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The effect of computer simulation designs on students' learning motivation and conceptual scientific understanding

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Abstract: This study aimed to explore the effectiveness of computer simulations in learning optical imaging concepts and mainly studied the effects of different interfaces on conceptual learning and students' learning motivation. Forty primary students, who were randomly assigned tablet PCs (gesture-based group) and desktop PCs (button-based group) for learning, participated in this study. The research showed that the use of gesture-based computer simulations was more effective than button-based computer simulations in providing perceptual experiences and helping elementary students understand the principles of optical imaging. In addition, compared with desktop PCs, students exhibited higher learning motivation while using tablet PCs.

Keywords: computer simulations, learning optical imaging, motivation

1. Introduction

Learning optics is often considered by teachers and students to be a difficult pursuit. Students make spontaneous efforts to understand the world around them, construct their own interpretations of optical phenomena, and then bring this informal knowledge to classroom. Hence, a lot of knowledge naturally forms before any formal learning takes place. Students believe that intuitive knowledge is correct, even if it is inconsistent with scientific knowledge. According to many studies on optics, students' prior knowledge about optics was usually inconsistent with scientific knowledge (Igal Galili & Amnon Hazan, 2000). Posner et al. (1982) found that students regard their own intuitive knowledge as more reasonable and meaningful than the scientific knowledge they are exposed to in class. Traditional teaching may not be effective enough to change the innocent minds of students. In order to address this problem, computer simulations are widely used in science classes. De Jong and van Joolingen (1998) defined computer simulation as "a program that contains a model of a system (natural or artificial; e.g., equipment) or a process." Their application in science classrooms has the potential to yield higher learning outcomes in unprecedented ways (Akpan, 2001). Furthermore, interaction with the environment through hands-on operation can facilitate the development of conceptual understanding (Lindgren, 2015). However, few articles have examined the impact of computer simulations on optical imaging learning in primary schools. Therefore, this study aims to explore the effectiveness of computer simulations, based on different interactive interfaces, on students' learning motivation and learning outcomes and provide empirical evidence to support the application of computer simulations in science education.

2. Literature review

2.1 Computer simulations and science learning

With the increasing popularity of computers and mobile devices and the wide application of computer simulations in various scientific disciplines, simulations have become an integral part of many science courses (Rutten et al., 2012). Computer simulations appeal to students in interesting ways, so they are willing to spend the necessary time and energy to experience a concept and acquire a new understanding of it (Richards, Barowy, & Levin, 1992). These simulations are based on scientific models and combined with practical activities; moreover, they provide students with a series of experiences that challenge the way they think about the world, thus enabling students to create simulations based on their own interpretation of various phenomena and test them. Simulations have been successfully applied in science classes to help students understand abstract concepts (Chiu et al., 2015). Chiu et al. (2015) conducted a study on the effectiveness of using augmented virtual science laboratories to enhance the understanding of gas properties among middle school students. The results demonstrated that augmented virtual science laboratories could enable students to acquire molecular level knowledge and alter their previous ideas. Richards et al. (1992) described a science teaching software based on constructivist learning epistemology, and found that the use of simulation and practice activities can enhance students' ability to actively participate in learning. Jong et al. (1998) reported that computer simulations facilitated students' scientific discoveries and their learning in conceptual domains. Introducing additional support tools into teaching is an effective way to accomplish certain behaviors, and it can also be used to reduce cognitive load. It enabled students to study in a relaxed and pleasant environment.

Some studies have found that tablet-based simulations can promote scientific learning more effectively. The rapid development of interactive technology has made touchscreens as common as mouse and keyboard input devices (Romeo et al., 2003) since they allow people to interact with computers through gestures. Schneps et al. (2014) mentioned that on touchscreens, you can zoom using pinching gestures, which naturally combines zooming and scrolling, making the interface particularly suitable for zooming simulated concepts. Researchers have found that even a brief lesson based on a scaled simulation of the solar system can improve students' understanding of the solar system and more successfully address students' misconceptions (Schneps et al., 2014). Lindgren (2016) also reported that implementing concepts and experiencing critical thoughts in physics through the activities that engage the entire body would bring significant learning gains, higher participation, and a more positive attitude toward science. In recent years, several studies have compared computer simulation to conventional instruction; however, little research has focused on comparing the effects of different interactive interfaces on students' science learning. Thus, the study aimed to explore the effects of different simulation interfaces on students' learning motivation and learning outcomes in learning optical imaging.

2.2 Learning motivation and science learning

Learning and motivation are very complex aspects of human behavior. Kukkonen et al. (2013) defined motivation as an individual's external behavior and internal learning motivation. Cindy & Douglas (2000) argued that motivation is necessary for long-term, effective, and meaningful learning. The relationship between students' learning motivation and learning outcomes has always been the focus of educational researchers. Motivation is strongly related to students' learning behavior and learning outcomes (Schunk, Meece, & Pintrich, 2013). Ying et al. (2008) also reported that learning motivation has a positive predictive effect on learning outcomes. Wu and Tai (2016) found, through an experiment, that there are significant relationships between students' motivation and learning outcomes.

In recent years, computer simulation has been widely used to improve students' learning motivation and learning outcomes. Yusrizal and Khairul (2017) studied students learning physics through computer simulations; their results revealed that the application of computer simulation in teaching can improve students' learning motivation. However, little research has been conducted on the application of computer simulations to improve students' learning motivation and learning outcomes in primary school science courses. Therefore, this study aims to explore the effects of different simulation interfaces on students' learning motivation and learning outcomes.

3. Materials and Method

3.1 Computer simulation design

This research considered how different interaction interfaces may affect students' learning and motivation. By using the Apache server, the PHP language design, and the MySQL database, online digital optical imaging learning materials were developed. It can work on computers and mobile terminals (intelligent tablets), and its functions include providing simulated interaction, online testing, and automatic recording of the students' behavior, which is stored in a database. The learning materials mainly cover the following learning points: light refraction and reflection, plane mirror imaging principle, and convex lens imaging principle. Learners can manipulate objects with a mouse or hand gesture to discover how optical imaging works. In Figure 1, students zoom in, zoom out and rotate the small turtle using a mouse. In Figure 2, students control the turtle through a touchscreen.

3.2 Participants

Forty sixth-grade students (27 females and 13 males between the ages of 11 and 12) from central China participated in this study. The research objects were selected through convenient sampling and none of the students had studied optics before our interventions.

3.3 Procedures

Prior to the experiment, a pre-test on optical imaging concepts and students' motivation (60 minutes in duration) was conducted in the classroom. According to the pre-test results, 20 students were randomly assigned to the group using tablet computers (gesture-based group), and the remaining 20 students were assigned to the group using desktop computers (button-based group). Both groups showed equivalent prior knowledge in optical imaging and topics related to this study. To avoid the influence of different teachers on experimental results, all students operated interactive simulation learning materials under the guidance of the same teacher. Each group took about 30 to 40 minutes to learn optical imaging through different devices. After the learning activity, all 40 students spent 40 to 60 minutes completing the post-test (designed to test their optical imaging concepts learning) and the second questionnaire (designed to assess their motivation for science).

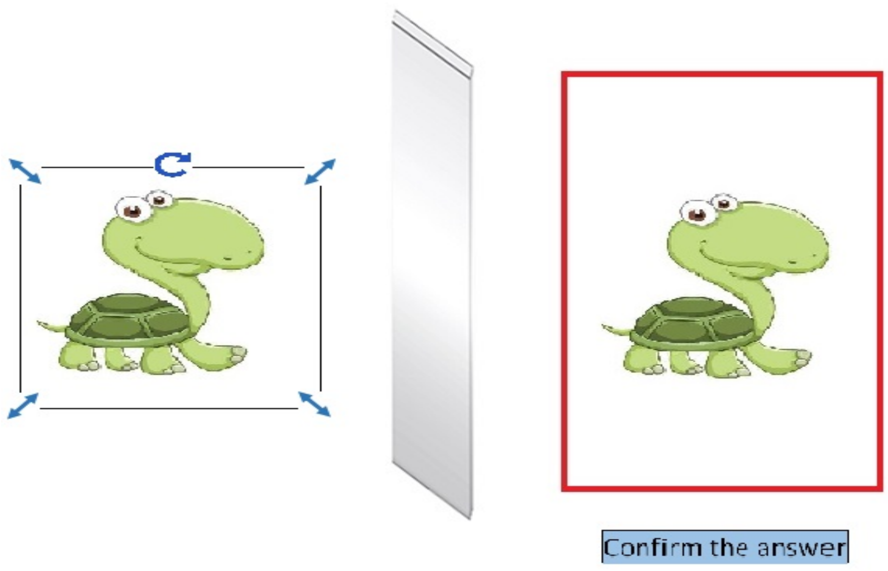

Figure 1. The material of button-based computer simulations for learning plane mirror imaging

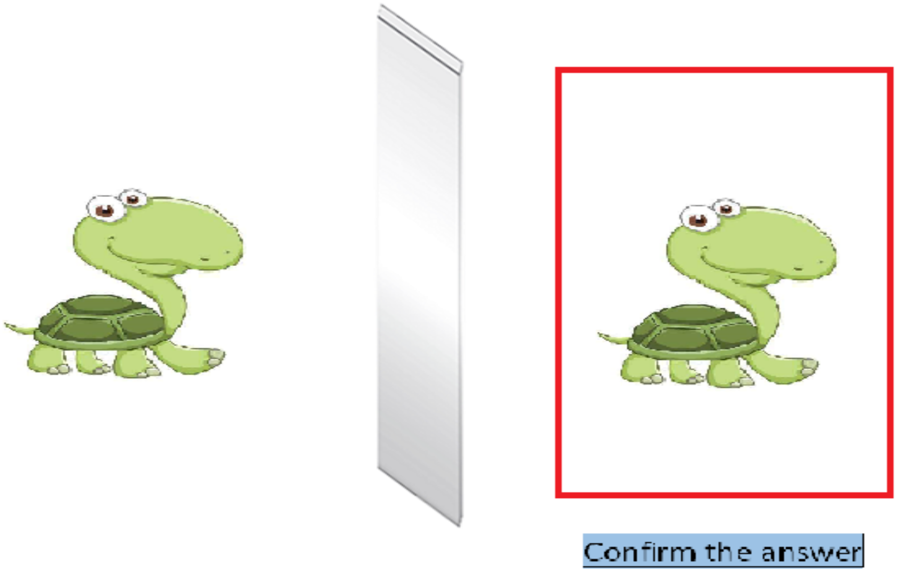

Figure 2. The material of gesture-based computer simulations for learning plane mirror imaging

3.4 Optical imaging concept test

The optical imaging concepts test consisted of 40 single choice questions (e.g., “According to the law of reflection of light, which of the following illustrations is correct? What is the reason for choosing this answer?”), with one point given for each correct answer. This mainly tested the effects of computer simulations on students’ knowledge of optical imaging concepts. Seven experts, including science teachers and researchers, developed the test. The Cronbach’s α was 0.816, thus the Optical imaging concepts test had good reliability.

3.5 Learning motivation

“Motivated Strategies for Learning Questionnaire,” developed by P.R. Pintrich (1991), was adapted for the motivation questionnaire. It was combined with Likert scale, ranging from 1 (strongly disagree) to 6 (strongly agree). It consisted of 18 items in five dimensions: intrinsic motivation, extrinsic motivation, interest, self-efficacy, and expectation. The Cronbach’s α was 0.903.

4. Results

4.1 Analysis of the optical imaging concept test

The paired sample t-test examined the students who studied on tablet computers ($T[20]= -7.716$, $p<0.001$) or desktop computers ($T[20]=-5.004$, $p<0.001$); they made statistically significant progress from pre-test to post-test. One-way ANCOVA was employed to examine the effects of two different interactive interfaces on the optical imaging concepts test. Students’ pre-test scores were used as covariates, the post-test results were the dependent variables, and the two different interactive interfaces were the control variables. Regression coefficients showed that there was no significant interaction between the pre-test scores and post-test results ($F [1, 40]= 1.449$, $p = 0.248 > 0.05$, partial $\eta 2= 0.073$).The Levene’s test results were not significant ($F [1, 40] = 0.743$, $p= 0.394>0.05$), showing that the homogeneity of variance hypothesis was established, and ANCOVA can be used to confirm the differences between two groups in the optical imaging concepts test after intervention. As shown in Table 1, the ANCOVA results showed that the change in interactive interface has no significant influence on the performance of post-optical concepts test ($F[1,40]=2.615$, $p= 0.114>0.05$, partial $\eta 2= .066$). Furthermore, students’ post-test scores were 14.90 and 12.75 for the experimental and control groups, respectively. The post-test results revealed that the students in the experimental group had higher achievements than the students in the control group.

Table 1

ANCOVA results of the optical imaging concept test

Group	N	M	SD	F
Experimental group	20	14.90	3.782	2.615
Control group	20	12.75	4.435	

4.2 Analysis of students' motivation

The paired sample t-test revealed that students' motivation improved from pre- to post-test both in the gesture-based group ($T[20] = -0.711$, $p > 0.001$) as well as in the button-based group ($T[20] = -0.292$, $p > 0.001$). The one-way ANCOVA was employed to examine the effects of two different interactive interfaces on students' motivation. Students' pre-test scores for optical imaging concepts were used as covariates, the post-test results in motivation were the dependent variables, and the two different interactive interfaces were the control variables. Regression coefficients showed that there was no significant interaction between covariates and independent variables ($F [1, 40] = .174$, $p = 0.841 > 0.05$, partial $\eta 2 = 0.009$). The Levene's test results were not significant ($F [1, 40] = 1.520$, $p = 0.225 > 0.05$), showing that the homogeneity of variance hypothesis was established and that ANCOVA could be used to confirm the differences between the students' motivation in the two groups after intervention. As shown in Table 2, the ANCOVA results showed that interactive interface has no significant effect on students' motivation ($F [1, 40] = 0.308$, $p = 0.582 > 0.05$, partial $\eta 2 = 0.008$). Furthermore, it was found that students in the experimental group ($M=81.65$, $SD=13.507$) had higher motivation than those in the control group ($M=78.65$, $SD=20.21$).

Table 2

ANCOVA results of student's motivation

Group	N	M	SD	F
Experimental group	20	81.65	13.507	0.308
Control group	20	78.65	20.21	

5. Discussion

The study focused on desktop and tablet-based simulations that can be operated with a mouse, keyboard, and gestures. The researchers found that optical imaging concepts post-test scores for all students, whether they were in the gesture-based group or the button-based group, had significantly improved. The results provided us with empirical evidence to support the application of computer simulation in science teaching and learning. In addition, the study revealed that computer simulations had positive effects on students' motivation. In addition, the ANCOVA results indicated that different interactive interfaces had similar effects on students' conceptual understanding and motivation. A possible reason for this is that both gesture-based simulations and button-based simulations may contribute equally to conceptual understanding and motivation. Another reason is that the two systems are very similar, and only the interaction interface is different. Thus, none of them introduced new and helpful features. However, the post hoc demonstrated that gesture-based simulations are superior to button-based simulations in facilitating students' learning and increasing students' motivation. In other words, students in the experimental group obtained higher learning outcomes and motivation than those in the control group. This implies that the gesture-based computer simulations may be more effective than the button-based computer simulations in providing perceptual experiences and helping elementary students learn optical imaging concepts. For students, learning on a tablet is more fun than on a computer. The results are consistent with previous findings, which showed that students using haptic augmented simulations to learn scientific concepts could achieve higher learning outcomes than those using equivalent non-haptic simulations (Han & Black, 2011); furthermore, they provide empirical evidence for both groups' basic understanding of concepts, which can serve as a cognitive basis for understanding their conceptual level (Barsalou, 2007).

6. Conclusion

This study examined the effects of computer simulations on students' science learning and motivation, and whether different interactive interfaces have different effects on students' conceptual understanding and motivation. The data indicated that the students who learned using tablet PCs achieved better performance in optical imaging concepts test than those who learned using desktop PCs; however, both types of simulations helped students acquire a conceptual understanding. The study suggested that gesture-based simulations could be more effective in helping students learn optical imaging concepts than button-based simulations, and could potentially be used in future science courses. Furthermore, the students in the gesture-based group had higher motivation than the students in the button-based group. This finding implies that there is a positive correlation between students' motivation and achievement and that motivation can be used as a predictor of students' conceptual understanding. Future researchers may be able to improve students' final grades by improving their motivation to learn using digital materials.

Until now, the research on computer simulations has mainly compared it with traditional teaching, without considering the effects of different interactive interfaces. In other words, instead of comparing different kinds of simulations, scholars studied the effects of computer simulations as a supplement to or substitute for traditional teaching (Rutten et al., 2012). Our research has compared the effects of gesture-based simulations and button-based simulations on students' science learning. Therefore, this study breaks through the limitations of previous studies on computer simulations, and offers a new way to understand why and how students obtain better understanding of optical imaging while also taking motivation into consideration. For this study, the post-test was launched immediately after intervention, so the long-term effects of computer simulations could not be measured. In future studies, researchers should try to measure the long-term effects of computer simulations.

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