Collaborative Problem Solving and Observation in 3D Virtual Worlds for Secondary School Students

Introduction

A growing number of studies have paid attention to the affordances of 3D virtual worlds (VWs) in education. The VWs allow learners to create and manipulate virtual objects, explore novel environments (e.g., ocean, space, historical site), have embodied experience, and interact with other learners by using 3D avatars (Dalgarno & Lee, 2010). Despite the potential of VWs in education, previous studies have been carried out mainly in higher education rather than primary and secondary school contexts (Wang & Burton, 2013). More research is necessary to investigate learning principles and instructional strategies that help K-12 school teachers to use VWs for meaningful learning. Particularly, more attention should be paid to affordances of VWs for collaborative learning. The VWs allow students not only to share their ideas and opinions but also to carry out collaborative tasks by creating or manipulating objects together (Dalgarno & Lee, 2010).

Collaborative Problem Solving and Observation

The VWs provide authentic contexts in which students learn through collaboratively solving complex and ill-structured problems. Through collaborative problem solving (CPS) in VWs, students can share their knowledge, compare and evaluate diverse perspectives, use knowledge as a tool for solving a problem, and jointly develop a solution in authentic contexts. Hung, Lee, and Lim (2012) asked secondary school students to collaboratively create their own river basins by manipulating the virtual land as part of geography coursework.

However, there are several concerns about CPS in VWs. To carry out CPS tasks, all students should be able to use computers connected to high speed Internet and have sufficient knowledge and skills in using VW software. Teachers also have difficulty in classroom management because students' attention can be easily distracted in the complex and immersive environment. In addition, Kirschner, Sweller, and Clark (2006) pointed out that problem solving or inquiry-based activities make heavy cognitive load that rarely contribute to knowledge acquisition in long-term memory.

Teachers can consider collaborative observation (CO) as an alternative to CPS in VWs. Students can learn from observing what a teacher or other students solve a problem in VWs and collaboratively carrying out tasks pertaining to the actions observed. For CO, students do not need to carry out tasks with their own avatars in VWs, so it is not necessary to teach students how to use VW software. A teacher can prevent students from being distracted by VW objects unrelated to learning objectives, and CO does not require highly advanced ICT facilities. Although there are few empirical studies about CO, Chi, Roy and Hausmann (2008) found that collaborative observers who watched a videotape of tutoring sessions gained as much knowledge as tutees who solved problems through individual interaction with a tutor.

Despite the advantages of CO, it is possible that observing actions of other people is not as effective as direct experience in VWs. Because students have low autonomy in deciding the behaviors of avatars, their intrinsic motivation may be reduced (Ryan & Deci, 2000). In addition, CO provides students with fewer opportunities to express their naive thoughts and learn from failure experience in VWs when compared to CPS (Kapur, 2010).

The purpose of this study is to investigate the effectiveness of VW-based collaborative problem solving and observation for secondary school students. Specifically, this study includes the following research questions:

- What are the effects of collaborative problem solving and observation in a virtual world on intrinsic motivation?
- What are the effects of collaborative problem solving and observation in a virtual world on comprehension and application of knowledge?
- What are the effects of collaborative problem solving and observation in a virtual world on group performance?

Research Methods

Participants

This study was conducted in three geography classes at a secondary school in Singapore. The three classes were randomly assigned into collaborative problem solving (CPS), collaborative observation (CO), and teacher-directed instruction (TD, control) conditions. A total of 101 secondary school first grade students (65 males and 36 females) completed all tasks required in the current study. In the pre-test, there was no significant difference in prior knowledge of topographical maps among the three conditions, F (2, 98) = .27, p = .76.

Procedure

In this quasi-experiment, students took pre-tests of their prior knowledge and intrinsic motivation, studied topographical maps according to their research conditions for three sessions (55 minutes for each session), took post-tests of comprehension, application, group performance, and intrinsic motivation, and carried out delayed post-tests 12 weeks after the post-tests. In the CPS condition, students collaboratively solved problems like calculating bearings and compass directions with the reference of other objects and creating a contour map of the landform in the VW. They carried out tasks by operating their own avatars in the VW. In the CO condition, students observed what the avatar of a teacher carried out tasks in the VW and then collaboratively discussed their observation to solve problems. In the TD condition, a teacher explained concepts of topographical maps in a textbook, and students individually solved geographical problems without observing or exploring the landform in the VW.

Learning Environments

Students in the CPS condition carried out tasks in a computer room in which everyone was able to use a computer with access to high speed Internet. Students in CO and TD conditions conducted learning tasks in general classrooms equipped with a single computer and a beam projector. Figure 1 shows the virtual learning environment in which CPS students collaboratively solved geographical problems like creating a contour map.

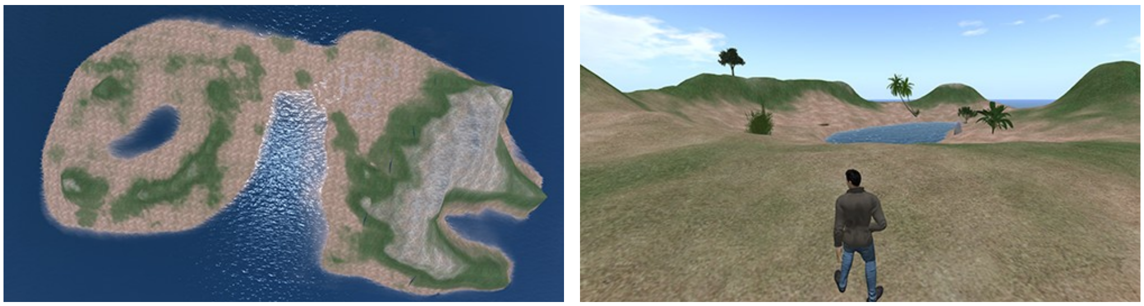

FIGURE 1. *Virtual learning environment*

Measures

Intrinsic motivation of geography was measured with nine survey items using a five-point Likert scale (1: strongly disagree, 5: strongly agree). The survey was modified from the Children's Academic Intrinsic Motivation Inventory (Gottfried, 1985). The reliability of intrinsic motivation survey items was high (Cronbach's alpha = .81). Comprehension tests included five multiple-choice questions pertaining to the interpretation of a topographical map. Application tests required students to draw a sketch of a topographical map based on teacher-provided descriptions. In group performance tests, four students collaboratively solved a decision-making problem (e.g., "Decide the best place to locate a hotel resort on the map"). Two researchers rated students' drawings and answers to the application and group performance tests with rubrics. Inter-rater reliabilities (Cohen's kappa) ranged from .9 to .97, and disagreements between raters were all resolved through discussions.

Results

Intrinsic Motivation

A repeated-measures ANOVA was carried out to investigate how intrinsic motivation changed from the pre-test to the post-test. As shown in Figure 2, intrinsic motivation of geography declined in the TD condition (M = 3.75 vs. 3.24), while the motivation was sustained in both CPS (M = 3.65 vs. 3.59) and CO (M = 3.48 vs. 3.49) conditions. This interaction effect was statistically significant, F (2, 98) = 4.99, p = .009, η_p^2 = .09.

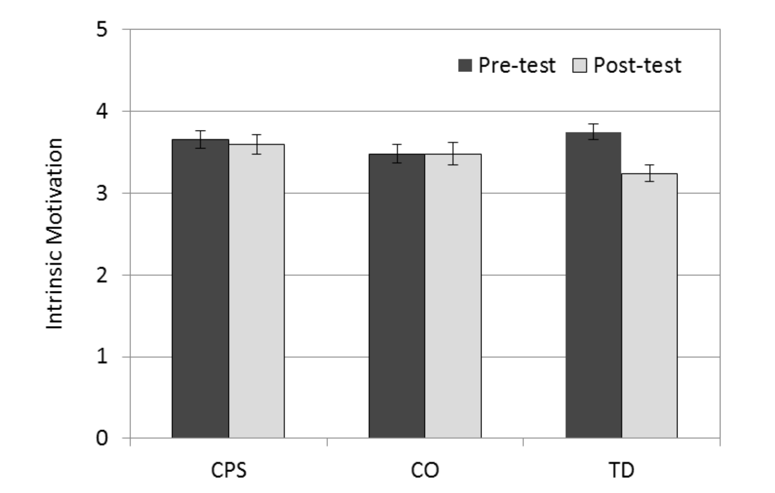

FIGURE 2. *Means and standard error bars of intrinsic motivation*

Academic Achievement: Comprehension and Application

An ANCOVA was carried out to investigate the influence of learning conditions on comprehension of topographical maps after controlling the influence of prior knowledge as a covariate. When the effect of prior knowledge was controlled, there were significant differences among the three conditions, F (2, 97) = 4.65, p = .012, η_p^2 = .09 (see Figure 3). The follow-up comparison of the CO condition (M = 3.5, SD = 1.08) with the CPS condition (M = 2.77, SD = 1.02) was significant, p = .003, Cohen's d = .69. There was no other significant difference between conditions. However, this difference disappeared in the delayed post-test, F (2, 97) = .29, p = .747.

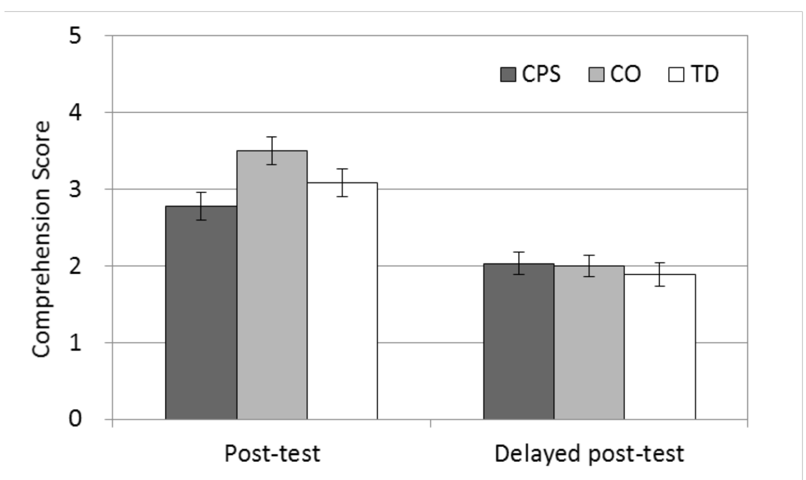

FIGURE 3. *Means and standard error bars of comprehension scores*

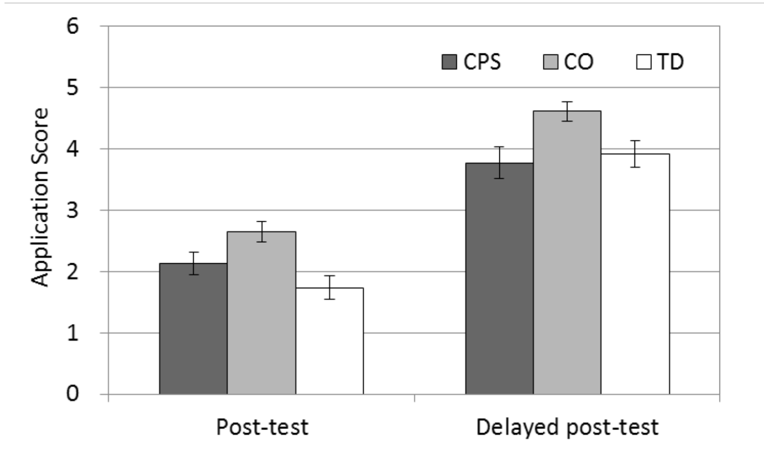

FIGURE 4. *Means and standard error bars of application scores*

An ANCOVA was carried out with the learning conditions as an independent variable, prior knowledge as a covariate, and application scores as a dependent variable. When the effect of prior knowledge was controlled, there were significant differences among CPS (M = 2.13, SD = 1.02), CO (M = 2.65, SD = 1.02), and TD (M = 1.74, SD = 1.14), F (2, 97) = 7.3, p = .001, η_p^2 = .13. The follow-up comparison of the CO condition with the TD condition was significant, p < .001, Cohen's d = .85, and the difference between CO and CPS conditions was significant, p = .032, Cohen's d = .51. However, there was not a significant difference between CPS and TD, p = .132. In the delayed post-test, an ANCOVA showed that the learning conditions had a significant effect on application scores, F (2, 97) = 4.64, p = .012, η_p^2 = .09. Follow-up comparisons showed that students in the CO condition (M = 4.61, SD = .96) got significantly higher application scores than those in the CPS (M = 3.77, SD = 1.43), p = .006, Cohen's d = .7, and TD conditions (M = 3.91, SD = 1.26), p = .019, Cohen's d = .62.

Group Performance

An ANOVA was carried out to investigate the effect of the interventions on group performance in solving decision-making problems about topographical maps. As shown in Figure 5, the differences were marginally significant in the post-test, F (2, 26) = 2.58, p = .095, η_p^2 = .17, and the delayed post-test, F (2, 27) = 2.95, p = .069, η_p^2 = .18. Follow-up comparisons showed that CPS groups significantly outperformed TD groups in both post-test (M = 2.63 vs. 1.68), p = .037, Cohen's d = .96, and delayed post-test (M = 3.9 vs. 2.9), p = .024, Cohen's d = 1.26. There was no other significant difference.

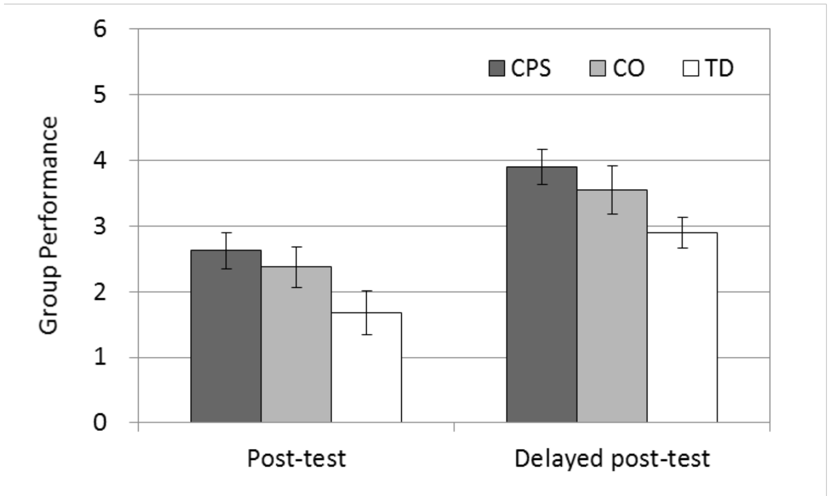

FIGURE 5. *Means and standard error bars of group performance*

Conclusion

This study investigated the effectiveness of CPS and CO that used the VW as a learning environment. Both learning activities were beneficial for sustaining students' intrinsic motivation in geography, whereas TD reduced intrinsic motivation. In addition, CO was more effective for academic achievements of comprehension and application when compared to CPS and TD. This result supports the assertion that CO is more effective for knowledge gains than CPS that makes unnecessarily high demands in working memory (Kirschner *et al*., 2006). However, we should not overlook the potential of CPS because students can develop intuitive and implicit knowledge, which can be used for future learning, through failure experience (Kapur, 2010). Moreover, this study showed that students in the CPS condition outperformed those in the TD condition in group performance. This result implies that CPS is helpful for the development of collaborative problem-solving skills, which is one of key competencies in the 21st century. Future research is recommended to investigate the learning processes of CPS and CO in order to explain why they are effective or ineffective.

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