Exploring How Mobile Technology Provides Inquiry Supports for Middle School Students in Conducting Scientific Practices in a Ubiquitous Learning Context

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Abstract: In a ubiquitous learning context, students can conduct scientific practices by using mobile and wireless technologies inside and/or outside of school. This particular learning context provides learning opportunities for students to collect and evaluate first-hand data anytime anywhere. However, learning challenges emerge in ubiquitous learning context when students are situated in both non-traditional classroom setting and information-rich out-of-class setting. To identify and address students' challenges in ubiquitous learning context, this study takes a longitudinal view to examine students' scientific practices throughout a school year. This paper explores how mobile and wireless technology can provide students with inquiry supports in conducting scientific practices, which include collecting qualitative multimedia data, evaluating and using first-hand collected qualitative data to construct scientific explanations in three different ubiquitous learning environments.

Introduction

Ubiquitous learning refers to a new learning paradigm in which students can learn anytime, anywhere, using tools such as portable and wireless communication technologies (Burbules, 2009; Yahya, Ahmad, Jalil, & Mara, 2010). Traditional technology-based learning environments allow students to use computers and the Internet in a fixed classroom setting. However, in a ubiquitous learning environment, students have more agency when their tools become mobile and personal. In other words, learning is no longer limited to a classroom setting; instead, students can move around between learning environments (Ogata & Yano, 2004) and conduct inquiry activities in different environments (Chen, Kao, Sheu, & Chiang, 2002, August; Chen, Kao, Yu, & Sheu, 2004, March; Hsi, 2003). Moreover, students are able to carry out investigations by collecting data inside or/and outside of school via mobile devices. They can further access and retrieve those data for later use through mobile technology and cloud services (Quintana, 2012). Hence, the distinction between formal and informal learning has become blurred (Burbules, 2009) as learning can take place seamlessly inside and outside of school. In addition, science educators have called for the need to expand students' learning opportunities in informal environments (e.g. everyday settings and family activities, designed settings, afterschool programs) (National Research Council, 2009), which are also characterized as learner-motivated, guided by leaner interests, personal, and ongoing learning (Falk & Dierking, 2000). More importantly, informal science learning experiences are believed to lead to learners' further inquiry and enjoyment (National Research Council, 2009). To respond to the need for greater integration and connection of informal environments and learning experience, ubiquitous learning environments has become a unique context in terms of potential learning opportunities.

For science learning, a ubiquitous learning context allows students to utilize mobile devices and wireless networks to engage in scientific practices in a real world environment. A set of practices including "asking questions and defining problems," "developing and using models," "planning and carrying out investigations," "analyzing and interpreting data," "using mathematics and computational thinking," "constructing explanations and designing solutions," "engaging in argument from evidence," and "obtaining, evaluating, and communicating information" have been defined and emphasized in the Next Generation Science Standards (NGSS Lead States, 2013). These practices such as collecting data, analyzing data, and using data to construct explanations are commonly seen in a ubiquitous learning context. However, students may also face inquiry challenges when situated in this unique context. Essentially, inquiry comprises a series of hands-on and minds-on activities that students need to be engaged in. But, some studies have shown that students face challenges when conducting data collection, including mindless observation and careless recording (Driver, 1983; Eberbach & Crowley, 2009; Smith & Reiser, 2005). In addition, more challenges may emerge when students move from a familiar classroom environment to a novel and unfamiliar environment outside of school. This unfamiliar learning context such as a museum may cause cognitive load when students conduct scientific practices on their own (Falk & Dierking, 2000). Students may need different learning supports within these learning settings from a highly structured setting (e.g., museum) to a less structured one (e.g., a park). Furthermore, teachers' real-time and in-person feedback is limited especially when students are moving around outside of school. Second, students may face difficulties in choosing appropriate data to collect when they are situated in an information-rich learning environment (Vavoula, Sharples, Rudman, Meek, & Lonsdale, 2009).

Lastly, students may struggle to evaluate their first-hand collected data and to select appropriate data as scientific evidence from a data pool. As discussed, these challenges introduce complexity for ubiquitous learning in science contexts. Unfortunately, few studies have addressed the complexity of ubiquitous learning and discussed how educators can scaffold learners during inquiry processes in ubiquitous learning environments.

Since ubiquitous learning can extend students' science inquiry experiences, there is a need to understand how students perform in these environments and how we can support students to mindfully engage in scientific practices in a ubiquitous learning context, specifically collecting data, evaluating the qualitative data they collected, and using those data to construct well-supported scientific explanations. Hence, we designed this year-long study to examine how a mobile computing tool can provide inquiry supports in a ubiquitous learning context. The main research question drives this study: *"How do students use mobile-based inquiry tools to facilitate their scientific practices in a ubiquitous learning context?* We examine students' performance when conducting scientific practices in different environments, and discuss if the technical support of mobile technology helps students to conduct scientific practices. This ongoing study has been enacted in a middle school in the Midwestern USA over the past year. Currently, we have completed data collection and we are now in the process of analyzing research data. Here, we will discuss the design of this longitudinal study, preliminary findings, and how this study may provide more information about how to support students in science-oriented ubiquitous learning contexts.

Study Overview

Participants included 35 eighth grade students and one science teacher recruited from a middle school. The teacher chosen for this study was comfortable using technologies and inquiry-based pedagogy in her class. In order to answer our research question, we situated students in a ubiquitous learning context where they used the Zydeco mobile-based system (Quintana, 2012) to conduct scientific practices. Each student was assigned an iPad loaded with the Zydeco program, and students could work in a group that consists of three persons. Over one school year, students conducted three different investigations in three environments: a classroom lab setting, a museum, and an outdoor river site. For the first investigation, students were asked to conduct a project related to plant growth. Students carried out experiments in the classroom lab and collected data during their class periods. The whole plant project lasted for two months. In the second investigation, students were introduced to a vehicle design project in which students needed to collect relevant data from the exhibits to figure out how to make a vehicle move from a one-day museum field trip. In the last investigation, students conducted an investigation related to the water quality of a local river, where they collected data during one-day outdoor field trip. When students returned from their fieldtrips, their collected data was accessed and used for later analyses. Both the museum and the river investigations lasted for one month. All the lesson plans were developed collaboratively with the teacher, and the other Zydeco project researchers to make sure the plans were aligned with the teacher's curricular plan, Grade Level Content Expectations, and the Next Generation Science Standards (NGSS Lead States, 2013.)

Zydeco, a combined mobile and web-based learning system (Quintana, 2012), has been developed to support scientific inquiry activities across different learning environments such as in a museum (Cahill et al., 2011; Cahill, Kuhn, Schmoll, Pompe, & Quintana, 2010) or in a science center (Lo et al., 2012). The Zydeco system consists of two parts: a tablet program for iPads and a website. Students can conduct a set of scientific practices via different phases on Zydeco: "Plan", "Collect", "Review", and "Explain" (Figures 1-4.) Figure 1 shows the "Plan" workspace where students can add sub-questions (or "helper questions") to refine the driving question, or hypotheses. Figure 2 shows the "Collect" workspace with a variety of data collection methods including capturing photos, text notes, audio and video. When collecting data, students can link specific helper questions or hypotheses to collected data, or use the "Other stuff" category for unsorted data. Additionally, Zydeco has a labeling system that allows students to attach a short textual label to a specific piece of data to easily annotate and search for data. With this annotation support, students are encouraged to reflect on their data collection and collect more meaningful data. Figure 3 shows the "Review" workspace where students can review and filter data collected by all users within the same investigation. The filter system allows students to sort data by the data collector, the data type, labels attached to the data, helper questions, and hypotheses associated with the data. Figure 4 shows the "Explain" workspace where students construct their scientific explanations based on the "Claim, Evidence, Reasoning" model to address the driving question (McNeill & Krajcik, 2011). According to this model, a "claim" can be defined as an answer to a question, "evidence" is the scientific data collected by students that supports their claims, and "reasoning" is the justification that explains the link between the evidence and the claim. With Zydeco, students have easy access to personal and peer data, which give students opportunities to think over the data more carefully when making an explanation.

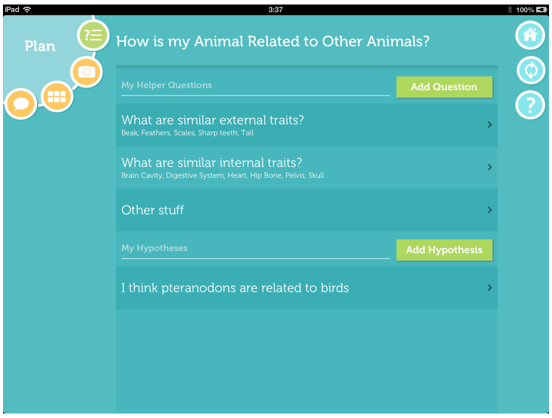

Figure 1. Zydeco plan workspace

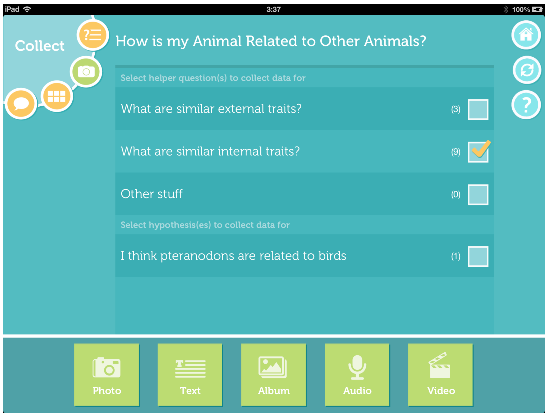

Figure 2. Zydeco collect workspace

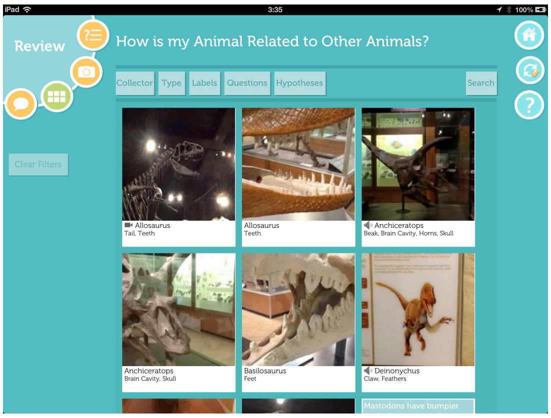

Figure 3. Zydeco review workspace

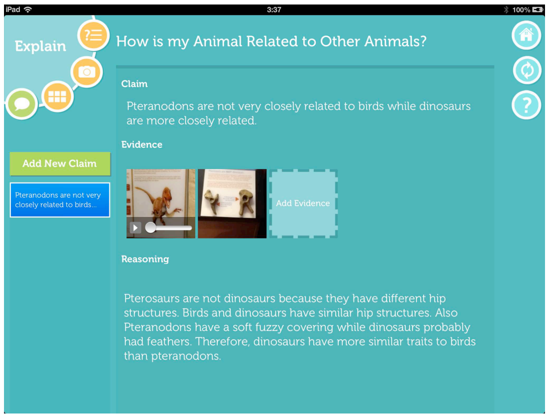

Figure 4. Zydeco explain workspace

Data Collection and Analysis

In order to answer the research question, students' iPad data were collected through the Zydeco web server. We examined whether students used the annotation system to help them collect more meaningful data on site. Based on the coding rubric that was tested and modified from previous Zydeco studies (Cahill et al., 2011; Lo et al., 2012; Lo et al., 2013), we determined whether the data were attached with labels, titles, and other additional information. We further examined the quality of that annotated information (whether labels or other information in relation to the object and the investigative question), and if those data and assigned to hypotheses or helper questions were related. This analysis is helpful to determine whether students make mindful observation and collect appropriate data. The coding rubric can be seen in Table 1.

Table 1: Rubric for analyzing students' on-site collected data

Coding	**Data Type (Video, Audio, Photo, Text)**	**Data Quality**			**Data Relatedness**	
		Object	**Title Accuracy**	**Label Accuracy**	**Helper Question Relatedness**	**Hypothesis Relatedness**
0	no data	the object is unclear to be defined (e.g., blurred photo)	no title	no label	no question attached	no hypothesis attached
1	with data	the object is mismatched with the investigative question	the title is mismatched with the object	the label is mismatched with the object	the object is mismatched with the question	the object is mismatched with the hypothesis
2	-	the object is matched with the investigative question	the title is matched with the object	the label is matched with the object	the object is matched with the question	the object is matched with the hypothesis

Another supportive feature of Zydeco is the embedded "Claim-Evidence-Reasoning" template that is designed to help students construct evidence-based explanations. To analyze students' explanations constructed on iPads, we adopted the rubric from McNeill et al. (2006) as shown in Table 2. Based on students' explanations created on iPads, it is useful to determine whether the embedded “Claim, Evidence, Reasoning” template helps students construct better supportive explanations throughout a school year.

Table 2: Rubric for analyzing students’ explanations (modified from McNeill, 2006)

Scale	**Claim** A conclusion to a question.	**Evidence** Sceintifc data that supports the claim.	**Reasoning** A justification that explains the link between the claim and the evidence.
0	No claim	No evidence	No reasoning
1	Make inaccurate or incomplete claim	Provide appropriate but only one piece of evidence.	Link evidence to claim, without including scientific principles.
2	Make accurate and complete claim.	Provide appropriate and multiple pieces of evidence.	Link evidence to claim, including scientific principles.

Preliminary Findings

On average, every student collected 11 pieces of data from the lab investigation, 15 pieces of data from the museum investigation, and 6 pieces of data from the river investigation. In Figure 5, it indicates that in both lab and river investigations, the object and the title accuracy of the data is over ninety percent. However, in the museum investigation, students collected less accurate data and attached less appropriate title. In terms of data relatedness, Figure 6 shows that when students were situated in the museum investigation, students tended not to attach any helper question to their data. In comparison of three investigations, the river investigation shows the highest percentage of the data relatedness (50.68%) in terms of the accurate associated helper questions, and there was only 36% in the museum investigation.

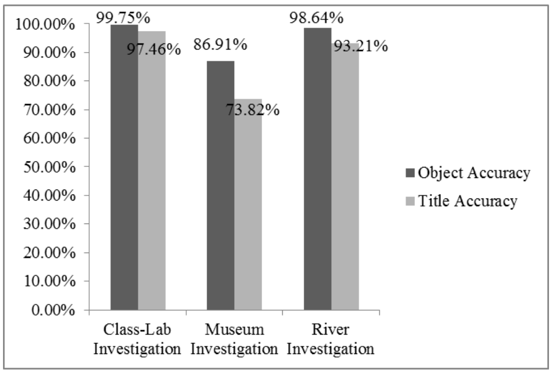

Figure 5. Accuracy of students’ collected data

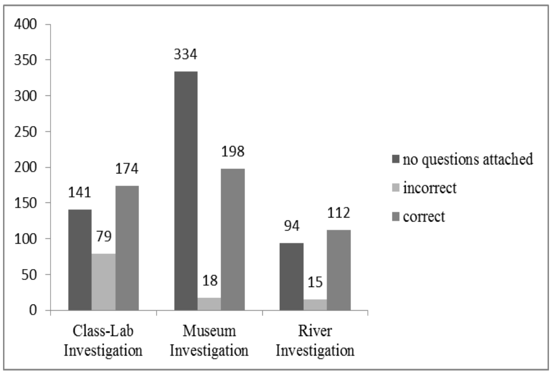

Figure 6. Helper question relatedness

Concluding Remarks

To expand students’ science learning opportunities in K-12, researchers and school teachers have tried to seek a way to integrate mobile technology into their curricula. By situating students within a ubiquitous learning context across environments, this study is helping us examine whether one single tool with embedded supportive features (i.e., the data annotation feature, accessible class data sets, the embedded “Claim, Evidence, Reasoning” template) can help students conduct scientific practices across environments. Our preliminary findings show that students may collect less accurate data and tended not to attach helper questions in the museum investigation. This indicates that when students are situated in a less-structured environment, students may collect less appropriate data. This suggests that educators may need to provide more inquiry supports before and during museum visits. Although in this report paper, we only provide some preliminary findings. However, we believe that this longitudinal study can help us understand whether students’ practices change overtime through the use of mobile tools in this ubiquitous learning context.

With the increasing use of mobile devices in educational fields, more educators are aware of the educational potential that mobile technology and cloud computing may bring into the school (Johnson et al., 2013). Therefore, before making an investment in mobile technology at school, district, or state level, researchers need to understand how students engage in complex practices like inquiry in a variety of environments, what types of challenges students may face, and how educators or program designers can provide support accordingly. Unlike previous studies that are constrained by a particular learning environment, this study will provide a more generalized and holistic view since students’ performances were evaluated based on three science projects in multiple settings. Furthermore, the findings from this study will be useful for educators from informal learning institutions (e.g., museums, zoos), and possibly formal classroom educators, to design more ubiquitous learning activities. Additionally, the learning scenarios used in this study can be adopted and further modified to broaden and connect visitors’ learning experiences.

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