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Title: The use of wikis in a science inquiry-based project in a primary school

Abstract: This study explored the use of wikis in a science inquiry-based project conducted with Primary 6 students (aged 11 - 12). It used an online wiki-based platform called PBworks and addressed the following research questions: (1) What are students' attitudes toward learning with wikis? (2) What are students' interactions in online group collaboration with wikis? (3) What have students learned with wikis in a science inquiry-based project in a primary school context? Analyses of the quantitative and qualitative data showed that with respect to the first research question, the students held positive attitudes toward the platform at the end of the study. With respect to the second research question, the students actively engaged in various forms of learning-related interactions using the platform that extended to more meaningful offline interactions. With respect to the third research question, the students developed Internet search skills, collaborative problem solving competencies, and critical inquiry abilities. It is concluded that a well-planned wiki-based learning experience, framed within an inquiry project-based approach facilitated by students' online collaborative

knowledge construction, is conducive to the learning and teaching of science inquiry-based projects in primary school.

Keywords Wikis**,** Inquiry-based learning, Project-based learning, Inquiry project-based learning, Science education, Primary education

Introduction

Today's students, from kindergarten to secondary school, are often referred to as 'digital natives' (Prensky, 2001) or 'net gens' (Tapscott, 2008). They are creative, interactive, and media savvy (Greenhow, Robelia, & Hughes, 2009), and are heavy consumers of information and communication technology (ICT) both in and outside school. They grow up in a participatory culture and are often involved in some form of co-creation, such as Wikipedia (Tapscott, 2008). Social media can play an important role in education by providing a learning environment that suits this generation of students. Arguably, both teachers and students should be prepared for the new challenges to learning and teaching brought about by the adoption of social media.

This study focused on the use of the social media tool wikis in primary education. Several studies have demonstrated the educational benefits of using wikis for primary school students. Desilets and Paquet (2005) showed that primary school students (Grades 4-6) were able to use

wikis for the purpose of collaborative Web-based storytelling, and included guidelines to enable teachers to use wikis for collaborative storytelling in classroom. A study by Li, Chu, and Ki (2014) on collaborative writing in Chinese revealed that primary school students showed positive attitudes toward an online collaborative discussion platform, while Woo, Chu, Ho, and Li (2011) suggested that wikis helped primary school students to collaboratively engage in creative problem solving and peer critiquing. Students can even improve their language abilities and writing skills through collaborative writing in a second language. A study by Wong, Chen, Chai, Chin, and Gao (2011) on collaborative writing in a second language indicated that primary school students' writing skills were significantly improved, and the improvement was attributable to the emerging peer coaching practices among them.

Apart from collaborative writing, inquiry-based learning allows students to construct new knowledge as they make sense of the information they have discovered, and to extend their learning beyond normal classroom teaching. When students work in groups on a given project, they can learn from each other throughout the process, even at the primary level (students aged 6 to 12). However, few studies have examined collaborative inquiry-based learning in a wiki environment. We believe that it is essential to examine how collaborative inquiry-based learning using wikis can be integrated into learning and teaching at the primary school level. Therefore, in this study we investigated collaborative inquiry-based learning among students in the context of a science inquiry-based project.

We anticipate that the incorporation of wikis into the learning and teaching process will help students to develop a learning routine in and outside school in a collaborative inquiry-based learning environment. We hope that this educational practice will help to inform new and effective learning and teaching approaches in the primary school curriculum.

Literature Review

The theoretical framework of this study is based on collaborative inquiry project-based learning in a technology supported environment. We first review a number of studies on inquiry-based learning and project-based learning within a constructivist learning paradigm, as collaboration has been identified as a key component of such a paradigm (Carr, Jonassen, Litzinger, & Marra, 1998). We then focus our review on the use of wikis for collaborative inquiry project-based learning.

Collaborative inquiry project-based learning

Biggs (1996) claimed that in constructivism, "meaning is created by the learner, not imposed by reality or transmitted by direct instruction" (p. 348). Mayer, Moreno, Boire, and Vagge (1999) noted that constructivist learning takes place when learners actively create meaningful mental representations from the given information. Collaboration is an important element in constructivism because there are opportunities for individuals to test their own understanding and at the same time examine others' thoughts to expand their understanding

and learning (Savery & Duffy, 1995). Jonassen (1999) suggested that "learning most naturally occurs not in isolation but by teams of people working together to solve problems" (p. 228). He argued that a collaborative learning environment should provide access to shared information for students to construct knowledge together. O'Loughlin (1992) also asserted that students should be encouraged to collaborate with others in the knowledge construction process.

Inquiry project-based learning is a combination of inquiry-based learning and project-based learning. According to Savery (2006), inquiry-based learning is "a student-centered, active learning approach focusing on questioning, critical thinking, and problem solving" (p. 16). Hmelo-Silver, Duncan, and Chinn (2007) pointed out that inquiry-based learning heavily emphasizes collaborative learning activities in which "students are cognitively engaged in sense making, developing evidence-based explanations, and communicating their ideas" (p. 100). This mode of learning also allows students to associate their existing knowledge with new experiences, refine and accommodate previously held beliefs and conceptual models, and create new knowledge (Llewellyn, 2002).

Colburn (2000) suggested that successful inquiry-based instruction involves more than merely preparing curriculum materials. Teachers play a crucial role in facilitating the learning process, during which they may pose questions, provide demonstrations, and generate hypotheses for students to explore during the discovery stage (Moran, 2007). Students thus

learn from their teachers while at the same time constructing knowledge through their own investigations (Hazari, North, & Moreland, 2009).

In project-based learning, students engage in in-depth exploration of issues, themes, or problems with no predefined answers, and then present their findings in their final products (Krajcik & Blumenfeld, 2006). Generic skills including problem-solving, critical thinking, collaboration, self-management skills, and communication skills are employed in the learning process (Education Bureau [EDB], 2001). Project-based learning has been identified as one of the most successful approaches to implement inquiry-based learning (EDB, 2002). In inquiry project-based learning, students often investigate collaboratively with the support of technology to find solutions to a problem, and then evaluate their findings through discussion (Savery, 2006). With the advantages of inquiry-based learning and project-based learning over traditional didactic teaching (Hmelo-Silver, Duncan, & Chinn, 2007; Gallagher & Gallagher, 2013), integrating inquiry-based learning and project-based learning in student group work has been tried out with positive learning outcomes (Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 1998; Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013).

The use of wikis for collaborative inquiry project-based learning

In reviewing various approaches to collaborative learning, Dillenbourg (1999) asserted that a collaborative situation should be interactive and should influence the cognitive processes of the collaborators. One prominent aspect of cognitive influence is the motivation students develop as a result of collaboration with each other - motivation is socially constructed, and maintained by "an active and ongoing process of socially shared or coregulation" (Järvelä, Järvenoja, and Volet, 2010, p.18). In layman terms, students help each other in the collaboration process during learning. More capable students scaffold their own learning through providing explanations to those who are less capable. The less capable students are help-seekers, and they play an active role in interpreting the explanations they receive (Webb & Matergeorge, 2003).

With these criteria of collaboration in mind, wikis provide an effective platform for collaborative learning. Primarily used in writing assignments, group projects, and online and distance education (Parker & Chao, 2007), wikis enable students to engage in collaborative activities that might not be possible in a classroom setting (Educause, 2005). They also make it possible for students who are geographically separated from one another to develop social ties (Wheeler, Yeomans, & Wheeler, 2008). For instance, in collaborative class projects, wikis allow students to meet online at any time and any place and work together on projects (Byron, 2005). Team members can have access to shared resources, create task lists, and make

individual contributions to co-construct a project based on wikis (Hazari *et al.*, 2009). As wikis can be used as a notepad for common information items, they enhance project knowledge management, which includes brainstorming and exchanging ideas, coordinating activities, and coordinating and recording meetings (Parker & Chao, 2007). Wikis also serve as a knowledge creation platform that promotes collaborative problem solving and provokes critical inquiry, such that project outcomes are enhanced (Chu, Siu, Liang, Capio, & Wu, 2013, Pifarré & Li, 2012). All these functions make wikis an efficient platform for communication, sharing, and collaboration.

Empirical studies on the use of wikis for collaborative learning have been conducted in primary schools with positive results. Fu, Chu, and Kang (2013) selected students from four Chinese primary schools to examine the use of wikis in the subject of General Studies. Surveys and interviews with students showed that they held positive attitudes toward the online collaborative discussion platform. Similar results were obtained in Schmid and Trevisan's (2013) empirical study, in which students were enthusiastic about the use of wikis and shared creative ideas through the platform, while teachers appreciated that they could monitor students' progress and give timely feedback. With regards to scaffolding student learning, Woo, Chu, Ho, and Li (2011) examined the use of a wiki for collaborative English writing in a Chinese primary school, with the results highlighting the wiki's key affordances in facilitating students to collaborate on creative problem solving and peer critiquing. A small-scale study by

Pifarré and Fisher (2011) demonstrated that wikis facilitated and supported primary school students aged 9 to 10 in their use of composition and revision strategies. Content analysis of students' writing using wikis showed that the tool encouraged students to share ideas so that they could learn from other students' points of view to enrich their own writing. The above studies all suggested that wikis were well received by users and were able to facilitate effective collaboration.

Research gaps

Although social media tools such as wikis are increasingly used for educational purposes (Ertmer, Newby, Liu, Tomory, Yu, & Lee, 2011), there has been comparatively little research on their use at the primary school level. There has been even less research on collaborative inquiry project-based learning. This study addressed these research gaps by exploring the effectiveness of using wikis for collaborative inquiry project-based learning for students in a primary school setting. It investigated students' interactions and learning using wikis and also their attitudes toward such learning. This study contributes to the development of new pedagogical practices that make use of social media tools. Based on the studies reviewed, the following research questions were proposed:

RQ1. What are students' attitudes toward learning with wikis?

RQ2. What are students' interactions in online group collaboration with wikis?

RQ3. What have students learned with wikis in a science inquiry-based project in a primary school context?

Method

Participants

The participants were 37 Primary 6 (Grade 6; aged 11-12) students attending a local primary girls' school in Hong Kong. The school adopted English as the medium of instruction, meaning that students were educated in a second language (with their native language being Cantonese). There were four mixed-ability classes at the Primary 6 level and one class was randomly selected to participate in this study. The students in the selected class were divided into mixed-ability groups according to their average academic performance in Chinese, English, Mathematics, and General Studies subjects, with four to five members in each group.

Each group member was responsible for the role she was allocated within the group. The design was based on Johnson and Johnson's (1984) roles for cooperative learning-based groups. Student A was the facilitator, who ensured that the project was on the right track and made decisions for the group when there were differences of opinions among the group members. Student B was the checker, who checked the accuracy of the group work and ensured that the work was of good quality. Student C was the IT helper, who supported the members when they encountered problems while using the online platform by asking the teacher for help

or solving the problems on their own. Student D was the noise monitor, who ensured the group remained on task in the discussion on the online platform.

Design and implementation of the wiki-based inquiry learning experience

In collaborative inquiry project-based learning, the students are required to investigate together with the support of technology to find solutions to a problem that has no predefined answers, present their findings in their final products, and then evaluate their findings through discussion. The principles of this learning approach guided the design of the following tasks for the students to complete with the facilitation of the teacher:

Task 1: Mindmap. All students would build their online mindmaps (https://bubbl.us/) on the topic ‘forms of energy’ and upload to the wiki. Each student had to give comments on their group members’ mindmaps and at least comment on one of their classmates in other groups.

Task 2: Energy in Daily life. Students needed to find pictures/videos/websites about the application of energy conversion in daily life on the Internet and share their findings on the wiki.

Task 3: Problem Setting. Students worked in groups, they had to solve a problem that they discovered while using a modern machine and write about 100 words on the problem.

Task 4: Designing a Machine. Students had to design a machine that could solve the problem they identified and explain how it worked. Students were reminded to include the

principles of the conversion of energy. They could use either PowerPoint or Paint to create illustrations of their machine.

Task 5: Presentation. Each group would present their final product in class. Their peers evaluated their work. As this was not a learning task that counts toward the students' learning achievement report, the whole project was not graded. Yet the teacher considered the learning progress, participation, and attitudes as part of the daily participation score. The teacher went through the tasks that students had to work on in the classroom. The teacher would then monitor each student's progress on the wiki and provide oral (if necessary) and written feedback/comments on each group's performance in tasks. The teacher would remind students to work on the tasks if she noticed that the students' progress was not on track or if some students were not collaborating with their fellow group members. Students were allowed to seek advice from the teacher for all tasks, both in person during class or on the wiki platform. The teacher was also responsible for teaching students IT skills required in using the platform. Most of the technical problems raised by students regarding the use of the platform were managed by the teacher.

Measures

The adapted survey from Hazari *et al*. (2009) and the focus group interview questions adapted from Li, Chu, Ki, and Woo (2012) were used to assess students' learning attitudes, online interactions, and learning benefits with wikis, which attempted to answer RQ1, RQ2, and RQ3. The viewing frequency and the comments on students' group pages and the "Problem Setting" part of the project provided additional information for students' online interactions to answer RQ2. Students' findings from the Internet and their designed machines were examined to determine whether students developed Internet search skills, collaborative problem solving competencies, and critical inquiry abilities after the completion of the tasks, which were the learning objectives under RQ3.

Procedure

The students participated in the study for 7 weeks during their General Studies lessons. The selected topic, "Technologies and Daily Life," is one of the major themes in the primary General Studies curriculum. Students were taught the conversion of energy and were introduced to some simple machines. The online platform PBworks (http://pbworks.com/academic.wiki) was used for the project. This platform was selected because the students had used it for small-scale group work during Computer and General Studies lessons for one week in the previous academic year. The lessons were planned for online learning both in and outside the classroom.

In the first stage, the students mainly worked on their own. First, a K-W-L chart (What I *K*now, What I *W*ant to Know, What I *L*earned) adapted from Ogle (1986) was given to the students to understand their current level of knowledge and their learning expectations. Upon filling up the charts, the teacher selected some students to present what they had written on their charts. This exercise improved the students' orientation of the project.

Next, the students each used e-Mindmap (https://bubbl.us/) to generate a mindmap showing their understanding of the types of energy and posted them on PBworks for comments (See Figure 1). In the next step, the students searched the Internet and collected information about the application of energy conversion in daily life. In the second stage, the students began to work in mixed-ability groups. They worked together on using modern machines to solve problems that they have encountered in daily life. The goal of the task was to create a machine that could solve the problem that the students had identified. In the last stage, they presented their ideas to the whole class and completed a questionnaire survey.

<<Insert Figure 1 here>>

The survey items were adapted from the instrument used by Hazari *et al*. (2009). Good internal consistency was demonstrated in the four subscales, (learning, $\alpha = 0.92$, motivation, $\alpha = 0.93$, group interaction, $\alpha = 0.87$, and technology, $\alpha = 0.85$), and in the overall scale ($\alpha = 0.97$). The results of the item analysis suggested that the items showed higher correlations with their respective scales than when compared with the items on the other subscales, and supported the

convergent and discriminant validity of the scale (Gerbing & Anderson, 1988). Fifteen items were selected to form three subscales (attitudes, $\alpha = 0.84$, group interactions, $\alpha = 0.74$, and learning with technology, $\alpha = 0.80$), because these items were the most relevant to address the above three research questions (see Table 1). The Cronbach's alphas of the three subscales were all greater than 0.7, providing evidence of modest reliability in the early stage of the research (Nunnally, 1978). The items were anchored on a 5-point Likert-type scale from 1 "strongly disagree" to 5 "strongly agree".

<<Insert Table 1 here>>

The teacher conducted focus group interviews with each group after the completion of all of the presentations (see Appendix 1). The interview questions were adapted from a study of Chinese primary school students' collaborative writing experience with a wiki-based application (Li, Chu, Ki, & Woo, 2012). Two research assistants independently coded the focus group interview transcripts using the NVivo software. The following six themes were identified in the coding scheme (see Appendix 2): (i) attitudes toward wiki (both positive and negative); (ii) interactions; (iii) learning experience; (iv) wiki way of learning vs traditional way of learning; (v) information search; and (vi) teacher's guidance (Bricki & Green, 2007). The coders were experienced and well-trained in qualitative data coding. The first coder was the teacher in charge of the project and was also the students' subject teacher. She obtained a master's degree in Library and Information Management. The second coder was a part-time

research assistant working in a center for information technology in education at a university, and held a master's degree in Applied English Linguistics. The inter-rater reliability for the groups ranged from 80.0 to 86.7% with an overall mean of 83.3%, which is considered excellent (Hallgren, 2012).

Results

Students' attitudes toward the online discussion platform

The data from the student survey and the focus group interviews helped to answer research question RQ1. For the closed-ended statements, students were asked if it was easy for them to browse and edit the posts on PBworks (Q4), whether it was worth spending their learning time on PBworks (Q6), whether PBworks helped them to become more involved in learning the topic (Q7), whether PBworks made the learning topic more interesting (Q8), whether their knowledge had increased through learning with PBworks (Q11), and whether they would recommend PBworks to their friends (Q15). All of the statements had mean ratings above 3, ranging from 3.4 (Q15) to 3.9 (Q4 and Q11), and subscale mean was 3.7 (sd = 1.0). The results suggested that the students generally had positive attitudes toward using PBworks as an online collaborative tool.

All 37 students participated in the focus group interviews in their assigned groups. The qualitative data collected in the interviews further supported the quantitative findings of the survey.

Theme 1: Attitudes toward wiki. Some students mentioned in the focus group interview that they found PBworks convenient and good to use for different reasons. For example, the following interview excerpts illustrated this characterization:

“We can add comments, chat together and discuss.”

“Even when I am at home I can communicate with my friends.”

“In PBworks we have a record of everything.”

“We prefer talking on PBworks because we can express our feelings easily.”

“We don’t have to access the platform at the same time but we can still chat there.”

Some students also mentioned that they would like to use the online discussion platform again if they needed to do another project because they did not have much time for face-to-face discussion at school. This benefit was demonstrated by the following interview excerpts:

“It is convenient to do work at home instead of at school.”

“I think doing group work online is quite a good idea because we usually find and search information on the Internet.”

“We don’t have to do all the work at school.”

“I don’t have to meet my friends at recess time.”

The students identified many advantages in using the online collaborative method, and shared their positive feedback in the interviews. For example, consider the following interview excerpts:

“We also learn how to communicate and cooperate with others.”

“We can use others’ comments to improve our project and make it better.”

“One of the advantages is that we can share our findings easily on the Internet.”

“You can do it at any time or anywhere, even if it’s a school holiday.”

“We learn a lot of about teamwork, being independent and self-learning, and also creativity.”

The students’ positive feedback was generally in line with the findings from the survey. However, there was some negative feedback about the online collaborative method. Some students found it difficult to learn with this approach. The following interview excerpts exemplified this point:

“We can just see others’ words but we cannot see their facial expression.”

“PBworks is quite difficult to use.”

“I think in a face-to-face meeting, we can talk faster and obtain the solution faster too.”

“If others cannot use the computer, we need to talk about what we talked about before at school.”

“Sometimes if you have problems with your computer, then it can affect the process.”

Students’ interactions in online group collaboration

The quantitative data from the student survey and the qualitative data from the focus group interviews were analyzed to answer the second research question (RQ2). For the closed-ended statements, students were asked if they enjoyed their classmates reading their feedback on PBworks (Q2), whether they enjoyed using PBworks as a discussion tool (Q3), whether they had more communication with their fellow group members when using PBworks (Q10), and whether PBworks made compromising within the group easier (Q12). All of the statements had mean ratings above 3, ranging from 3.4 (Q3 and Q10) to 4.1 (Q2), and the subscale mean was 3.7 (sd = 1.0). The results indicated that the students enjoyed the experience of collaborating with their fellow group members using PBworks. They enjoyed the process of collaboration on the online platform.

The number of times each student's page was viewed and the comments on PBworks were tracked. Figure 2 shows how often each student's page was viewed on PBworks. These figures further supported the results of the student survey.

<<Insert Figure 2 here>>

The frequency of page viewings on PBworks during the study period ranged from 3 to 197, with a mean of 54.8 and median of 37.5. The findings showed that in general, students were fairly active in participating in the online platform outside the classroom, as they were only given two 25-minute lessons during the project period for setting up the group page and revision on how to use PBworks.

The comments on the “Problem Setting” part of the project were used for the analysis of students’ interactions online in order to assess their within-group collaboration, as the group interactions began with this part. Figure 3 shows the frequency of comments posted on PBworks by each group. The frequency of comments posted during the study period ranged from 0 to 81, with a mean of 14.7 and median of 7. All nine groups posted problems that they came across on their group page. However, there were considerable differences among the groups in terms of the interactions on PBworks; some groups made good use of the comment function but some of the groups did not. Two groups did not post any comments because of the problem of time constraints and computer accessibility and more details on this issue can be found in the discussion section.

<<Insert Figure 3 here>>

The comments posted by the groups were further analyzed based on Woo’s three-level categorization of comments on wikis (Woo, 2013), which was adapted from Liu and Sadler’s (2003) categories of comments for examining peer discussion on technology-enhanced platforms. The categories are (1) content-related, (2) surface level, and (3) management-related. Surface level comments comprised 11%, content-related comments comprised 25%, management-related comments comprised 22%, and other non-related comments comprised 42%. The total number of comments posted by the class was less than the total number of types of comments, because one comment could be categorized into more than one category.

Theme 2: Interactions. The qualitative data from the focus group interviews further explained the interactions in students' collaborative learning. Students reported that they learned a lot from their peers, including how to cooperate and collaborate with each other. Some of the interview excerpts that indicated students' interactions were as follows:

"Before I worked in this group…I could not talk to my friends very much…now we talk a lot on PBworks."

"If we cooperate, we can have more ideas."

"If there are more comments, we can elaborate our findings."

"I may not have enough ideas and they can help me to think better."

"When we have an idea we discuss and it becomes a new idea."

Theme 3: Learning experience. The following interview excerpts showed students' overall learning experience of the whole project. They appreciated individual differences and the effort made by others.

"We learn to accept others' opinions and comments."

"I have learned that our personalities are very different."

"Doing work by myself is more lonely."

"Some of them just sacrifice things for the project and time. It is really hard to sacrifice your time because we are really busy these days, so I really appreciate this."

Theme 4: Wiki way of learning vs traditional way of learning. Apart from learning from peers, the students also mentioned that they preferred this new way of learning instead of learning in the traditional classroom setting. The online discussion platform motivated them. In support of this, consider the following interview excerpts:

"Discussing with each other is more interesting…I find more information from the Internet and we learn from each other."

"You just have one G.S. lesson a day, but on PBworks, you can check it before you sleep, before you go to school or even on your phone when you are not at home."

"This new way of learning can help us become more creative."

Nevertheless, one group of students mentioned that they did not prefer learning through the online discussion platform because they had experienced difficulties. They reported that:

"I think the traditional way is better. Sometimes we do not know the answer and the teacher can explain to us at once clearly."

"The traditional way. Because we can communicate together face-to-face."

Students' learning in a technology-supported environment

Again, the data from the student survey and focus group interviews and the students' work on PBworks provided the quantitative data and the qualitative data for answering RQ3. For the closed-ended statements, the students were asked whether they found the layout and functions of PBworks to be clear and user friendly (Q1), whether PBworks helped them to learn about the

topic (Q5), whether there were more benefits than difficulties in using PBworks (Q9), whether PBworks was more user-friendly compared with the other online discussion forums (Q13), and whether they hoped to use PBworks for different subjects in the future (Q14). All of the statements had ratings above 3, ranging from 3.7 (Q13 and Q14) to 4.2 (Q1), and the subscale mean was 3.8 (sd = 1.0). The results showed that the students generally acknowledged the benefits of PBworks for learning.

Theme 5: Information search. The qualitative data from the focus group interview further elaborated what students learned using the tool. The students generally agreed that the skill of searching on the Internet was important to learning in this setting. In this regard, the students mentioned the following in the interview excerpts:

"If we have better skills for searching the Internet, then we can search for more information and obtain a better result."

"Maybe when you add a word after the original keyword for searching, there will be different results."

"If we know more websites then we can find out more."

"Some team members specifically just search from Wikipedia, so the information maybe not enough. We have to search other Internet sources to see if the facts are correct…not just from Wikipedia."

The students' most commonly used search engines were Google, Yahoo, Wikipedia, YouTube, and Bing. Some students searched more references to make sure that the information they obtained was trustworthy. Some students also discovered the importance of inputting correct keywords for better results.

Theme 6: Teachers' guidance. The role of the teacher was also important in the learning process and the students reiterated the importance of the teacher's guidance in online learning. The following interview excerpts supported this view:

"If we had some IT problems, our teacher can help us."

"The teacher could teach me how to use the Internet."

"Advise us when we have different opinions."

"Because everyone made mistakes, we needed our teacher to show us the right way."

"The teacher must teach us how to use PBworks and the Internet."

In addition to the above findings, the students' work on PBworks was evaluated. In the first task of the project, students had to upload their own mindmaps to PBworks and comment on others' work. All of the students completed this task successfully. In the second task, students were required to set up a page and insert videos, images, or paragraphs to share their findings. Figure 4 shows an extract of a student's work. All of the students managed to complete the tasks. The third and fourth tasks were related to the creation of a new machine to solve a problem that the students had identified. It was expected that students would illustrate

their creative artifacts with ICT tools such as Paint, PowerPoint, or Photoshop. Figure 5 shows an example of a group's creation. Only five out of the nine groups of students posted their creations with ICT tools. One group posted a pencil and paper drawing, and another posted a photo. One group only posted descriptions of their creations and one group did not post anything at all. All nine groups presented their creations using PowerPoint slides in front of the class.

<<Insert Figure 4 here>>

<<Insert Figure 5 here>>

Discussion

Students' attitudes toward online collaborative learning

The students provided positive feedback about their experience of using PBworks. The students quickly adapted to the new learning environment and found it interesting and inspiring, and found PBworks easy to use and useful to their learning. These findings are consistent with those of Fu, Chu, and Kang (2013). Students in their study claimed that the wiki was user friendly and helpful. They also held positive attitudes toward the use of the wiki for collaborative project learning.

In the past, the students shared their findings using printouts, which they found to be inconvenient. The implementation of an online discussion platform supported by social media

tools allowed them to share information efficiently and even share videos and animations, which was not possible in the past or in the other classes. The students were also able to co-construct the project through the sharing of various resources (Hazari *et al*., 2009). These benefits brought about by using the wiki help explain the positive attitudes held by the students toward the platform.

Primary six students have to undergo frequent assessments for the allocation of secondary school places. They put great effort into the assessment tasks, and it was anticipated that this might lower the students' learning motivation. However, the students were highly motivated toward the project work using the online collaborative learning platform. They continually helped each other with the work and sought help from the teacher. This can be explained by the fact that their motivation is socially constructed and sustained through active engagement among learners (Järvelä, Järvenoja, & Volet, 2010).

The teacher had been teaching the class for two years and was experienced in leading students' group work in class. Problems concerning disputes among group members, which can lead to emotional problems among students, are common in group work. Yet the students in this study worked together in a harmonious atmosphere, and some even made new friends in their new groups. The students were enthusiastic about the use of wikis for online project work.

It is noted that one of the nine groups in our research did not post anything for the third and fourth tasks. The teacher later found out that the group did not post anything because the

group encountered time constraints in completing the tasks. One of the group members did not have access to computers at home, so she could not read or post anything on the online platform after school. The group was of the view that it was better for them to discuss the project face-to-face at school rather than using the online platform, so they did not utilize the online platform. It was an accessibility issue rather than their dislike of the online platform.

The extent of contributions also varied within a group. Some students suffered from health issues so they contributed very little to the online discussion. Yet most students contributed to and benefited from the project. Some students were more vocal on the online platform than they would normally be in class, as they feel more comfortable sharing their views online when no one is looking at them. Most groups collaborated well in completing their projects. Students with higher capabilities within the group were able to lead the online discussion most.

Students' interactions in online group collaboration

The online discussion platform provided a virtual space for students to share their work. The feedback and comments from fellow group members were important for the students' learning. The students reported that they liked to receive feedback from others, whether it was praise for or advice on their work. The students improved their work and developed a better understanding through the exchange of ideas. These findings are in line with those of Li, Chu,

Ki, and Woo (2012), who found that Chinese primary school students engaged in deep thinking and learned new knowledge from other group members during online discussion.

Over 50% of the comments posted by the students were related to the project rather than unrelated issues. The students understood the importance of giving comments and made good use of them, although a few groups reported a low frequency of comments.

At the beginning of the group project, the students spent most of their time learning the technical skills of PBworks. The teacher had to make sure that everyone was on task, and there was little learning of the topic at this stage. In the second task, the students needed to gather information from the Internet and share it with the class. Learning of the subject started to expand from this stage. This is because the inquiry nature of the project provided students with the opportunity of expanding both their scientific knowledge and language proficiency in the relevant topics. The students searched for information to extend their knowledge beyond the set curriculum, and to expand their vocabulary more efficiently than simply learning words from textbooks. Through sharing information with the class, they practiced speaking in English to develop the communication skills needed to present scientific knowledge using a second language. They also evaluated each other's findings to check the accuracy of the information, which is considered an important activity in inquiry project-based learning (Savery, 2006). In the next task, students identified a problem related to the use of energy that they had come across in daily life. This was different from an assessment based on traditional homework, such

as a workbook. They had to identify a problem by themselves, which was challenging. Every, except one, group managed to work on it online, either synchronously or asynchronously (Pifarré & Kleine Staarman, 2011), and enjoyed the process.

At the end of the project, the groups presented their creations using PowerPoint, supported by images. The creativity of the designs was highly appreciated and the work was logical with clear explanations. Each group had a question and answer session, during which the students raised sensible questions that the groups were able to answer correctly. They critiqued the work of others. Some students said that they intended to develop a real machine in the future. The learning process was found to be motivating and stimulating. Students' online interactions seemed to extend to more meaningful offline interactions, as indicated in the presentations.

Students' learning with technology

The students enhanced their skills in using PBworks throughout the project. They were confident about learning with PBworks again in the future. Some students developed Internet search skills in the learning process. They found that different keywords affected the search results, and compared different sources of information to find the best one.

More importantly, the students were able to post their digital artifacts, such as the mindmaps and the machines created during the learning process, for peer review and improve their products after receiving comments from others. The platform seemed to promote collaborative problem solving and stimulate critical inquiry among students so that better

outcomes were achieved (Chu, Siu, Liang, Capio, & Wu, 2013). These outcomes were made possible by the educational affordance features of wikis, which support information sharing, collaboration, and reflection among learners that lead to the co-construction of new knowledge (Pifarré & Li, 2012).

Implications of the findings for researchers and practitioners

Overall, this study provided a theoretically-informed and practically-oriented approach for conceptualizing and contextualizing learning in a computer supported collaborative environment implemented in wikis. In particular, we applied a relatively new and promising collaborative inquiry project-based learning framework, which combines inquiry-based learning and project-based learning, to scaffold students in learning science and found some empirical evidence to support the efficacy of this wiki-based pedagogical practice to students' learning. While there are indeed cases of wiki application in primary school classroom, our study offers new insights into how the use of wikis can enhance inquiry project-based learning. Researchers can translate the experience and knowledge gained in this study into design principles that guide future studies utilizing wikis as a collaborative learning platform. Further adaptation to the research design can be made to studies that involve different academic disciplines and students of different grade levels.

In practice, the infrastructure of wikis fosters participation and social interactions among learners, it affords the creation of online community of practice that extends students'

learning beyond formal classroom. Within this community setting, there are opportunities to blend learning in an informal setting outside school with formal instruction offered by teachers in school. Students as members of the online community of practice are encouraged to share and reflect on their ideas, experience, and resources with each other. Teachers need to direct students' attention and effort to activities that focus on learning, and develop their identity from novice to expert as they participate in the community (Lave & Wenger 1991).

Conclusion

This study provides preliminary evidence that the use of wikis for collaborative inquiry project-based learning can help primary school students to construct science knowledge in an online environment. The students' attitudes toward the wiki were found to be positive at the end of the 7-week study. They actively engaged in various forms of learning-related interactions using the platform that extended to more meaningful offline interactions, and developed Internet search skills, collaborative problem solving competencies, and critical inquiry abilities. Overall, the results showed that a well-planned wiki-based learning experience is conducive to the learning and teaching of a science inquiry-based project in primary school.

There were several limitations to the study that should be addressed in future research. First, the participants comprised only one class of Primary 6 students in a girls' school.

Students of diverse demographic and academic backgrounds should be recruited in future studies. In particular, more attention should be paid to students' familiarity with the wiki, as this is likely to influence how teachers design and deliver a lesson. Second, the sample size was small and this may limit the generalizability of the findings to the whole population of primary school students in Hong Kong. A larger random sample should be collected for future investigation. Third, the post-test only design adopted in this study may have reduced the internal validity of the findings. However, the quantitative evidence, interpreted in conjunction with the qualitative evidence, provided cross-validation or substantiation of the findings, which served the purpose of concurrent triangulation (DeVos, Strydom, Fouché, & Delport, 2005). Although the findings from the two perspectives agreed to a large extent, further research is needed to replicate the current study using a pretest-posttest control group design. This research design controls for all of the standard threats to internal validity and thus allows practitioners to attribute any treatment effect to the intervention. Finally, as many studies have found, Asian cultures tend to be more collectivistic and value interdependence over personal interest, this may promote more interactions and cooperation in online learning among students in this study. Future studies should therefore focus on the design of culturally adaptive online learning environments and systems that cater to the needs of different learners and support intercultural interactions (Zhang, 2013).

Appendix 1 Student Focus Group Interview Questions

1. Compared with discussion with your friends face to face, do you enjoy discussion on PBworks more? Why? Why not?
2. Do you think you can learn a lot from your peers in the collaborative process? What have you learned?
3. Do you think the different opinions of your group members will affect your learning? Why?
4. Do you think you still want to work collaboratively online when you work on a project next time?
5. Do you think the collaborative discussion approach can help you improve your learning in General Studies, compared with a traditional discussion approach?
6. Do you think the teacher's guidance is very important in the collaborative discussion process? What other help do you need from the teacher?
7. Do you think receiving your peers' comments is better than only receiving comments from your General Studies teacher?
8. How can the searching skills of your group members help with your work?
9. What are the advantages that you experienced with this wiki-based collaborative learning?
10. What are the disadvantages that you experienced with this wiki-based collaborative learning?

11. What keywords did you use for searching? How did you select the materials that you needed?

Appendix 2 Coding Scheme for the Focus Group Interview

Theme	Definition	Sample references
Attitudes toward wiki (RQ1)	Students' positive and negative feedback on using PBworks and online learning.	We can do this project not only at school, but also at home and everywhere. So I think it's very convenient. (Group G)
Interactions (RQ2)	Peer interactions within group and among other groups.	I think that their opinions really affect my learning because I often don't have that many ideas. Sometimes my partners give me a lot of ideas and we can combine them all together. And it's great work! Our project turned out well. (Group B)
Learning Experience (RQ2)	Overall learning experience of the whole project.	I think that we can learn to cooperate and communicate. My idea is not enough, so I can hear their opinions. (Group C)
Wiki way of learning vs traditional way of learning (RQ2)	The differences between learning collaboratively through the online discussion platform and being taught by teachers in a classroom.	It's because you just have one lesson a day, but on PBworks, you can check your PBworks before you sleep, before you go to school or even on your phone when you're not at home. (Group D)
Information search (RQ3)	Students' ways of searching for information.	…some team members specifically just searched Wikipedia, so the information may not be enough. So we have to search other sources and gather all the information and just check that the facts are correct. We have to search more but not just from Wikipedia. (Group B)
Teacher's guidance (RQ3)	Teacher's support during learning.	Yes, I think it's important because if the teacher didn't guide us, we wouldn't know how to use PBworks and we would do it wrong. (Group G)

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Table 1 Survey items used in the study

	Attitudes
Q4	It was easy for me to browse and edit the post on PBworks
Q6	It was worth spending my learning time on PBworks
Q7	PBworks helped me to become more involved in learning the topic
Q8	PBworks made the learning topic more interesting
Q11	My knowledge had increased through learning with PBworks
Q15	I would recommend PBworks to my friends
	Group interactions
Q2	I enjoyed my classmates reading my feedback on PBworks
Q3	I enjoyed using PBworks as a discussion tool
Q10	I had more communication with my fellow group members when using PBworks
Q12	PBworks made compromising within the group easier
	Learning with technology
Q1	I found the layout and functions of PBworks to be clear and user friendly
Q5	PBworks helped me to learn about the topic
Q9	There were more benefits than difficulties in using PBworks
Q13	PBworks was more user-friendly compared with the other online discussion forums
Q14	I hoped to use PBworks for different subjects in the future

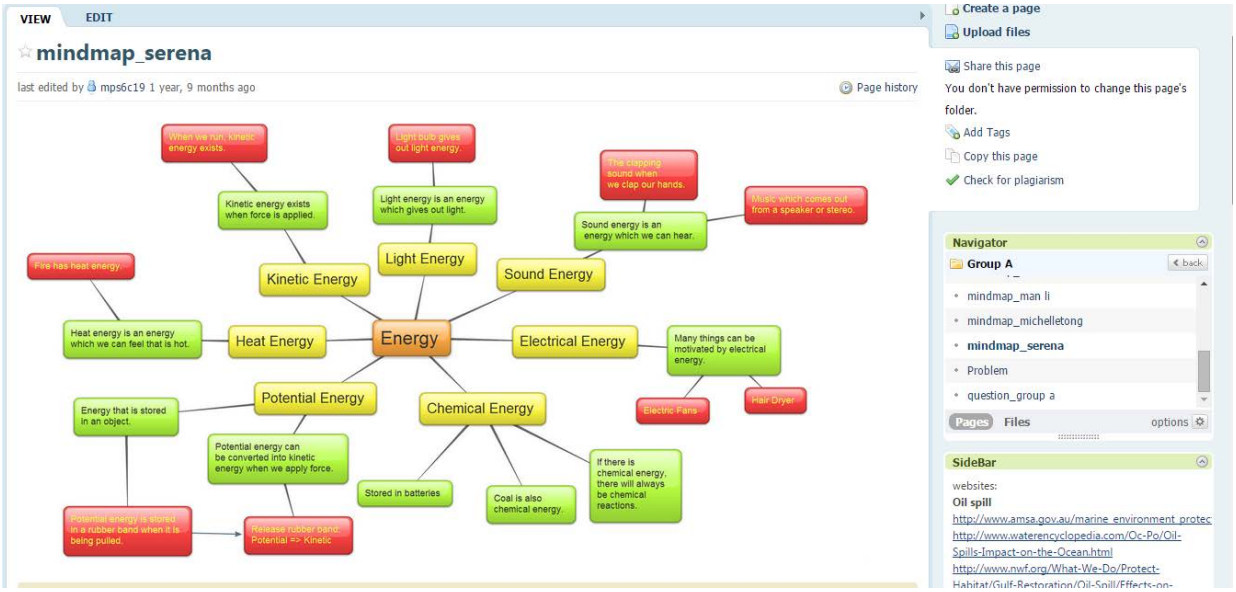

Fig. 1 A student's e-Mindmap

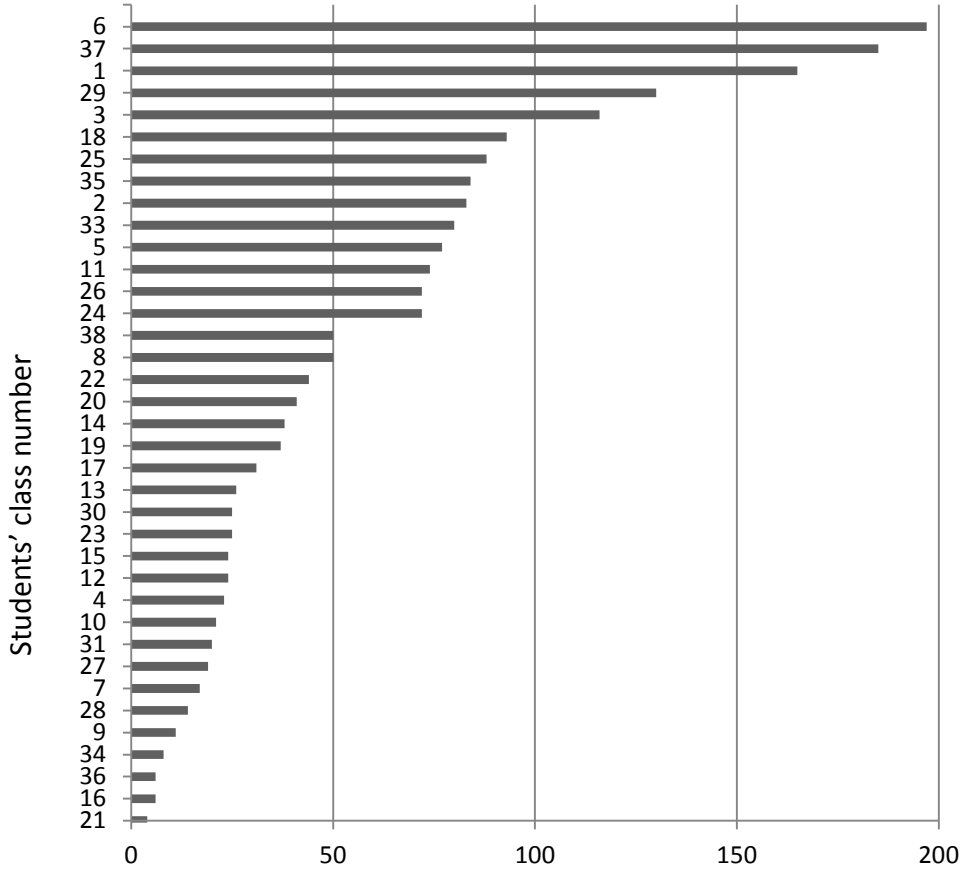

Fig. 2 Students' page view on PBworks

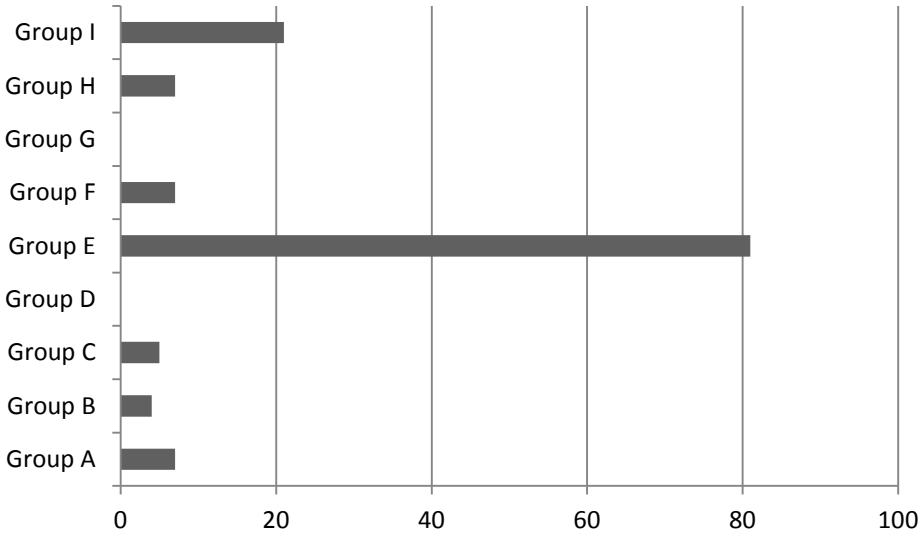

Fig. 3 Number of comments posted on PBworks on the part ‘Problem Setting’

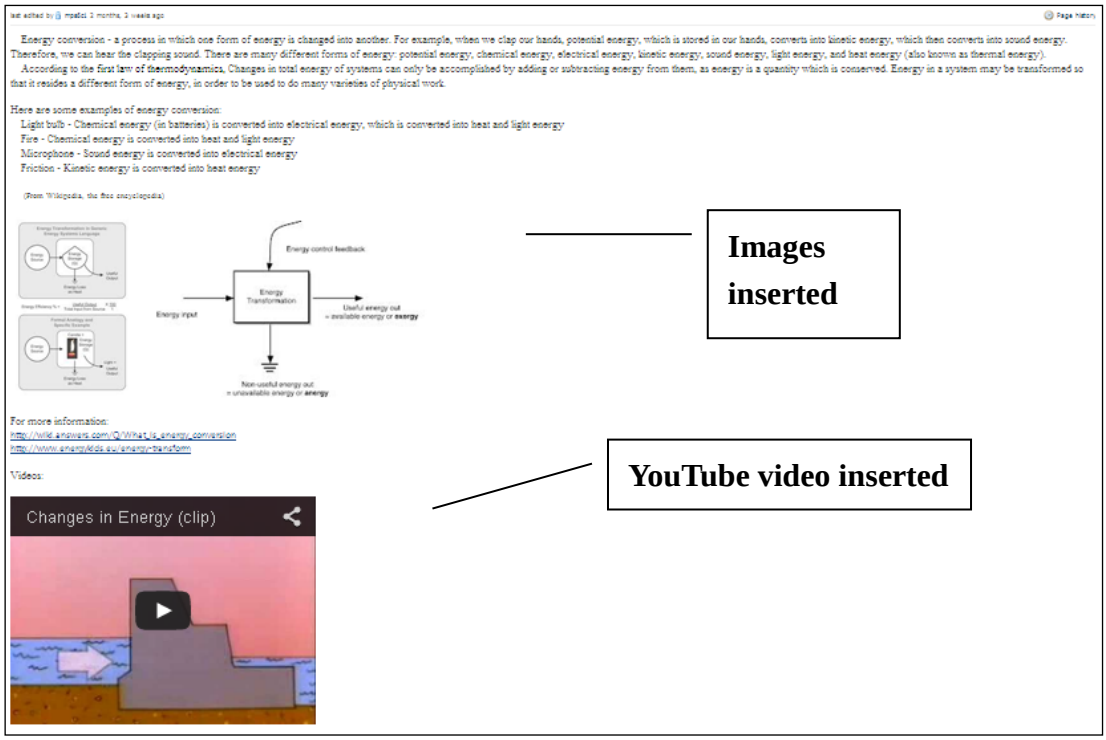

Fig. 4 An extract of a student's work on PBworks for Task 2 – Findings

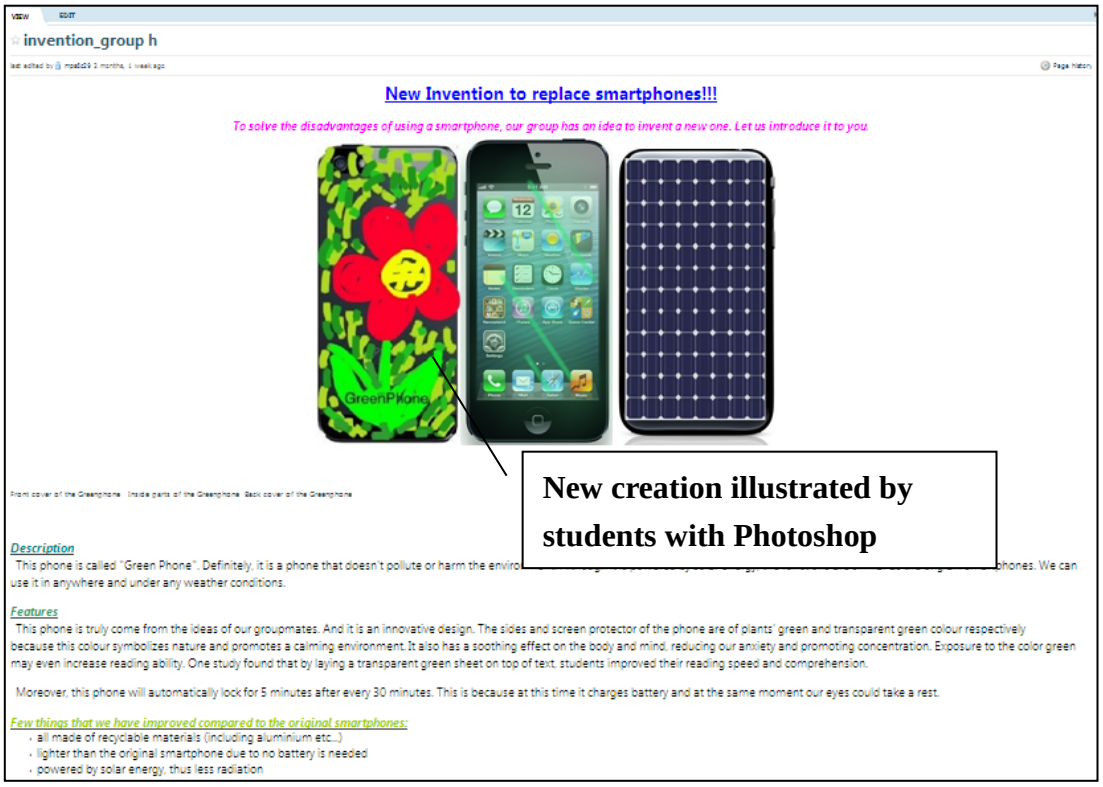

Fig. 5 An example of a group work on PBworks for Task 4 - Creation