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Wikis for a Collaborative Problem-Solving (CPS) Module for Secondary School Science

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ABSTRACT

Collaborative problem solving (CPS) can support online learning by enabling interactions for social and cognitive processes. Teachers may not have sufficient knowledge to support such interactions, so support needs to be designed into learning modules for this purpose. This study investigates to what extent an online module for teaching nutrition in secondary school science, using a wiki for CPS, enables interactions, and social and cognitive processes. The module was implemented with 31 volunteer participants. Data collected from the online communications was analyzed for the types of interactions and processes based on the Community of Inquiry Framework. This was triangulated using transcripts of interviews with students. In addition, pretests and posttests were conducted to determine whether the learning outcomes were achieved. Analysis of the online communications showed that the interactions were mainly between learner and content (64.4%), with a large portion of cognitive processes (69.3%) but little social (4.0%), attitudes (9.9%), teaching processes (12.9%) and noise (5.9%). The findings suggest that the module could be used to improve outcomes of learning and encourage interactions for cognitive processes and online presences. The findings may provide insights in encouraging CPS for learning science online.

Keywords

Collaborative problem-solving, Community of Inquiry Framework, Online pedagogy, Wiki

Introduction

Collaborative problem-solving (CPS) in online environments can afford high levels of interactions among learners which can serve to develop critical thinking skills (Kim & Song, 2006; Manathunga & Hernández-Leo, 2015). The authentic and non-linear approach in problem-solving with sufficient support from peers, instructors and the learning environment can support learning (Cela, Sicilia & Sánchez, 2015; Heo, Lim, & Kim, 2010; Puntambekar, 2006; Siraj & Norman, 2012; Vaughan & Garrison, 2005). Collaborative learning and problem-solving have also been shown to be effective in science education, yet few studies have examined online collaboration and problem-solving in science (Slotta & Linn, 2000; van der Spa, 2004; Turcotte, 2012). In this paper, the integration of collaborative problem solving in a wiki to support science education is addressed. What is perhaps unique is the investigation of collaboration and interaction activities in the wiki and the measurements made to determine how CPS activities in the wiki may have contributed to learning science.

In Malaysia, mathematics and science achievement have declined in the last 5 years (Ministry of Education Malaysia, 2013). In order to assist in improving the education system, several shifts have been identified in the Malaysia Education Blueprint 2013-2025 to ensure that students could compete globally (MOE, 2013). One of the shifts identified is for the use of Information and Communication Technology (ICT) using new pedagogies to deliver quality education. However, in Malaysian schools, CPS and new pedagogies are rarely used in teaching science in secondary schools (Mohamad Said, 2011). Teachers generally teach facts and concepts, and emphasize memorization and recall (DeWitt & Siraj, 2008; Phang, Abu, Ali, & Salleh, 2012). Teachers perceive there is a lack of time for completing the syllabus in the classroom and rarely use ICT for instruction (DeWitt & Siraj, 2008). In addition, to be able to employ ICT for instruction, teachers require knowledge of online pedagogies. The principles of an online pedagogy include: (a) students are responsible for their learning as they search for materials and build their knowledge, and (b) students should collaborate and interact while working on projects (Pelz, 2004).

This study investigates to what extent CPS can support those principles of online pedagogy in the context of teaching science in a Malaysian school. This study is a single case with a specific cultural context; however, it can assist in the implementation of online CPS in other schools in Malaysia and in the region. A module using a wiki was used in this study. Due to the lack of time, the CPS module was implemented outside the classroom after school hours. A wiki was chosen to minimize the burden on teachers while emphasizing collaborative problem solving. It is assumed that successful implementation requires knowledgeable and engaged teachers.

In this study, collaborative learning is defined as new knowledge, skills and attitudes acquired as a result of interactions in a group (Jonassen, Lee, Yang, & Laffey, 2005). Collaborative mLearning occurs when new knowledge and skills can be accessed anywhere and anytime in online environments, and the acquisition of knowledge is a result of online interactions in a group (DeWitt & Siraj, 2008). These online interactions include postings on wikis, discussion forums and chat groups.

Purpose of the research

This study investigates to what extent a module using a wiki for online CPS is useful for learning science. The research questions were:

- What kinds of student interactions occur in a wiki for learning science?
- To what extent does CPS in a wiki encourage social interactions, and cognitive processes?
- To what extent does the module improve achievement?

Interactions for understanding in science

In science instruction, providing opportunities for interaction and collaboration is important for learners to acquire scientific knowledge (Etkina, Mestre, & O'Donnell, 2005; Hogan & Fisherkeller, 2005; Osbourne & Henessy, 2003). Scientific verbal knowledge assists the construction of meaningful language to discuss and give feedback during communication (Hogan & Fisherkeller, 2005).

In collaborative learning, learners communicate and resolve differences during discussions to reach mutual understanding (Jonassen et al., 2005; Palloff & Pratt, 1999). This process of collaboration and resolving differences can develop learners' critical thinking skills (Kim & Song, 2006). The learners' interactions, from learner to learner; learner with the instructor; and learner with the learning materials, can enhance understanding of science concepts and principles (Kim & Song, 2006). However, interactions alone do not ensure effective collaboration among the groups; tasks and guidance are needed to ensure effective online learning collaboration (Collazos, Guerrero, Pino, & Ochoa, 2003).

Collaborative problem-solving (CPS)

Collaborative learning is a natural learning process (Vygotsky, 1962; 1988); it occurs as a result of learners' responses and interactions within the community of learners (Barrows & Tamblyn, 1980; Johnson & Johnson, 2004; Seel, 2003; Spector, 2004). Learning is still an individual process, but is influenced by group and inter-personal interactions (Kaye, 1992; Manathunga & Hernández-Leo, 2015). Each individual brings prior knowledge and perspectives to the learning environment, and collaborative learning allows these different perspectives to form a shared knowledge within the community as a result of social interactions (Jonassen et al., 2005; Kaye, 1992; Palloff & Pratt, 1999).

The dialogues and interactions with other learners and the instructor can have a positive influence on learning. When collaborative activities effectively promote learning, positive interdependence develops as group members work together on shared tasks and resolve conflicts while working toward a common goal (Collazos et al., 2003). However, negative interdependence may occur when individuals have little interaction and do not focus on the goals of the group..

Problem-solving tasks allow learners to take responsibility for their own learning, which is the first online pedagogical principle (Barrows & Tamblyn, 1980; Johnson & Johnson, 2004; Pelz, 2004; Seel, 2003; Spector, 2004). In line with this principle, learning should be learner-directed and the instructors' role is to provide the learning tasks and support (Hannafin et al., 2009; Johnson & Johnson, 2004; Jonassen et al., 2005; Pelz, 2004). Learners should be allowed the responsibility to determine their own learning (Hannafin et al., 2009).

Ill-structured problem-solving tasks are meaningful and authentic. Creative ideas are generated and higher order thinking increased during the interactions in problem-solving activities (Hannafin et al., 2009; Heo et al., 2010; Jonassen et al., 2005; Palloff & Pratt, 1999; Puntambekar, 2006; Siraj & Norman, 2012; Vaughan, 2010; Woo & Reeves, 2007).

Lack of adequate prior knowledge may contribute to learners' misconceptions (Hannafin et al., 2009; Kirschner, Sweller, & Clark, 2006). Hence, the importance of the second online pedagogical principle, interaction, for scaffolding among peers, with an instructor, or with the content and technology, through system prompts, support the learner in solving ill-structured problems (Hannafin et al., 2009; Pelz, 2004; Vaughan & Garrison, 2005). Scaffolding, through interactions, could assist learners in constructing accurate representations of solution to problems (Belland, 2010)

CPS promotes strategies for positive interdependence. Scaffolding needs to be incorporated with the suitable problem tasks as learners help each other in the collaborative classrooms, aided by their instructor to improve learning achievement (Collazos et al., 2003; Whipp & Lorentz, 2009). The instructor should not intervene too much in the online interactions and instead allow learners to be independent and learn from their peers; however, the groups still need to be monitored and some guidance and scaffolding should be provided to help students reason through ill-structured problem tasks (An, 2010; Collazos et al., 2003).

In this study, the problem-solving task required learners to be responsible for their learning as they search for information and post solutions on the wiki. Support was provided in the content and reference learning materials and tools; support came from peers and the instructor.

Wikis for collaboration

Wikis and discussion forums have been used for collaborative learning in an inquiry-based teaching approach in science (Slotta & Linn, 2000; van der Spa, 2004; Turcotte, 2012). Wikis enable high levels of collaboration and stronger mutual engagement in the community of learners who interact with each other (Lu, Lai & Law, 2010). When used for problem-solving and social interaction, wikis can encourage reflection, critical thinking, motivation and understanding (Altanopoulou, Tselios, Katsanos, Georgoutsou, & Panagiotaki, 2015; Biasutti & El-Deghaidy, 2012; Driscoll, 2007; Higdon & Topaz, 2009; Jonassen et al., 2005; Kaye, 1992; Lu, Lai & Law, 2010; Osbourne & Hennessy, 2003; Siraj & Norman, 2012).

Wikis have been used for documenting scientific inquiry in secondary school science (DeWitt, 2010; DeWitt, Alias & Siraj, 2015; Hannafin et al., 2009). Designed for collaboration, this asynchronous communication tool can transform knowledge as learners generate, share and reshape knowledge (Bonk, Lee, Kim, & Lin, 2009). Learners participate in active learning and contribute to building knowledge on the wiki (Bonk et al., 2009; Pifarré & Li, 2012). When information is obtained and evaluated, the learner assimilates and applies the knowledge while solving problems (Biasutti & El-Deghaidy, 2012). Simultaneously, the learner's peers and instructors scaffold him or her to achieve expert status (Pifarré & Li, 2012; Whipp & Lorentz, 2009).

Wikis can enable development of reading and writing skills (Imperatore, 2009; Shihab, 2009). When CPS is employed in wikis, it can assist in developing project management skills as learners are responsible for managing their teams, assigning roles and responsibilities, improving motivation, and monitoring group efforts (Biasutti & El-Deghaidy, 2012; Ertmer et al., 2011; Hannafin et al., 2009).

Some studies have shown low interaction between learners involved in activities on wikis; however, on investigation the lack of interaction was due to the lack of knowledge (Ertmer et al., 2011; Huang, 2010). Students feared negative judgment; the decreased confidence and expectancy for success was the problem (Ertmer et al., 2011). As a result, it is important to ensure that students have the requisite knowledge need to make positive contributions in the wiki.

The full potential of wikis in learning science needs to be investigated further to determine its usefulness in supporting an online pedagogy which enables self-directed learning, promotes interactions, and maintains an online presence with social and cognitive processes for learning (Ertmer et al., 2011). As the type of interactions in a wiki used for CPS may differ from other Web-based learning tools, there is a need to investigate the processes present in a wiki (Huang, 2010; Pelz, 2004). This study represents one step in that direction.

Processes in online interactions

A progressive pedagogy encourages higher order thinking as instructors use arguments, debates, dilemmas for conceptual conflicts, sharing of ideas, reflection and problem-solving in instruction and encourage positive interdependence in collaborative groups (Collazos et al., 2003; Kanuka, 2010; Spector, 2015). Pelz (2004) summarized three principles for effective online pedagogy: students are responsible for their learning as they independently lead discussions, access materials, assist their peers and perform self-assessment; interactivity is maintained through collaborative activities; and online presences is enabled through social, cognitive, and teaching presences. In this study, the collaborative task allowed students to be self-directed learners, and an attempt to measure the interactions and presences were made.

However, collaborative processes are difficult to measure. Most researchers focused on the outcomes of the collaborative process using tests, while others some have attempted to measure group performance. The Index of Collaboration uses metrics such as number of errors during the activity, ability to solve problems, number of queries, explicit use of a strategy, maintaining and communicating the strategy and the different forms of messages (Collazos, Guerrero, Pino, Renzi, Klobas, Ortega, Redondo, & Bravo, 2007). These metrics were used as indicators, examples, for developing strategies and intra-group cooperation, reviewing success criteria, and monitoring group performance (Collazos et al., 2007). Attitudes and social aspects were not measured. However, Collazos et al. (2007) did recommend that other factors be studied in future: subject of the collaborative task, age, culture, and types of groups.

In CPS, the type and quality of interactions could influence learning. Originally, three types of online interaction were classified: learner-content, learner-learner, and learner- instructor (Moore & Kearsley, 2005). Later, another category of online interaction where the learner interacts with the technology medium or learner-interface interaction, was included (Hillman, Willis, & Gunawardena, 1994; Thurmond & Wambach, 2004). Meaningful interactions are important as solving authentic and meaningful problems will enhance learning (Kim & Song, 2006; Woo & Reeves, 2007).

Table 1. Categories for analysis of online interactions

Categories of interactions	Explanation
Cognitive Process:	Critical thinking components: triggering, exploration, integration and resolution
• Triggering	Phrases that encourage thinking about or posing a problem
• Exploration	Phrases that are related but are not supported, phases which indicate search for information
• Integration	Phrases that build on previous messages and are supported. This is the development of a possible solution
• Resolution	Phrases that suggest a hypothesis and ways to test and assess the solution
Teaching Presence	Design of the learning experience, as well as delivery and facilitation of students (and teacher)
Social Presence	Characteristics of social interaction such as cohesiveness.
Attitude	Components that indicate the affective aspect of communication
Noise	Communications that cannot be categorized

Note. Adapted from Shedletsky (2010), and Pinzon-Salcedo et al. (2008).

Online interactions can be further analyzed to determine cognitive, social, and teaching processes, and attitudes (Moore & Kearsley, 2005). Some research reports show little evidence of the cognitive processes in students' online communications (Garrison, Anderson, & Archer, 2010), but other research shows evidence of more critical thinking processes in online communications as compared to face-to-face communications (Shedletsky, 2010). These interactions can be analyzed using the Community of Inquiry (COI) Framework for *social, cognitive and teaching presence* (Garrison et al., 2010; Vaughan, 2010). Shedletsky (2010) included a fourth category, *discourse*. Further, Pinzon-Salcedo, Barros, Zarama, de Meza, Carulla, and Bejarano (2008) included two additional categories: (a) *attitudes* about interaction (affective aspect), and (b) *noise* (communications that could not be identified or placed in other categories). These two categories can be analyzed as part of the discourse (Shedletsky, 2010). Hence, the types of presence and processes can be investigated. In this study, social, cognitive and teaching presence, as well as attitudes and noise were analyzed in the wiki (see Table 1).

In this study, the interactions in the online environment were analyzed to determine the types of interactions and presences (Pelz, 2004) and the outcomes of learning were compared using pretests and posttests results.

Methodology

Significance of the study

The results of this study can be used to determine if CPS using wikis encourages an online pedagogy suitable for learning. Teachers could then use this approach in teaching online and developing positive interdependent tasks for self-directed learning, and enable interactions for an online presence for learning.

Scope and limitations

In this study, an urban secondary school with a multiracial population reflective of the multiracial communities in Malaysia was selected on the bases of representativeness and convenience. The sample of 31 student volunteers comprising of high, medium and low-achievers in science were selected to participate in the implementation of a science lesson on Food Classes. Lessons were designed and developed for evaluation in this study using a wiki for CPS. One limitation in this study is that only the online interactions in the wiki and in the discussion forum were captured and analyzed. There may have been face-to-face interactions, but these were not analyzed as it was not within the scope of the study. In addition, the focus of the study was on the interactions, presences, and achievement as an outcome of learning, and not on other metrics of collaboration.

Instruments

Firstly, the online interactions were analyzed and classified as learner-content, learner-learner, learner-instructor, and learner-interface. Next, the interactions were analyzed based on the categories of cognitive, social, and teaching presences, as well as attitude and noise (see Table 1). Coding of the online documentations on the wiki was done by the researcher based on these categories and reconfirmed by a co-researcher to determine if there were differences in coding. The differences were resolved through discussion.

The second instrument involved two sets of test questions consisting of simple open ended questions for pretest and posttest. This test was designed to determine students' achievement in the Food Classes module. The 10 items in each instrument tested the same constructs, such as naming the foods in the different food classes. The instrument was content-validated by two Biology teachers with more than 10 years' working experience, and is in use for testing understanding of the module's content.

Implementation procedure

A CPS module using a wiki was developed for learning food classes. The participants could use the module either during, or after school hours, and laptops were made available for those who did not have access to computers. Students worked in groups of seven to eight on the wiki. The students who volunteered to use the module were given a face-to face orientation to the module, which consists of a web page with links to learning resources and tools, and the problem tasks and a wiki was set up for each group for the task which was to analyze the food classes in a meal.

Different meals were assigned to the groups, and they were given three weeks to complete the task on their group wiki page. The group members could add pages, links and graphics to their wiki page. During the implementation, feedback on the task could be given on the wiki or through other forms of communication by other learners and the instructor. The instructor communicated online, but the students interacted both online and face-to-face in the school environment.

Results and discussion

Data collection and analysis

In this study, data were collected from communications on the wiki and discussion forums, journal records; interviews after task completion and tests (An, 2010; Whipp & Lorentz, 2009). The communications and solution displayed in the wiki were coded and analyzed according to the types of interactions (Hillman et al., 1994; Moore & Kearsley, 2005; Thurmond & Wambach, 2004) and further into processes (Pinzon-Salcedo et al., 2008; Shedletsky, 2010). In addition, randomly selected students were interviewed to probe further into the process and the problems encountered. The pretest and posttest scores were analyzed for significance using a paired *t*-test to compare means of their scores.

Types of interactions

The first research question to determine the types of interactions among students in the context of the study when using a wiki showed the interactions occurring in the wiki were mainly learner-content (see Table 2). There was little evidence of learner-learner interaction, and learner-interface interaction on the wiki.

Table 2. Types of interactions on wiki in all groups

Types of interaction	*f*	(%)
Learner – Content	29	(64.4)
Learner – Learner	3	(6.7)
Learner – Instructor	13	(28.9)
Learner – Interface	0	(0.0)
	45	(100.0)

Note. *f* = frequency of interactions.

Lack of learner-learner interactions seemed to be because learners only posted information on the problem solution on the wiki. An example of interaction in one group discussed what they needed to do:

W: What do we need to do?
M: I think that they want us to classify the meals.
N: Should we classify the meals?

This lack of interaction on the wiki seems to be similar to other studies (Ertmer et al., 2011; Huang, 2010). Interviews suggested that the apparent lack of contribution in the wiki was because group discussions had already taken place in online chats and face-to-face discussions.

There was evidence of learner-instructor interaction through emails and text messages on *Yahoo Messenger*, an online chat application. The instructor had given suggestions through text-message chat on how to improve the task and assisted in solving a technical problem (Figure 1). Hence, the absence of interaction on the wiki did not mean there were no interactions.

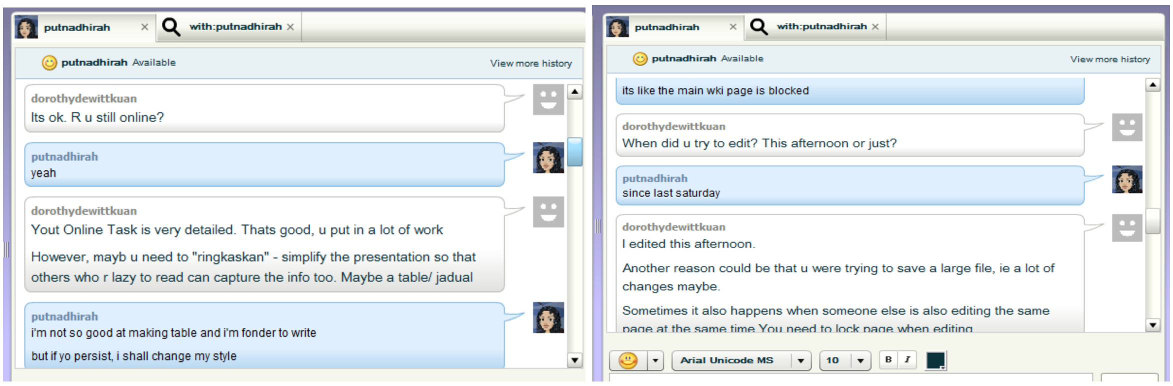

Figure 1. Learner-instructor interactions in a discussion forum

There was little positive interdependence strategy for the instructor to redirect questions learners posed back to the individual, or to ask teams to seek help from other teams (Collazos et al., 2003). Learners seem to prefer interacting with the instructor. However, the groups seemed to achieve positive goal interdependence as there was motivation in working together for task completion, perhaps because there was reward independence due to the marks given for successful group work (Collazos et al., 2003).

As for learner-content interaction, participants collaborated on the tasks in most groups. However in all groups, there seemed to be one dominant member posting most of the solutions. This was because the groups had assigned one group member responsible for wiki posts (Ertmer et al., 2011),

Social and cognitive processes

To answer the second research question on social interactions and cognitive processes, analysis of the online communications transcripts was conducted. There were mostly cognitive processes (69.3%), with very little social (4.0%), attitude (9.9%), teaching (12.9%) and noise (5.9%) on the wiki (see Table 3). Analyzing the cognitive processes, hardly any triggering interactions to encourage thinking on the issues occurred on the wiki, but there was evidence of some exploration (3.0%) in searching and connecting information. A large proportion in all groups was integration (54.5%), in which messages are built on other messages in order to construct a solution, while resolution to assess the solution was much lower (11.9%).

Table 3. Categories of interactions on the wiki

Categories of	Group 1		Group 2		Group 3		Group 4		Total	
interactions	*f*	(%)	*f*	(%)	*f*	(%)	*f*	(%)	*f*	(%)
Cognitive Process:										
• Triggering	0	(0%)	0	(0%)	0	(0%)	0	(0%)	0	(0%)
• Exploration	1	(33.3%)	0	(0%)	2	(66.7%)	0	(0%)	3	(3.0%)
• Integration	22	(40.0%)	6	(10.9%)	5	(9.1%)	22	(40.0%)	55	(54.5%)
• Resolution	3	(25.0%)	0	(0%)	6	(50.0%)	3	(25.0%)	12	(11.9%)
Teaching Presence	2	(15.4%)	5	(38.5%)	2	(66.7%)	4	(30.8%)	13	(12.9%)
Social Presence	0	(0%)	1	(25.0%)	0	(0%)	3	(75.0%)	4	(4.0%)
Attitudes	10	(100.0%)	0	(0%)	0	(0%)	0	(0%)	10	(9.9%)
Noise	5	(83.3%)	1	(16.7%)	0	(0%)	0	(0%)	6	(5.9%)
Total	43	(42.6%)	13	(12.9%)	13	(12.9%)	32	(31.7%)	101	(100.0%)

The lack of triggering interactions could be attributed to the fact that the wiki was considered as a space to publish their completed task. It is believed that the triggering interactions occurred during the face-to-face interactions and was not captured online. This was reinforced during the interview when members clarified group discussions was done on other platforms before posting online.

Evidence of exploration was seen as in two groups. In one case, a tool for computing the number of calories in the different meal ingredients was shared: "*I utilized the tool to compare nutrition data.*" In another example, a statement on comparison of the type of flour was made to gather information for group agreement: "*The recipe included 100gm of whole meal flour, that's nearest to whole- grain wheat flour.*"

There was integration recorded in all groups, as messages are built on other messages in order to construct a solution with the highest number in Groups 1 and 4 (40.0% each). The statements written showed the solution directly, example: "*That contains 339 calories. There is 2g of fat and 73g carbohydrates, with 12g is dietary fiber and 14g of protein.*"

Resolution, a higher level process in which the solution is assessed, was observed in three groups. In one example the learner made an assessment that there were other minerals they had not learnt in school.

There seems to be a lot of Vitamin B (Thiamin, riboflavin, niacin, folate and vitamin B6 and B12 - are all vitamin Bs), a little of vitamin E and K. It is also rich in iron and phosphorus, and a bit of calcium. There is also a lot more minerals which we do not learn about in school.

In another example, the food classes in the chapatti meal were discussed, and the learner concluded that it comprised all the food classes:

So in chapatti alone there is carbohydrate, protein, fat, vitamins A, B, E and K, minerals calcium, iron, phosphorous. Fiber and water too. I think most of the food classes are here.

Social interactions were few, and detected in two groups, for example:

M: *I know it's a bit late but I found out a lot about our meal. Nasi lemak is served for breakfast and is widely eaten by all races. The rice is served with anchovies and peanuts.*
N: *I don't like it, it always gets stuck in my throat.*

Where it occurred, social interactions were a positive interdependence for the group. However, fewer social processes online did not mean there was less interactions among group members, as the social processes seemed to have occurred outside the wiki.

On the other hand, the teaching process was evidenced in all groups when the instructor was asked questions on discussion forums and online chats, and when learners accessed content for learning. There was a lot of noise and attitude among the learners. The birthday wishes in Figure 2 was considered social, and noise. The description after one meal, a meal *Yum…yum!,* is considered noise. Another example, *"Some just eat nasi lemak to save money."* Attitude can be seen from an elaborate description of the meal: "*As its name suggests, the rice is cooked by steaming in coconut cream with pandan leaves to give a seductive fragrance. Spices such as ginger and lemon grass may be added for fragrance."*

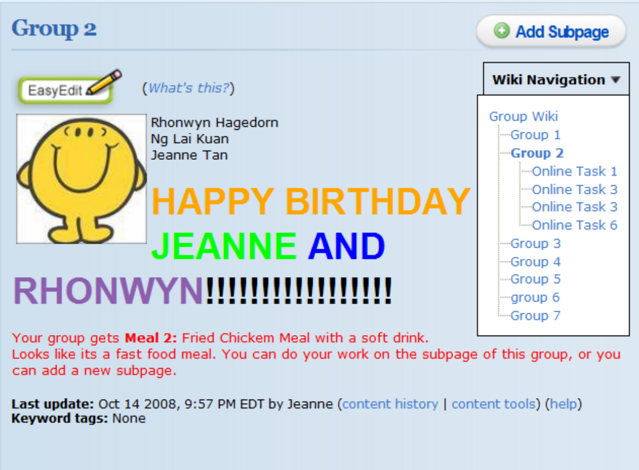

Figure 2. Screen capture showing noise and attitudes in the wiki (Group 2)

To answer the research questions, there were cognitive and social processes occurring. Specifically, there seemed to be few triggering processes probably because the search for information was not required in the task. There were also not many explorations of the solution probably because discussions to explore the suggested solutions were done elsewhere, face-to face or online, and were not captured on the wiki.

Hence, more opportunities for sharing and debating ideas online should be provided, such as an online chat platform for group members. This might also promote social processes which are important in encouraging a positive attitude among group members towards online learning for positive interdependence. Hence, the pedagogy should include opportunity for learners to explore, search and share information with group members assigned different resources to share in the group (Collazos et al., 2003).

The highest cognitive process, resolution, did occur in the wiki as learners assessed the solutions but only in three groups. Learners might not be able to demonstrate it effectively. In the wiki, a simple form of assessing the solution was indicated. In future, an assessment of their work should be included as part of the CPS task. In conclusion, social and cognitive processes did occur, but might not have been captured on the online interactions in the wiki. These processes were important and contributed to science learning.

Learning effectiveness

The final research question is whether interactions improved outcomes for learning science. The effectiveness of the CPS module was analyzed using paired *t*-test for 31 participants to determine if any significant differences existed between the mean pre and post test scores. Table 6 shows the results of *t*-test comparison of pre and posttest achievement. The findings showed that the CPS module is effective for teaching science. There is a significant difference between pretest (mean = 62.37, SD = 19.23) and posttest (mean = 82.55, SD = 12.78) scores, $t(31) = 7.230$, $p < .05$ (Table 4). The *t*-test indicates that the mean score of the posttest is significantly higher than for the pretest.

These findings are verified from the large number of cognitive interactions in the wiki. The learners demonstrated the different cognitive processes of exploration, integration and resolution in the online interactions on the wiki in most groups. Social interactions are important for learning science as these develop learners’ cognitive skills (Karpov & Haywood, 1998). In this study, there was not much online social interaction recorded. However, the face-to-face peer interactions had facilitated the knowledge-building processes.

Table 4. *t*-test comparison of pre and posttest scores

	Pretest (n = 31)	Posttest (n = 31)	t-value	p	Effect size
Mean	62.37	82.55	7.230	< .05	0.00
SD	19.23	12.78			

Note. n = number of participants.

Implications and conclusions

The learners in this study were novice users of the wiki and unfamiliar with ill-structured problem-solving processes. They were accustomed to traditional teacher-centered instruction. However, this did not seem to be a problem as regardless of their lack of experience in online CPS, the learners managed to present acceptable solutions on the wiki. In addition, they managed to participate in the tasks, which afforded the principles of effective online pedagogy. The learners were responsible for their learning and were self-directed, actively interacting and collaborating, and striving for social, cognitive or teaching presence (Pelz, 2004).

There did not seem to be many interactions in the wiki but it was not because of lack of knowledge as cognitive processes were detected on the wiki (Ertmer et al., 2011; Huang, 2010). The interactions between learners were conducted outside the wiki as well. Hence, future studies should be conducted to investigate these interactions as well. Similar studies could be conducted in a more controlled environment to capture both online and offline interactions for learning. Another alternative is to conduct the study with group members who are separated by distance, and unable to conduct face-to-face meetings except through online platforms.

The instructors could play an important role in scaffolding learners for positive interdependence toward achieving higher level cognitive skills and preparing learners for learning environments with ill-structured problem-solving. Further investigation is required to determine whether additional support strategies for positive interdependence and social interactions between the instructor and among learner-learner interaction could increase cognitive skills in such complex, ill-structured problem-solving environments.

Social interactions are important for learning science (Hogan & Fishkeller, 2005). In addition, interactivity and creating social presence is important for online pedagogies. During CPS, social interactions contribute to the acquisition of knowledge and skills through cognitive processes such as concept-formation, resolving differences and critical thinking (Tzeng, Chiang, Yang, & Huang, 2012; Karpov & Haywood, 1998; Kim & Song, 2006). Hence, there is a need for investigating the strategies for encouraging social interactions. In addition, future studies could be done to determine whether academic performance could improve with the use of wikis for CPS in other subjects besides science.

This study supports prior research and indicates that CPS can be conducted in a wiki (Altanopoulou et al., 2015; Bonk et al., 2009; Manathunga & Hernández-Leo, 2015; Pifarré & Li, 2012). In addition, a CPS module using a wiki can be effective for teaching science and developing cognitive skills and processes among novice learners. The interactions and presences on the wiki can help transform learning and develop understanding in online environments.

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