Exploring the Effect of "Color Cueing" on Mobile Learning in Physical Environments

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Abstract: This study proposed a cueing technique named "color cueing" to assist students attend to the important learning information of texts in the mobile learning environment. The effect of"color cueing" was examined by a between subjects experiment. Forty fifth-grade students were randomly assigned to the"color cueing" and "non-color cueing" conditions. The results indicated that effect of "color cueing" was not significant. There was no significant difference in the students' learning time, cognitive load, retention, comprehension and application test performance between the two conditions. The results were discussed and some recommendations were proposed to future studies.

Keywords: cognitive load, cueing effect, mobile technology assisted learning, elementary science

1. Introduction

Mobile technology assists students' learning in rich physical environments is used widely in different learning fields (e.g., Chen, Kao, & Sheu, 2003; Liu, Peng, Wu, & Lin., 2009). In such learning environments, students are provided with multiple learning information sources including authentic objects surrounding them and texts and pictures embedded in the mobile devices (Liu, Lin, Tsai, & Paas, 2012). Although multiple learning information sources could give students multiple learning experiences that may benefit their learning, dealing with multiple learning information sources may also put students in the risk of cognitive overload and hinder their learning (Liu et al., 2012; Liu, Lin, & Paas, in press; Sweller, Van Merrienboer, & Paas, 1998).

Identifying useful information from multiple learning information sources is an important task for students' learning, however, the task is not easy for them, especially for low prior knowledge students. Cueing is one potential way to assist students to perform the task more effectively. Cueing is generally defined as a way to draw students' attention to essential elements of the learning materials (de Koning, Tabbers, Rikers, & Paas, 2009). Another term with similar meaning is "signaling" that is defined as adding cues to direct students' attention in processing the most important information in learning materials (Mayer, 2005). Cueing could be presented in different types (e.g., heading, outline, color coding, flash, arrow …etc.), and the different types of cueing have different impacts on the student's cognitive process (de Koning et al., 2009; Lorch, Julie, & Russell, 2011).

Cueing has been popularly used in many materials, especially in text (e.g., Lorch, Lorch, & Klusewitz, 1995) and the integration of text and static visualizations (e.g., Kalyuga, Chandler, & Sweller, 1999). Although the positive effect of cueing in reducing cognitive load and enhancing learning has been found in different learning environments, the effect of cueing is seldom explored in the mobile learning environment (Liu et al., in press). In order to reduce the risk of cognitive overload for students in the mobile learning environment, this study aimed to examine the cueing effect in the mobile learning environment.

Guiding students' attention to essential information and to distinguish particular information from unrelated information is an important function of cueing. Italicizing or bolding words are often used to guide students' attention to essential information in complicated texts. This paper proposes a cueing technique, entitled "color cueing". The important words of the guiding texts embedded in the mobile device are colored in red to make the students attend to the important information. In the mobile learning environment, with assistance of "color cueing", students can save their cognitive resources in finding the important information of the texts and put their cognitive resources in reading important information and observing the corresponding characteristics of authentic objects. Therefore, based on cognitive load theory, the students who learn with "color cueing" are expected to perform better than the students who do not learn with "color cueing" in the mobile learning environment.

2. Methods

2.1 Participants and design

Forty fifth-grade students (Mean age 11 years; 20 boys and 20 girls) of a primary school in Northern Taiwan participated in this study. All participants have been taught the essential knowledge of plant leaf morphology in their nature science classes in third grade. A between-subjects experimental design was used to address the hypotheses of this study. The independent variable is "color cueing" and the dependent variables are learning time, cognitive load in learning phases, retention, comprehension and application test scores. Forty students were randomly assigned to "color cueing" or "non-color cueing" condition. One day before the experiment, a prior knowledge test was conducted to collect the data of the participants' prior knowledge of leaves. No significant difference of prior knowledge scores was found in the two conditions (t (38) = 0.94, p>.05).

2.2 Learning materials and equipment

The learning materials of this study focused on plant leaf morphology. The texts embedded in the mobile device and six different plants surrounding students were used to teach students the knowledge of four subtypes of venation, four subtypes of margin, and five subtypes of phyllotaxy. Two versions of the learning materials (color cueing and non-color cueing) were developed by the research group. Each version had 18 screens and each screen had 20 to 57 words. The content of the two versions are the same, excluding the important information of the text is colored in red in the color cueing condition. Palmate-veined of leaf venation is used as an example to show the differences of the two versions in detail (see Figure 1).

The equipment used for the two conditions was an iPad like Tablet device with a 10-inch monitor. The instructional software for the tablet PC was developed in the programming language JAVA.

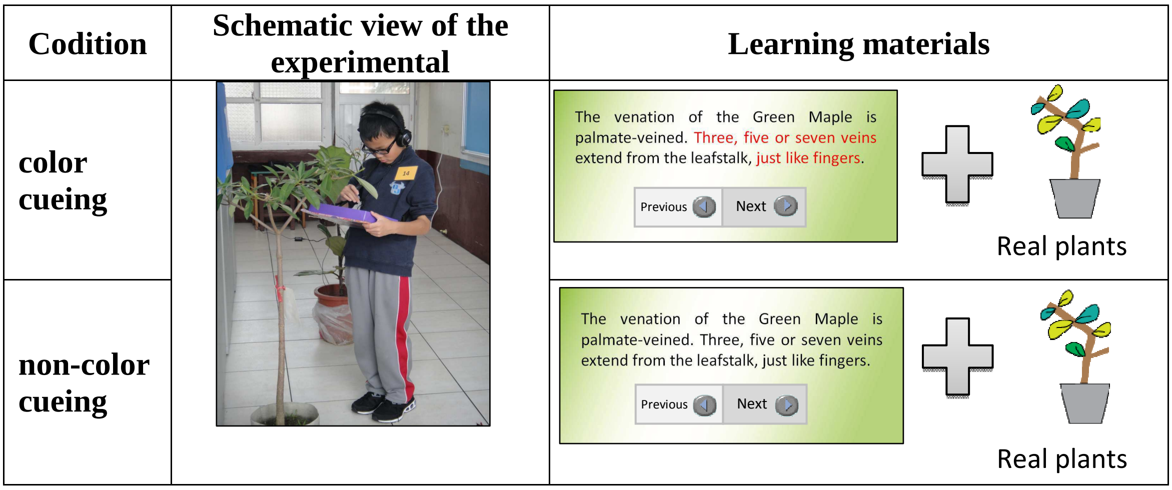

Figure 1. Examples of the different learning materials in the color cueing and non-color cueing conditions (original materials were presented in the Chinese language)

2.3 Measurements

A prior knowledge test was composed of ten multiple choice questions about the basic concepts of leaf morphology knowledge. The highest score of the test was 10 points and the lowest score was 0 points. The internal consistency reliability coefficient (KR-20) of the test was 0.81

A leaf morphology knowledge retention test was composed of 18 multiple choice questions. In this test, the participants were asked to observe the six pictures of the plants that were used in the learning phase and then identify the venation, margin, and phyllotaxy features of each plant by the paper based sheet. The highest score of the test was 18 points and the lowest score was 0 points. The internal consistency reliability coefficient (KR-20) of the test was 0.72

A leaf morphology knowledge comprehension test was composed of a drawing task and an assembling task. The drawing task consisted of 8 items and the assembling task consisted of 5 items. In the drawing task, the participants were asked to draw the four subtypes of venation feature and four subtypes of margin feature. In the assembling task, the participants were asked to assemble the five subtypes of the phyllotaxy feature. The highest score of the test was 13 points and the lowest score was 0 points. The internal consistency reliability coefficient (KR-20) of the test was 0.72.

A leaf morphology knowledge application test was composed of 18 multiple choice questions. In this test, the participants were asked to observe the six plants that were different from the plants used in the learning phase and then identify the venation, margin, and phyllotaxy features of each plant by the paper based sheet. The highest score of the test was 18 points and the lowest score was 0 points. The internal consistency reliability coefficient (KR-20) of the test was 0.75.

The cognitive load rating scale was used to measure the perceived difficulty of learning with different learning materials for the participants. The cognitive load rating scale was revised from Yeung, Jin and Sweller (1997).One item (e.g., “Please rate your level of the degree of difficulty on using this learning material to learn the characteristics of plant leaf”) in the rating scale is shown in the Likert type nine-point scale. The highest score on the rating scale was 9 points and the lowest score was 0 points.

2.4 Procedure

The experiment was conducted in a real classroom. There were three phases in the experiment, including a preparing phase, an intervention phase, and a test phase. All participants worked individually in all three phases of the experiment. In the preparing phase, participants were asked to read the outline of the three features of leaf morphology and they were trained to observe the three features of leaf. In the intervention phase, participants learned with different versions of learning materials within 8 minutes and their cognitive load was measured immediately after they have finished learning. Finally, three kinds of tests were conducted to measure participants' learning performance in different conditions.

3. Results

The results of independent t-test between the color cueing condition and the non-color cueing condition showed no significant difference for learning time ($t(38)= 0.87$., $p>.05$,one-tailed), cognitive load ($t(38)= -0.16$, $p>.05$, one- tailed), retention test scores($t(38)= 0.93$, $p>.05$,one-tailed), comprehension test scores ($t(38)= 0.23$, $p>.05$, one-tailed), and application test scores ($t(38)= 0.97$, $p>.05$, one-tailed). (See Table 1)

Table1. Results of word cueing in mobile environment

	color cueing		non- color cueing			
variable	*M*	*SD*	*M*	*SD*	*t(38)*	*p*
Learning time	5.22	1.20	4.81	1.70	0.87	.19
Cognitive load in learning phase	2.85	1.73	2.95	2.11	-0.16	.44
Retention test scores	9.95	3.99	9.00	2.20	0.93	.18
Comprehension test scores	7.40	2.32	7.25	1.74	0.23	.41
Application test scores	10.20	2.84	9.40	2.37	0.97	.17

4. Discussions and Conclusion

In order to reduce the risk of cognitive overload for students in the mobile technology assisted learning in the physical environment, this study proposed a cueing technique named "color cueing" to draw students' attention to the important information of the texts. An experiment was conducted to examine the effect of"color cueing" in reducing students' cognitive load and enhancing their learning performance. However, the effect of "color cueing" was not significant. The students who learned with the "color cueing" version did not perceive lower cognitive load, nor have better learning performance than the students who learned with the "non-color cueing" version.

The results indicated that the "color cueing" used for highlighting the important learning information of the texts is not enough for reducing students' cognitive load and enhancing their learning performance in the mobile technology assisted learning in the physical environment. Mayer (1997) referred that meaningful learning occurs when the learner engages in three basic kinds of cognitive process: selection, organization, and integration. Although the use of color cueing can attract students' attention to the important information of the texts, it is not useful for assisting students to integrate the information from multiple learning sources, including the texts embedded in the mobile device and authentic objects surrounding them.

The cueing technique used to support the integration of elements between multiple learning information sources was wildly used in different learning environments. For example, Kalyuga et al. (1999) used the same color in the text and accompanying parts of a graph to assist students to integrate the learning information of text and graph (i.e., color cueing). Liu, Lin and Paas (in press) used a cueing technique named “arrow line cues” to integrate the learning sources from texts and pictures embedded in the mobile device. Different from the mentioned cueing techniques which were used to integrate the multiple learning information sources of the same device, the cueing technique that can assist students to integrate the information from the texts embedded in the mobile device and the information from authentic objects is recommended to be proposed and examined in the future studies.

Short content in each screen is the other reason for explaining why the use of “color cueing” could not reduce students’ cognitive load and enhance their learning performance. Due to the limited size of the screen on the mobile device, it could only display short content in each screen at one time, which may decrease the necessity of using“color cueing” to assist students to find the important learning information from the texts composed short content. Finally, due to the learning topic of this study, which is “the identification of leaf morphology”, the leaf morphology feature of six plants was used as the example to teach the learning topic. Because some of the leaf morphology feature was introduced repeatedly, the cueing effect may be eliminated by the practice effect. Much complex material is recommended to be used in the future studies.

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