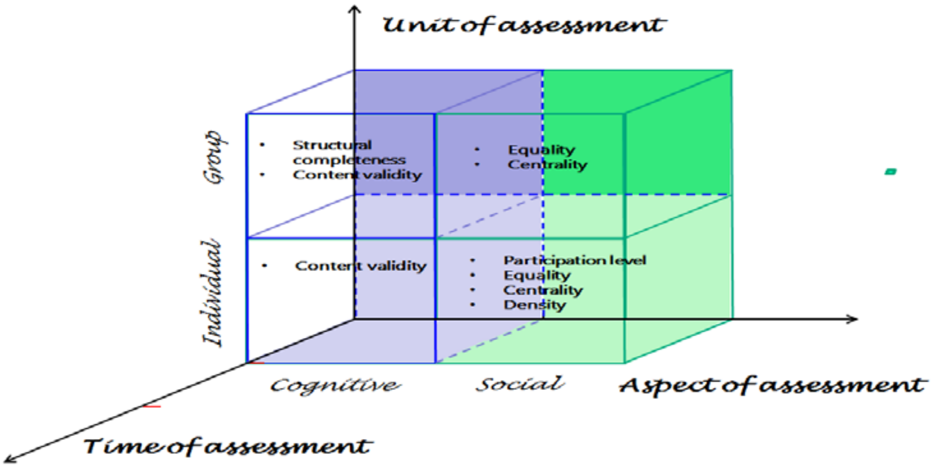
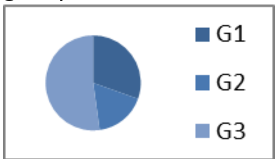
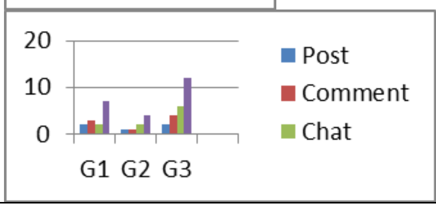


Figure 2.A framework for assessing collaborative argumentation

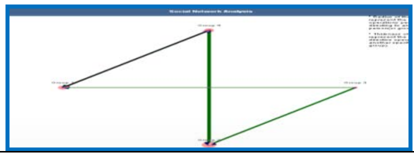
Combining computer support, self-evaluation and peer assessment, AppleTree provides theseaspects of assessment depicted in the three dimensions: the dimension of cognitive & social; the dimension of the time of assessment: real-time & longitudinal; the dimension of the unit of assessment: individual & group. Figure 2 presents a holistic view of the assessment components embedded. The cognitive aspect of collaborative argumentation is about the construction of sound and syntactically valid arguments which can be measured by the *structure* (using Erduran, Simon, & Osborne's grading scheme, 2004) and *content validity* (assessed by peers) of the argument. The social aspect of collaborative argumentation is about students' participation in constructing and communication of arguments which can be measured by *the amount of contributions* and *interactions* with others (using social network analysis). Besides, the assessments of social and cognitive aspects can be applied to both individuals and groups and to different time periods (real-time & longitudinal). In AppleTree, we designed two crystal balls (representing individual-level and group-level assessment respectively) to visually integrate all these assessment components. Taking assessment component at group level as an example, we illustrate they operationalization and visualization in Table 1.

Table1. AppleTree assessment components and visualization (Group level assessments)

Component	Operationalization	Visualization
	"Action" is about the frequency with which each student participates in different types of collaborative activities, namely, constructing arguments within the group(Posting), rating and commenting (Comment) other groups' work and Chatting with others (Chat). This assesses the social aspect of collaborative argumentation based learning environment (CABLE) and reflects the participation and equality of participation.	When students click "Action", the system will display pie and bar charts to illustrate the distribution of different types of activities of each group.  
	"Social" is about the frequency of participating and interacting with other groups of a group in collaborative argumentation based on Social Network Analysis. In the analysis of the	When students click "Social" , the system will display the social network analysis diagram to illustrate the participation rate of each group (represented by the volume of the

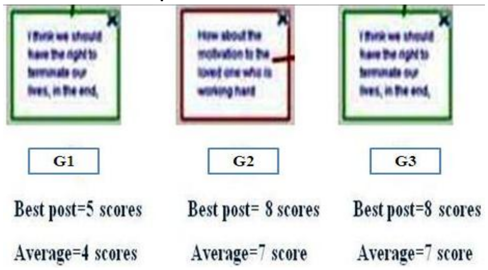
social network established, “Density” and “Centrality” are calculated. Social assesses the social aspect of CABLE and reflects participation and interactivity.

node) and the interaction rate the group has with others (represented by the thickness of the directed arrow).

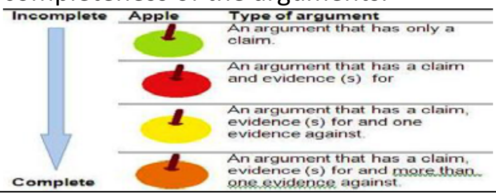


“Quality” is about the extent to which the “Evidence For” and “Evidence Against” produced is validate based on peer-assessment result. In peer-rating, each student will decide whether the evidence proposed in other groups each is valid or not by selecting “Like”, “Neutral”, or “Dislike”. Different types of judgments are assigned with different scores and the Quality is reflected by the total score of the argument elements. This assesses the cognitive aspect of CABLE and reflects the content validity of the arguments.

When students click “Quality”, the system will display the average score of the posts a group has developed. The post which has received the best score will be provided as well.



“Structure” is about the extent to which the argument produced is complete based on Erduran, Simon, & Osborne (2004)’s grading scheme. This assesses the cognitive aspect of CABLE and reflects the structural completeness of the arguments.



When students click “Structure”, the system will display the distribution of different types of arguments (represented by different types of Apples).

3.3 Staged-Based Collaboration Script

A stage-based collaboration script with a focus on guiding argumentation sequences (argument-counterargument-integration, Leitão, 2000) and communication is embedded in AppleTree to further scaffold the teaching and learning of collaborative argumentation.

- The teacher organizes students into small groups and introduces the task.
- Provided with source documents and assigned roles (e.g., advocate vs opponent), students brainstorm, generate and improve their own arguments and then to challenge the alternative arguments within the group.
- Once having completed one owngroup’s product, studentsvisit other groups’ spaces to review others’ work. They rate the quality of the argumentsand provide commentsto other groups (commenting on comments is also allowed). Justifications for their judgment have to be provided as well (Figure 3). During intra-group and inter-group interaction, the teacher and students can generate assessments with which they can adjust the teaching and learning processes.
- Students return to their own group to further improve the arguments by addressing the comments received from other groups, and discussing how to integrate the good points gained from other groups.
- If time permits, more rounds of peer-rating and commenting can be enacted to inspire greater improvement in group work.

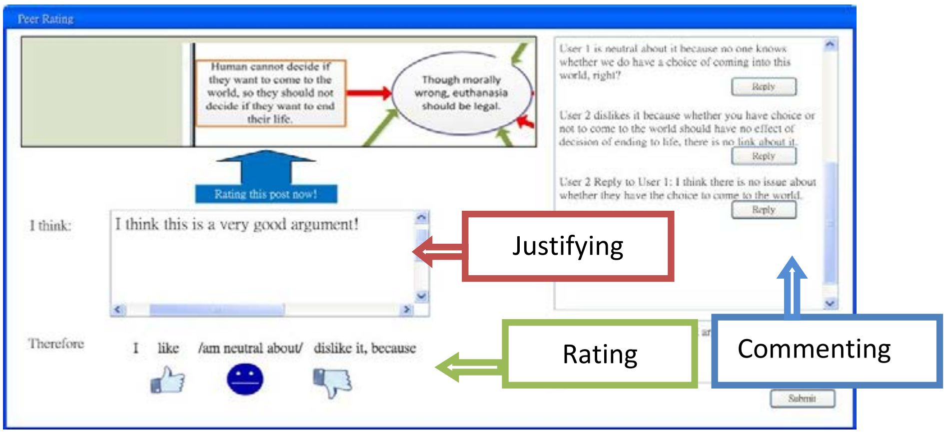


Figure 3. Peer-rating and commenting on AppleTree

During these iterative cycles of interaction, students are constantly involved in reflective thinking and negotiation processes by exercising their critical thinking and communication skills. They are also encouraged to take the perspectives held by others into consideration, through which they gradually develop a comprehensive and holistic understanding about the topic. Based on the stored artefacts, students can easily decide on their group stand on the issue. Variations of this generic script are also possible. For example, teachers can assign students (or groups) holding contradictory viewpoints to do a debate or to work in a group. In practice, adaptations can be made to this generic script.

4. A Pilot Study

An exploratory study was conduct in a secondary science grade 1 class to 1) examine whether AppleTree can help students improve their understanding of scientific knowledge; 2) assess the utility and usability of AppleTree system; 3) and investigate whether embedding automated assessment for learning in AppleTree leads to better learning gains.

4.1 Participants and activity design

32 students from a 7th grade class of a neighborhood school in Singapore participated in this study. They were heterogeneously grouped into 8 groups by their science teacher according to the school final-year examination score of science. They were randomly assigned to 2 experimental conditions (4 groups for each): 1) using AppleTree with the assessment functions (experimental group) and 2) using AppleTree without the assessment functions (controlgroup). The topic of the lesson was “diversity of plant and animal life”. A same lesson plan (co-designed by the teacher and researchers) was used in two separate lessons (90 minutes per lesson including pre and post-tests) for the two groups. The science teacher of the class instructed both lessons (control first). The lesson was designed to help students articulate the common characteristics of different types of animals, basing on which they can categorize living organisms. In the lesson, the main learning task for students was to identify an imaginary animal into Amphibians, Reptiles, Birds, or Mammals. The lesson design was in accordance with the proposed script (see Table 2).

Table 2. Lesson design

Learning activity	Time
1. Task introduction	5 mins
• Teacher introduced the scenario of the task	
• Teacher encouraged and motivated students to participate in the task.	
• Teacher guided students to enter the AppleTree system.	
2. Task Stage I: Intra-group (Constructing)	15 mins
• Students went through the source document	

• Students provided individual claims without providing evidence • Students deleted identical claims within a group. • Students provided evidence supporting each claim • Students challenged each other's claim/evidence within the group	
3. Task Stage II: Inter-group (Rating & Commenting) • Students visited another group's board (assigned by the teacher using Round Robin) to evaluate their postings. • Students who had finished the assigned rating and commenting work were encouraged to evaluate more groups' work • Students viewed comments from other groups	15 mins
4. Task Stage III: Intra-group (Enhancing) • Students improved their group work and took a group stand on the issue	8 mins
5. Conclusion • Teacher commented on students' answers and revealed the answer • Teacher guided students to clarify the controversial points	7 mins

4.2 Data source

A pre-&post-test design using the same test items (2 multiple choice questions and 1 open-ended question, validated by a group of science teachers) was used to examine whether the students hadimproved their understanding of the scientific knowledge (i.e. common characteristics of different type of animals) involved and whether the experiment Group, provided with AppleTree assessment for learning, performed better than the control group. The total score of the test was 25. The two tests were administered at the beginning and the end of the lessons respectively (5 minutes for each test).The test papers were independently marked by two researchers. Good inter-rate reliability (*r*= .81) measured with Cohen's kappa was achieved. Process data on how students used AppleTree was collected via a screen capturing software Morae 2.0 installed on every computer. Two researchers observed the lesson and took down detailed notes. All the process data were collected and put into analysis to examine students' engagement in the learning task and the utility and usability of the AppleTree system. Based on Morae recordings, two researchers coded and counted the time a student group (one from the E-Group was chosen through random selection) spent on different types of interaction (see Table 3). Moreover, the time the students from the E-Group spent on using the AppleTree assessment was also coded and calculated.

Table 3.Scheme for coding types of interaction

Category	Description
Argumentation-oriented interaction	Students construct, elaborate and communicate arguments. e.g., What you provided is not evidence.
Coordination-oriented interaction	Students regulate and manage their group work (e.g. negotiating working procedures or seeking assistance). e.g., We don't have enough time. Hurry.
Off-task interaction	Students discuss off-task topics. e.g., My computer is so slow.

4.3 Results

An independent same test was employed to examine the differences of pre-test scores between the experimental group and control group. Pre-test scores suggested the experimental group and the control group were equally competent in science (t (15) =1.32, p> .05). Students in both groups had higher scores in the post-test than they did in the pre-test. Statistical differences can be found in both the experimental group (t (15) =-4.60, p< .01) and the control group (t (15) =4.59, p< .01). No significant differences of learning gains (post-test score minus pre-test score) can be found in the experimental group and the control group (t (15) =-0.17, p> .05). The mean score of the experimental group (M=18.19) was higher than that of the control group (M=16.88) in the post-test.

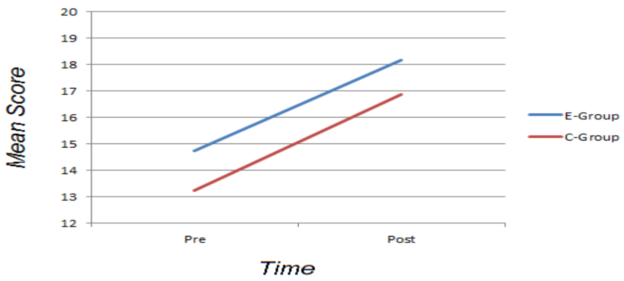


Figure 4. Pre-and Post-test scores

In the 90-minute lesson for the experimental group, the teacher used 16 minutes and 25 seconds to provide instructions. Excluding the time for instruction, greeting and tests, students spent 57 minutes and 50 seconds working in AppleTree. The results suggested high student engagement in the learning activity as little off-task interaction was observed. This was in consistence with the researchers' in-class observation. Most of time, students were developing arguments on the graph-based argumentation space. Though less adopted, the provision of online chatting was also useful as it enabled the coordination of group work, an important aspect of productive collaboration.

Table 4. Time distribution of different types of interactions using AppleTree (E-group)

		Graphical space	Online chatting	Total
On-task	Argumentation based interaction	32m33s	3m01s	46m36s
	Coordination based interaction		11m02s	
Off-task			2m03s	2m03s

Students from the E-Group did spend some time getting feedback about their performance using the AppleTree assessment. For instance, they sometimes clicked "Quality" to check the average score of the posts developed by themselves or their groups. The posts with extremely high or low scores were the ones that often caught students' attention and students often negotiated and discussed these posts with their peers. The average using time was 8 minutes and 54 seconds with a high standard deviation of 4 minutes and 33 seconds (Table 4). This suggested great variations between students though they had the same technical training and support (a user manual). As noted, some students frequently generated and read assessment reports while others only concentrated on developing arguments. Besides, though multiple assessment components embedded in AppleTree, students mostly used peer-rating. Other assessments were seldom used. This phenomenon, to some extent, could be ascribed to the collaboration scripts adopted. In both intra-and inter-group activities, students were asked to challenge each other's claim or evidence, and rate and comment on others' work. In other words, peer-rating was required to be used. That students did not use the assessments extensively was probably due to the fact that students were not familiar with the assessments and they had no clear idea how to interpret and react to the feedback provided by these assessments such as "Structure" or "Social". That students did not use the assessment sufficiently could possibly explain why no significant difference was found between the experimental group and the control group in learning gains.

5. Discussion and Future Work

In this paper, we introduced the design rationale and main features of our assessment-embedded CSCA system. This pilot study on design and implementation of AppleTree in science lesson, points towards some validation of the system on empowering learning. Our next step is to study the usability and the effectiveness of incorporating automated assessment for learning in CSCA in further experiments. In the short duration of usage of the system, the students may need more time to be familiarized and to understand the why and how of using the assessment. We also need to continue our professional development sessions for teachers to help them better understand and utilize AppleTree to design science lessons and enact collaborative argumentation activity making use of automated feedback. The system development and school implementation is still ongoing. More results will be reported in the near future. Through further design-based research practices using AppleTree, we can further conduct investigations into students' learning and interaction processes in scientific collaborative argumentation, automated assessment for learning, and teaching orchestration and learning regulation.

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