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Development of a Mobile Visualization Application for Constructivist Learning and Assessment in Science

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Abstract: In this paper we introduce a newly developed application for Android tablets that is designed based on the perspectives of constructivist learning and scientific modeling and representation. The purpose of this designed product is to facilitate visualization instruction and assessment in science class. We conducted an initial evaluation study for usability tests and investigated how case users from scientists, teachers, advanced learners and novice learners may use the tool to support their visualization of the concept of carbon cycling. Different patterns of use were identified for further research and tool development.

Keywords: Mobile technology, visualization, constructivism, science learning, assessment

1. Introduction

Visualization involves important practice for communities of scientists, engineers and many other professional experts (National Research Council [NRC], 2011). Visualization refers to processes of creating multiple representations, making meaning of and interacting with the representations (Gilbert, 2008). In light of education, students' ability to visualize or draw their ideas about certain phenomena and to use their visualizations to understand science concepts is important in terms of science education goals and 21st century knowledge and skills (NRC, 2012). Moreover, asking students to draw their ideas can be an effective teaching strategy since it follows the constructivist perspective that learning occurs when learners try to integrate existing and new information to form their own conceptual framework (Ainsworth, Prain, & Tytler, 2011; Linn, 2006).

There are numerous mobile applications available for the purpose of making digital drawings. However, while many applications allow drawing in general, we have not found any current mobile application that provides science content related functions and supports, which are important for students to make drawings efficiently and with scaffolds to benefit science learning (Quintana et al., 2004). For example, ChemSense (Schank & Kozma, 2002) and Chemation (Chang & Quintana, 2006; Chang, Quintana & Krajcik, 2010) provided built-in atom pallets and connection bonds for students to make digital drawings and animations to represent their ideas of chemical phenomena. Research has shown that students benefit from content specific functions to make their drawings to learn science (Chang & Quintana, 2006). However, neither application can operate on the Android system. Also, they only support students in making drawings of atoms and molecules, representing ideas at the particulate level. In this study we describe our efforts to develop a new mobile application for Android tablets, DrawScience, that allows students to visualize their ideas, not only at the particulate level, but also at the symbolic, systematic, and macroscopic levels, as these levels of representation are all essential elements for visualization of science phenomena and concepts. Currently DrawScience is designed as a formative assessment tool that can be seamlessly integrated in science class to make students' ideas explicit and accessible, and for teachers to learn from students' ideas to improve teaching and learning. Future research includes possibilities of automatic scoring of visualizations, real-time feedback for the making of visualizations, and collaborative construction of visualizations to spur discussion during the poster presentation.

2. The Mobile Application: DrawScience

The design of the application is based on the constructivist perspective that students' existing ideas are building blocks for their later learning (Linn, 2006). The interface is divided into three main areas (Figure 1, left) to allow students expressing their ideas: question, drawing and animation. During class, teachers can use an e-learning platform to type in their question for students; students respond to the question by using the features in the application to construct visualizations to make their thinking visible. The design of the four modes (Figure 1, middle) is based on the perspective of scientific modeling and representation that indicates four types of representation that are essential in science teaching and learning: particulate, symbolic, systematic, and macroscopic (Gilbert, 2008; Lehrer & Schauble, 2006). The four modes including the free drawing, textual, particulate, and link modes, enable users to draw the four types of representations in their visualization. In addition, users can use the animation function to create flipbook-style animations to represent a dynamic process in their visualization.

Figure 1. Screenshots of DrawScience: Left: the interface includes three major areas - question, drawing, animation; Middle: four modes - free drawing, textual, particulate, and link modes Right: an example drawing made using DrawScience

3. Evaluation of the Application

We interviewed a total of 16 participants to investigate how they used the tool to visualize their understanding of the concept of carbon cycling. We chose to focus on the topic of carbon cycling since it involves important science concepts within biology and across other subject areas such as earth and environmental sciences. Also, visualizing the carbon cycle involves the use of dynamic and multiple representations at particulate, symbolic, textual, systematic and macroscopic levels. We interviewed four cases from each of the distinct groups, biologists, biology teachers, 12^{th}-grade students (who had already learned carbon cycling) and 10^{th}-grade students (who had not yet learned carbon cycling), aiming to test the maximum variety of possible patterns of uses with the visualization tool. Each interview lasted about two hours, and consisted of five major questions asking the participants to make a total of five drawings or animations to show their ideas related to carbon cycling.

Overall the interview results indicate that all participants were able to construct their visualizations and animations of carbon cycling using DrawScience, while participants from different groups seemed to show different patterns of use. To further discern the patterns, we developed a coding framework to analyze the quality of the participants' visualizations (Table 1). We identified four aspects of visualizations emergent from the data, and developed detailed scoring rubrics to rate the participants' drawing in the four aspects: the use of animation, multiple representation, scientific concept and visualization strategy. We found that both the biologist and biology teacher groups scored higher than the students in representing more scientifically appropriate propositions and relationships of the concepts in their visualizations. The biology teachers seemed best at using multiple representations, probably due to their expertise in teaching in which multiple representations are often needed to help students learn the concepts. Interestingly, the students seemed as good as the scientists in terms of using visualization strategies. All participants created three to four frames to formulate an animation showing the directionality and continuity of a dynamic process of plant growth.

Table 1: A coding framework to analyze the quality of the participants' visualizations in four aspects.

Aspect	Definition
Use of animation	Participant created multi-frame animation to show the directionality and continuity of a dynamic process.
Use of multiple representations	Participant used the modes in the tool to create textual, symbolic, macroscopic, and particulate levels of representation.
Use of scientific concepts	Participant represented scientific concepts appropriately including propositions and relationships of concepts.
Use of visualization strategies	Participants used visualization strategies including use of color, zoom-in and zoom-out, and animation techniques.

4. Concluding Remarks

The results of the initial evaluation study indicate that for science learners the design of the visualization tool needs to embed supports in the aspects of appropriately using scientific concepts and multiple representations; for teachers, a reminder to use visualization strategies and for scientists, a reminder to use multiple representations might help. However this tendency of patterns we observed needs further tests with a larger sample size. Nevertheless the application enables scientific visualizations and we are working on providing automatic scoring, real-time feedback, and collaborative construction functions.

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