Bring Your Own Device (BYOD) for Seamless Science Inquiry: A case study in a Primary School

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Abstract: This paper reports an on-going case study on the project of "Bring Your Own Device (BYOD) for seamless science inquiry" in a primary school in Hong Kong. The study aims at investigating how the students advanced their content knowledge in science inquiry in a seamless learning environment supported by their own mobile devices. The topic of inquiry was "The Anatomy of Fish". Data collection included pre- and post-domain tests, student artifacts, class observations and field notes. Content analysis and a trialogical approach were adopted in the data analysis to trace the students' knowledge advancement. The work of one group of students was used as an example. The research findings show that the students advanced their understanding of the anatomy of fish well beyond what was available in the textbook.

Keywords: BYOD, seamless science inquiry, trialogical approach

Introduction

In the digital age, mobile technologies have become embedded and ubiquitous in students' lives. Parallel to that, studies on "mobile-assisted seamless learning" which refers to seamless learning mediated by a 1:1 setting, have boomed (Wong & Looi, 2011). In general, mobile-assisted seamless learning research has focused on students provided with a uniform type of device (Song, Wong, & Looi, 2012). However, nowadays more and more learners bring their own mobile devices wherever they go for their learning and communication needs. How school students use these various types of personally owned devices to support their science inquiry in a seamless learning environment has rarely been explored. In addition, despite the fact that inquiry-based learning in science supported by technologies has been promoted for decades and has apparently yielded intended outcomes, it is reported that science inquiry practices are challenging tasks for students, especially for young learners due to various issues (Krajcik, Blumenfeld, Marx, & Soloway, 2000). Further, with seamless learning studies on the rise, tracing the distributed and sparse nature of interactions through and over mobile devices poses a challenge for understanding students' knowledge advancement (Looi, Wong, & Song, 2012).

In the light of the above issues, this study is aimed at investigating the question, "how do students advance their content knowledge in science inquiry in a seamless learning environment supported by their own mobile devices?" The rest of the paper introduces the relevant literature first, then describes the research design. Finally it presents the results, followed by discussion and conclusion.

1. Literature

1.1 Bring Your Own Device (BYOD) for mobile-assisted seamless learning

According to Wong and Looi (2011), one aspect of mobile-assisted seamless learning concerns the "combined use of multiple device types" (p. 2367). In recent years, more and more studies have attempted to investigate how mobile learning can be leveraged to increase student engagement and teacher productivity through the Bring Your Own Device (BYOD) model (Project Tomorrow, 2012; Rinehart, 2012). According to Alberta Education (Alberta Education, 2012), BYOD refers to "technology models where students bring a personally owned device to school for the purpose of learning". MacGibbon (2012) maintains that the concept of BYOD is simple: if a student already has a preferred mobile device at home, it is practical to bring it to school rather than duplicate cost and waste learning time to navigate a school-issued device. BYOD is considered a technology model for learning in the 21st Century which is "Mobile Devices + Social Media = Personalized Learning" (Project Tomorrow, 2012). Although BYOD is generally considered to help promote better outcomes via a more personalised learning and an enhanced engagement between home, school and other spaces, how *BYOD* works in real-life inquiry-based pedagogical practices has rarely been studied. Moreover, possibly students' enthusiasm for using BYOD for learning anytime, anywhere might be reduced as time goes on (Rinehart, 2012), in which case, the use of the technology alone would be insufficient to foster learning without the adoption of appropriate pedagogies (Song, 2007).

1.2 Guided science inquiry for young learners

Inquiry learning can be charaterised as a process of posing questions, gathering and analyzing data, and constructing evidence-based explanations and arguments by collaboratively engaging in investigations to advance knowledge and develop higher-order thinking skills (Hakkarainen, 2003; Krajcik et al., 2000). Teachers are expected to play a facilitating role to help learners to brainstorm ideas, generate questions for exploration, plan and carry out investigations, collect data, gather information, and apply the information to analyze and interpret the data (Krajcik et al., 2000). However, research findings show that students lack inquiry skills and need considerable support to become knowledgeable about content, competent in using inquiry skills, proficient at using technological tools, productive in collaborative work and capable of articulation and reflection (Krajcik et al., 2000). To guide young learners in science inquiry, it is suggested that guided inquiry be adopted in the pedagogical design (Hakkarainen, 2003).

1.3 Methodological issues in mobile-assisted seamless science inquiry

In seamless science inquiry supported by mobile devices, due to the limited screen size, and the mobile nature of the activities, learning can occur in constantly changing contexts such as home, school and other spaces (Looi et al., 2012). To capture the seamless science inquiry process is a demanding task. We need to examine holistically and "re-construct" learning occurring in different contexts in order to track learners' inquiry learning processes and outcomes in continually moving and re-constructed contexts in a seamless learning environment (Looi et al., 2012).

2. This study

2.1 Context

The study took place as part of an on-going one-year project of "Bring Your Own Device (BYOD) for seamless science inquiry" in a class of Grade Six with twenty-eight students in a primary school in Hong Kong, adopting a case study approach (Merriam, 1998). The study was carried out for over half a year, and involved three science units with six topics. For this paper, we chose to examine the students studying the topic "The Anatomy of Fish" in the unit "Biodiversity".

2.2 BYOD and mobile apps

Of the twenty-eight students, twenty-four used mobile devices brought by them from home. These were ten iPads, eleven Android tablets or smartphones, two iPhones and one iPod. Four students did not own a device, so the school lent them iPads to use. "BYOD" in this study refers to "the technology model where students bring a personally owned mobile device with various apps and embedded features to use anywhere, anytime for the purpose of learning". Students could use the mobile devices to take photos, videos or record audio files for their own learning needs. They could also access the internet via WiFi in school. Three mobile apps were used in the science inquiry, namely Edmodo, Evernote and Skitch. Edmodo – a free social network platform - was used for students to communicate, share information and work, submit assignments, and coordinate learning activities seamlessly. Evernote is a suite of free software and services designed for note-taking and archiving (refer to http://en.wikipedia.org/wiki/Evernote for details). Students used Evernote to record their learning journeys, make reflections and share with peers. Skitch – a mobile app - was also recommended to the students for annotating images (refer to https://play.google.com/store/apps/details?id=com.evernote.skitch for details.).

2.3 Inquiry-based learning pedagogical design in primary science

In our pedagogical design, we adopted an inquiry-based learning model consisting of six elements, namely *engage, explore, observe, explain, reflect and share*. The model is shown in Figure 1. The learning activities were carried out in *a seamless learning environment* across class, home, school lab and online learning spaces.
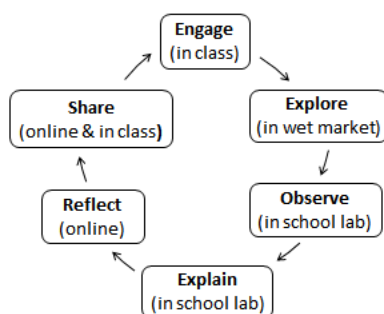

Figure 1. Seamless inquiry-based learning model in primary science.

The seamless learning activities for inquiry into understanding "The Anatomy of Fish" is presented in Table 1.

Table 1. The seamless inquiry-based learning activities on "The Anatomy of Fish"

Activities (As)	Description
A 1 Engage (in class)	Engage: Access Hong Kong marine fish database online http://www.hk-fish.net/chi/database/feature/feature.htm
A 2 Explore (in wet markets)	Explore a few kinds of fish in the wet market, take photos, find out the names of the fish and upload them to Edmodo. Students also share other information about fish on Edmodo.
A 3 Observe (in school lab)	There are four kinds of fish prepared by the teacher for each group to observe. They need to observe and find out the scientific names of the fish and their anatomy with the help of a magnifying glass. They are encouraged to make full use of their mobile devices in the observational process.
A 4 Explain (in school lab)	Label the body parts of the fish using the mobile app – Skitch to explain the anatomy of a fish, and upload it to Evernote which is shared in Edmodo.
A 5 Reflect (online)	Reflect on the guided questions in Evernote, e.g., Q1: Why are the four kinds of fish called fish? Q2: What have you learned?
A 6 Share (online & in class)	The students upload their labeled anatomy of fish and reflections to Evernote to share; they also share their work in class for evaluation.

2.4 Participants

The twenty-eight students were divided randomly into seven groups of four students. We chose to focus on one group as an example to trace the students' inquiry process. The group has four members, two boys and two girls, given pseudonyms of Ran (boy), Tin (boy), Ling (girl) and Nini (girl). Tin and Nini used their own iPads, Ling used her own smartphone, and Ran used an iPad borrowed from the school. The teacher had around eight years of work experience and had participated in the professional development of innovations using the inquiry-based approach. In the students' science inquiry process, the teacher acted as a facilitator to guide the students' inquiry skills, and encouraged the students to use the mobile apps of Evernote and Skitch, and Edmodo to facilitate their inquiry process.

2.5 Data collection and analysis

To examine how students advanced their scientific knowledge of the anatomy of fish, data collection included pre- and post-domain tests, student artifacts (postings on Edmodo, postings on Evernote, captured photos, captured recordings, captured videos, worksheets), and class observations. The pre-domain test had two main questions: pre-Question 1 (pre-Q1) "What do you know about fish?" and pre-Question 2 (pre-Q2) "Please draw a concept map to show what you know about fish." The post-domain test also had two main questions: post-Question 1 (post-Q1) "What have you learned most about fish?" and post-Question 1 (post-Q1) "Please draw a concept map to show what you have learned about fish."

In the data analysis, to explore their knowledge advancement process, we focused on examining how students constructed, refined, elaborated, and created artifacts both collaboratively and individually through three streams of analysis. First, regarding individual knowledge advancement, we examined and marked the whole class's pre- and post-domain answers to pre- and post-Q1 and Q2 by coding the students' answers and concept maps, and categorizing them into different types. We then counted the numbers in each category to gain better understanding of the students' learning, process. Secondly, regarding collaborative knowledge advancement, we adopted the trialogical approach (Hakkarainen, & Paavola, 2009) to trace students' progress in science inquiry, focusing on one group as an example. The trialogical approach emphasizes group collaborative development of mediating objects or artifacts rather than focusing solely on idea improvement. We traced the development of artifacts in the student learning activities in order to explore how groups work together to

make sense of the problem inquiry situations (Stahl, 2002), and understand how students progressively refined artifacts or further elaborated upon shared artifacts in their inquiry process (Hakkarainen, & Paavola, 2009). The artifacts included concrete objects (e.g., real fish), and conceptual / knowledge artifacts (e.g., text, pictures, and drawings). Finally, we coded students' postings in Edmodo and Evernote related to the development of content knowledge about fish (Merriam, 1998). Whenever necessary, field notes were used throughout the data analysis process for the purposes of triangulation.

3. Results

3.1 Results of pre- and post-domain tests

We collected 21 pre-domain test sheets, and 27 post-domain test sheets. By pairing the pre- and post-domain tests, we obtained 20 valid pairs of students' test sheets. Table 2 shows the summarised results of pre- and post-Q 1 ("What do you know about fish?" and "What have you learned most about fish?") and Q 2 ("Please draw a concept map to show what you know about fish." and "Please draw a concept map to show what you have learned about fish.").

Table 2. Pre- and post-domain test results

Questions	Summarized results
*pre-Q1	The answers varied and were categorized mainly into 7 types, including: knew that a fish uses gill to breathe (80%), knew that a fish lives in water (60%), knew that a fish takes various kinds of food (45%), knew that fish is our food (20%), knew that a fish has scales (20%), knew that there are different kinds of fish(15%), and others (40%). e.g., Student A: I knew that a fish can swim, has scales, lives in the seas or somewhere with water, uses gills to breathe, eats seaweed, small sea creatures or small fish. If there is no water, they will die.
*post-Q1	The answers also varied, and were categorized mainly into 7 types. They are: learned more about the anatomy of fish (85%), learned that a fish has more body parts than expected (40%); learned that a fish has lateral lines (45%), learned that a fish has a few fins and a tail (25%), learned that a fish has visible or invisible scales (25%), learned that a fish has teeth (15%), and learned that there are more varieties of fish(10%). e.g., Student A: Fish live in water. They have scales, teeth, gills, mouth, eyes and lateral lines.
Pre-Q2	The students expressed what they knew about fish in concept maps. Out of 20 students, 7 (45%) students used only one or two body parts (mostly gills) in the nodes of the concept maps; the other nodes and links between nodes were related to how fish live, eat, and grow in their world. e.g., Student A's pre-concept map
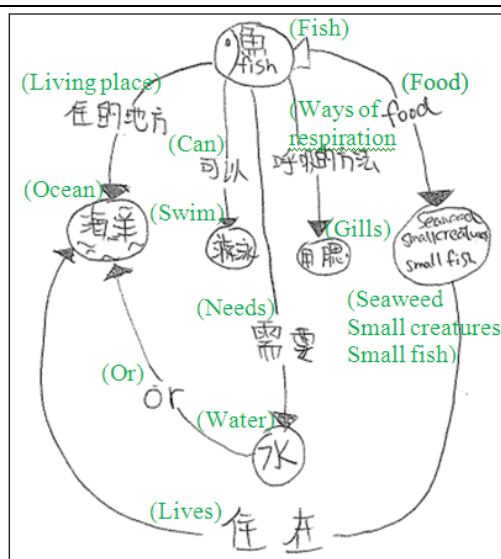
Post-Q2   The students expressed what they had learned about fish in concept maps. Out of 20 students, 19 (95%) students drew the body parts of the fish in the concept map, which exhibited knowledge that was well beyond that which was available in their textbook. In addition, 15 (75%) students extended and revised their prior concept maps done in the pre-domain test by adding the body parts and functions to the map except 5 (25%) students who only drew the body parts of the fish.

e.g., Student A's post-concept map
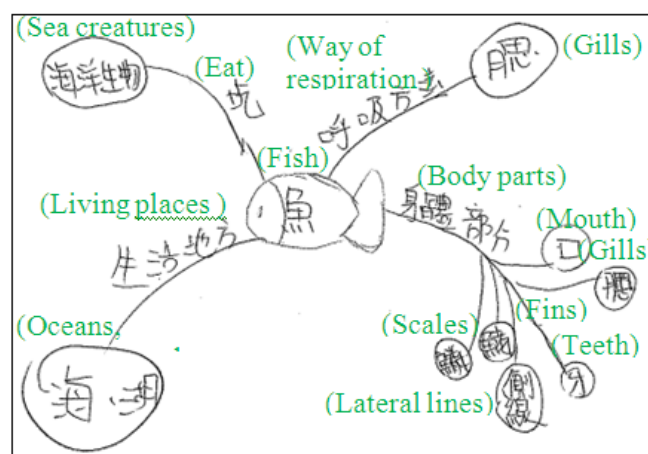
* Individual student's answers usually fell into a few categories.

3.2 Results of the group's knowledge advancement on fish in science inquiry

Activities 1 & 2: Engage and explore (in and out of class)
In the first activity, the teacher engaged the students by introducing some online information about fish in class, and then group members Ling and Tin explored the information about fish on various websites in class and at home, and shared these on Edmodo (see Figures 2 and 3) using their mobile devices or computers at home; group members Ling and Tin also went to the wet market and took some pictures of different kinds of fish and shared them on Edmodo to get a general understanding of fish. Figure 4 posted by Ling is an example of this. Ling also made a recording using her mobile device to describe the kinds of fish she observed in the wet market, and uploaded it to Evernote which was shared on Edmodo.

Figure 2 Website about fish shared by Ling

Figure 3 Website about fish shared by Tin

Figure 4 Photo taken in a wet market shared by Ling

Figure 5 Studying the fish by Nini

Activities 3 & 4: Observe and explain (in school lab)

In the lab, the four group members observed four kinds of fish bought and distributed by the teacher, and each of them was responsible for finding out the scientific name and labeling the body parts of one kind of fish. They studied the fish attentively with the help of a magnifying glass, took pictures of the fish, and labeled the body parts on the captured photo using Skitch app, and finally uploaded the labeled photo to Edmodo. Figure 5 shows Nini studying a fish using a magnifying glass. Figure 6 shows that in the group, three members were using an iPad and one was using a smartphone to explore the information about fish online in Edmodo. Figure 7 shows that Ran was comparing the information recommended by group member Tin in Edmodo about the fish online with the fish he was studying while labeling the anatomy of the fish using the mobile app Skitch.

Figure 6 Mobile devices used by the group members

Figure 7 Ran - working on the fish

Activities 5 & 6: Reflections in Evernote and share

All four members posted their labeled anatomy of fish to Evernote shown in Figure 8 (a), (b), (c) and (d) and wrote their reflections for sharing.
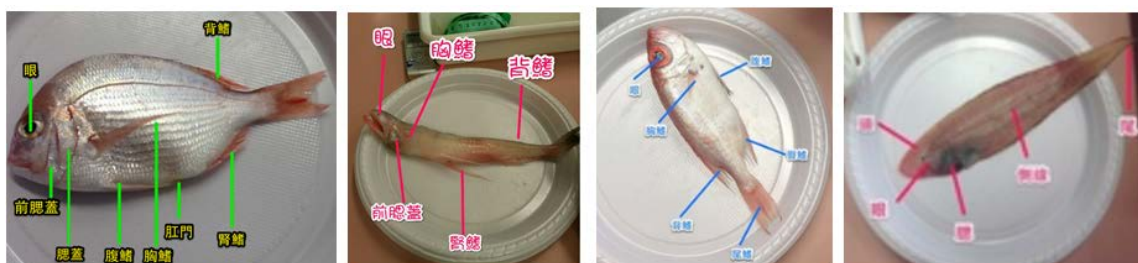
Figure 8 (a), (b), (c) & (d) Four kinds of fish labeled by Tin, Ling, Ran and Nini

All the members wrote their reflections on Evernote except Nini. Tin reflected:

"Today, we did an inquiry into "fish"… I divided the fish into several parts. They are: eye, pelvic fin, gill, spiny dorsal fin, anal fin, etc. The fish I studied and the other fish my group members studied all belong to fish because all of them have gills, anal fins, fins and scales. Based on these, I know that they are fish. In addition, before the experiment, I thought that fish is hard if it is not cooked; after the experiment, I learned that what I thought was wrong. Fish meat is not hard at all, but soft and elastic. From the experiment, I learned a lot of knowledge about fish, for example: anatomy, features, quality of fish meat and scales."

Ran reflected that "I learned in Wednesday's experiment, different body parts of the fish, for example: lateral line, gill, pelvic fin, and spiny dorsal fin. The fish I studied is Golden Threadfin Bream". Ling reflected that "All of them are fish because they use gills to breathe and use fins to move." Only Nini failed to post any reflections. The teacher encouraged her by commenting on the labeled fish she uploaded to Edmodo, "Great! Well done!! Can you find the name of this fish?" Encouraged by the teacher, Nini worked hard to find out the name and detailed information about the fish and posted it to Edmodo.

The group of students investigated both collaboratively and individually the anatomy of fish. The process was traced and documented, and is shown graphically in Figure 9. Due to space limitations, only a small number of the students' mediating and conceptual artifacts can be shown in the paper.
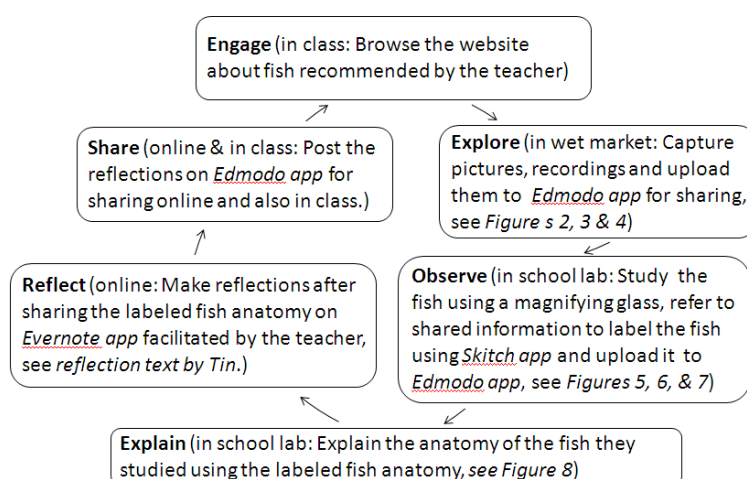

Figure 9 Tracing the group's knowledge advancement on "The Anatomy of Fish"

4. Discussion

The pre-domain test results show that students' pre-domain test answers and mapped concepts were not focused on the anatomy of fish (See Student A's example). After the inquiry in the lab supported by personal mobile devices was completed, the post-domain test answers

indicated that the students' learning was focused more on the anatomy of fish and the functions of the body parts. Their presented concepts shown in their post-domain concept maps also demonstrated more focus on the anatomy of fish. Also, in their maps, the relationships between the concepts were shown properly. This indicates that students' understanding of fish anatomy was enhanced as a result of their BYOD for seamless science inquiry. Further, by tracing one group's inquiry process, we were able to follow and analyse how the group members developed their artifacts relating to the anatomy of fish. Their science inquiry was mediated by the artifacts/objects developed earlier both collaboratively and individually supported by their mobile devices across different learning spaces of wet market, home and school lab.

The findings of the study indicate that integrating the BYOD technology model into guided inquiry-based pedagogical design and implementation in a seamless environment will help young learners' advance their content knowledge. By referring to shared artifacts on the social network Edmodo and Evernote, and their own observations of fish in the wet market and the school lab supported by their own mobile devices, the students acquired knowledge about fish way beyond what was available in the textbook. Our observation revealed that, in the course of their science inquiry, students had a sense of ownership and control over their own learning which was lacking in previous mobile learning research where they had to borrow the mobile device from school (Corlett, Sharples, Bull, & Chan, 2005). We found BYOD can facilitate students' science inquiry by enabling them to access and share artifacts online anytime, anywhere, which cannot be easily achieved using desktop computers. In addition, BYOD can enable students to capture "just-in-time" photos, and audio and video files, and to upload these files to Edmodo and Evernote for instant sharing. It can also allow students to edit captured photos for specific learning needs without time and space constraints (e.g., labelling the captured fish photo in the school lab). These can greatly enhance the flexibility, mobility and interactivity of learning at comparatively inexpensive cost (Hakkarainen & Paavola, 2009) and foster students' personalized learning (Song et al., 2012).

Nevertheless, the technology model alone might not be the full explanation for helping students learn (Song, 2007). Rather, it is its combination with the guided inquiry-based learning model that contributed to the students' inquiry process. This finding is in line with the relevant studies in the literature (Hakkarainen, 2003). The teacher's guidance is also needed during science inquiry.

The results of the study also show that using a trialogical approach to trace the students' individual and group inquiry in multiple spaces can help make the learning process and outcome visible (Stahl, 2002). The visible conceptual artifacts in the form of pictures, text, videos and recordings documented the students' learning process and mediated their learning progressively (Hakkarainen, 2003). Interestingly, students' science inquiry skills were also improved in tandem with their knowledge advancement. The development of student's inquiry-based skills will be addressed in later writings.

5. Conclusions

This paper reports an on-going case study on the project of "Bringing Your Own Device (BYOD) for seamless science inquiry" in a primary school in Hong Kong, choosing the topic of "The Anatomy of Fish". To understand how the learners advance their content knowledge in science inquiry in a seamless learning environment supported by their own mobile devices, the study focused on examining the pre- and post-domain test results as well as adopting a trialogical approach to trace the development of students' content knowledge about fish using a group of students' work as an example. The research findings show that the students made

great knowledge advancement in understanding the anatomy of fish beyond the knowledge in the textbook supported by BYOD.

The study contributes to the literature in two ways: (a) a BYOD technology model in conjunction with an inquiry-based pedagogical practice was shown to have a positive impact on students' knowledge advancement; (b) the trialogical approach used to trace students' domain knowledge advancement across different spaces shed some light on the types of methods that could be used to study seamless learning processes and outcomes.

Acknowledgements

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