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Investigating the Medium Effect of a Mobile Visualization Tool - "DrawScience"

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Abstract: Visualization technology allows students to make their own drawings to express their ideas in visual ways. Implementing visualization technology on mobile devices facilitates the integration of drawing activities with classroom or outdoor activities, creating ubiquitous learning experiences with visualizations. However, drawing on paper has been regarded as the most intuitive approach. We wonder whether asking students to draw on computers would hinder their performance due to the medium effect. In this study, we developed three versions of an assessment that required students to draw and explain their ideas of the particulate nature of matter. These three versions consisted of exactly the same items but were delivered through different media, namely, desktop computers, tablets, and paper, respectively. We randomly assigned 18 10th-grade students to use one of the three versions (a total of 54 students). We scored the students' performance in terms of their drawing and explanations. The results indicated no significant medium effect on their performance. The students drew or wrote on the computers as easily as they drew or wrote on paper. Furthermore, we found that the tablet drawing application was more able to efficiently facilitate the students' creation of animations than the desktop drawing tool. The results indicate that drawing on tablet computers would not hinder students' performance and could be more efficient than drawing on desktop computers.

Keywords: Mobile technology, visualization, medium effect, science learning

1. Introduction

Visualization technology has been regarded as one of the most influential computer technologies in recent decades. When learning science, there is a type of visualization technology that provides external computer visualizations to help students learn abstract concepts. There is also another type of visualization technology that allows students to make their own drawings and animations to express their ideas. In this study we focused on the latter, and developed a new mobile application for Android tablets, DrawScience (Figure 1), 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 into science classes to make students' ideas explicit and accessible, and for teachers to learn from students' ideas to improve teaching and learning.

However, making a drawing on paper, as opposed to on the screen of a desktop or tablet computer, has been thought to be the most intuitive and flexible approach. We therefore wondered whether asking students to draw through the medium of the tablet computer would actually hinder their performance, i.e., the quality of their drawings. On the one hand, theoretical perspectives predict that changes of media, such as delivering assessments or curriculum materials through paper-based or computer-based media, would not make a difference in terms of affecting students' learning performance (Clark, 1983, 1994). On the other hand, a consensus of the debate has been reached indicating that the design of a learning environment should exploit the affordances of a particular medium, and bring powerful methods that cannot be achieved using other media (Kozma, 1991, 1994). In our design of DrawScience, we embedded objects that can make the drawing task more efficient, such as the stamp, grouping, copy-and-paste, and animation functions. Compared to general drawing tools on desktop computers that require using a mouse to make a drawing, drawing on tablets seems more intuitive when using fingers or touch pens. However it is still not as intuitive as drawing on paper. Nevertheless, the embedded functions of computer drawing tools may compensate for this less-intuitive drawback. In this study, we compared the effects of three media, desktop computers, tablets and paper, on students' drawing performance.

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 by a student using DrawScience

2. Methods

2.1 Study Design and Participants

We employed a true experimental design. We randomly selected 54 10th-grade students at a public senior high school in Taiwan. These 54 students were randomly assigned to one of the three conditions (18 students in each condition): desktop computer-based, tablet computer-based, and paper-based assessments. We developed three versions of the assessment that had exactly the same items (Figures 2 and 3 show an example). The desktop computer-based version was delivered through the drawing tool in the Web-based Inquiry Science Environment (WISE, Linn, & Eylon, 2011) platform. The tablet computer-based version was delivered through DrawScience (Chang, Yu, Hung, & Hsu, 2014). Both drawing tools have been through developmental testing and revisions, and have been shown to have good usability. They have similar built-in object and animation functions.

Each version of the assessment contained a total of 6 constructed-response items that asked students to make drawings of concepts related to the particulate nature of matter, and type in (or write down) their explanations of a given visualization. The assessment focuses on this concept because visualization of the particulate nature of matter is important in science and science education. The validity and reliability of the assessment were checked and have been reported elsewhere (Chang & Tzeng, 2015). Although the assessment items are exactly the same, the desktop and tablet computer-based versions provide more functions such as those built-in objects. Also, students can build flipbook style animations by creating and playing multiple frames. In contrast, the paper-based version required the students to create exactly three drawings to depict the process of the particulate nature of matter, whereas the two computer-based versions did not set any limit with regards to how many frames the students could create to depict the process. All students completed the assessment in one class period (45 minutes). Students using the two computer-based versions were first given a brief instruction on how to use the drawing tool before they started to respond to the items.

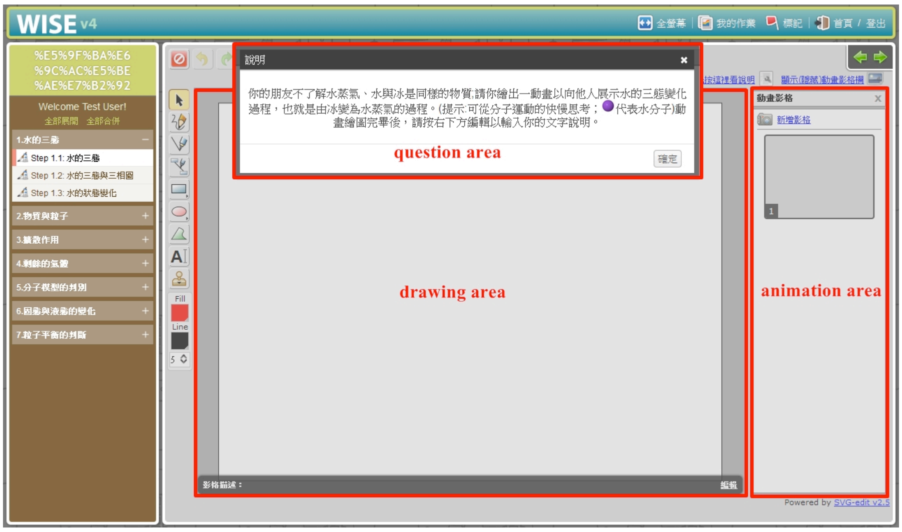

Figure 2. The desktop computer-based version of the assessment created using the WISE platform

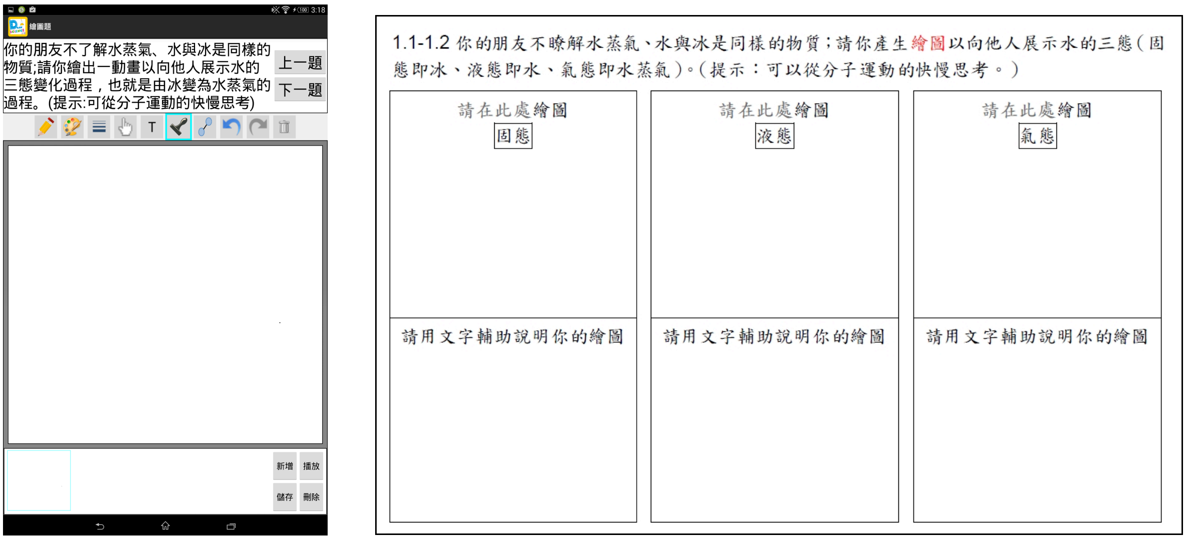

Figure3. Left: the tablet computer-based version of the assessment created using DrawScience; Right: the paper-based version of the assessment

2.2 Data Analysis

Detailed coding rubrics were generated for each item to rate the students' drawings and explanations. We summarize the overall coding criteria in Table 1 for the students' drawings and explanations. Two independent raters coded 18 of the 54 tests. The inter-rater reliability was 0.89, which is adequate. Inconsistent codes were discussed and resolved. The rest of the tests were coded by one of the raters. The students' scores on the drawing and explanation items were summed and compared. Tests of normality indicated that the scores for all groups were normally distributed (desktop computer group: W=0.95, p=.46; tablet computer group: W=0.95, p= .39; paper group: W=0.95, p=.49). We employed one-way ANOVAs to compare the mean differences of the students' drawing and explanation scores among the three conditions, using the scores as the dependent variables, and the condition as the independent variable.

Table 1: Summary of the coding rubrics to analyze the quality of the participants' drawings and explanations.

Aspect	Scores
1. Student's drawings	
1.1 Use of multiple representations	Student's drawing receives one point for containing each of the four components: textual, symbolic, macroscopic, and particulate representation (the maximum score is 4).
1.2 Use of scientific concepts	Student's drawing is rated based on the accuracy of the concepts expressed in the drawing: integrated adequate particulate (5); basic adequate particulate (4); partially adequate particulate (3); alternative or non-particulate (2); inadequate (1); irrelevant (0).
1.3 Use of visualization strategies	Student receives one point for using any of the visualization strategies: use of color, or zoom-in and zoom-out techniques (the maximum score is 2).
2. Student's explanations	Student's explanation is rated based on the adequacy of the concepts expressed in the explanation and the completeness of the explanation: complex adequate (4); basic adequate (3); partially adequate (2); inadequate (1); irrelevant (0).

3. Results

3.1 Medium Effect on the Students' Drawing Performance

The one-way ANOVA result indicated no significant medium effect on the students' drawing performance: F (2, 51) = 1.05, p=.36 (means and SDs are summarized in Table 2). The computer drawing tools, both on desktops and tablets, can support students' expression of their ideas via drawing just as well as those through the medium of paper. We further compared the average number of frames the students created in the desktop and tablet computer groups and found a medium effect. The students using tablets significantly created more frames (mean frames for each student=4.11, SD=2.40) than those using desktop computers (mean frames=2.83, SD=0.51): t(34)=2.21, p=.03. It seems that the tablet computer application enables students to create more frames to form an animation than the desktop computer tool.

Table 2. Means and standard deviations of the students' drawing scores

	Desktop computer version	Tablet computer version	Paper Version
Number of Sample	18	18	18
Mean	12.67	12.50	11.56
SD	2.66	2.28	2.50

3.2 Medium Effect on the Students' Written Explanations

The one-way ANOVA result indicates no significant medium effect on students' explanation performance: F(2, 51)=0.06, p=.94. This result indicates that the students wrote on computers, either on desktops or tablets, as easily as they wrote on paper. That is, writing in a computer-based environment did not hinder their writing performance.

Table 3. Means and standard deviations of students' explanation scores

	Desktop computer version	Tablet computer version	Paper Version
Number of Sample	18	18	18
Mean	12.67	12.78	12.39
SD	3.22	3.17	3.68

4. Concluding Remarks

The mobile visualization technology, DrawScience, has been through iterative phases of development, testing, analysis and revision. We have improved the usability of the application and incorporated built-in objects to address learners' needs (Chang et al., 2014). The results of this study further indicate that, compared to the media of paper or desktop computers, asking students to make drawings and write explanations using mobile devices would not hinder their performance. Although students may need to learn technical operations at first and allocate some of their cognition to navigating the different modes in DrawScience, these extraneous tasks would not affect the quality of the students' performance, given the same period of assessment time. Moreover, the mobile application seems to facilitate drawing more efficiently than the desktop drawing application that requires the use of a mouse to draw. As an ongoing project we are working on providing automatic scoring, real-time feedback, and collaborative construction functions to take advantage of the mobile technology to create a mobile visualization tool that helps improve research, teaching and learning of science with visualizations.

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