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The Effect of Game-Based Learning on Students' Learning Performance in Science Learning – A Case of "Conveyance Go"

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Abstract

Many previous studies have demonstrated that learning motivation and efficiency can be enhanced through educational games, and the recent introduction of enriched gaming elements has made such games increasingly popular. The main purpose of this study was to help elementary school student learn science-related concepts by participating in an educational card game, named Conveyance Go. We then investigated the perceptions of students regarding the integration of the game into science learning as well as the educational benefits of the game with regard to learning performance. A one-group pretest-posttest design was used with eighteen 5th grade students from a single elementary school in northern Taiwan. The students demonstrated positive attitudes toward the use of the educational card game in science learning. Our results also demonstrate the effectiveness of the proposed education card game in improving the students' scientific knowledge of transport and energy.

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Keywords: game-based learning; educational card game; science learning; game design

1. INTRODUCTION

Papert (1991) advocated the promotion of learning through real-life situations and the shaping of concepts through making. In recent years, many researchers have investigated the effectiveness of digital technology in the promotion of learning, the process of which is often conducted using games. The

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incorporation of games into education is often more effective than traditional teaching methods in enhancing learning motivation, active participation, and concentration among students. Furthermore, games can enhance the social skills of students as well as improve their skills in understanding and solving problems (Kirikkaya, Iseri, & Vurkaya, 2010).

Game-based learning has recently become an important domain of research. In a review of articles in seven major SSCI journals associated with technology and learning between 2001 and 2010, Hwang and Wu (2012) discovered that Taiwanese researchers published 22 articles on game-based learning, second only to researchers in the US (30 articles) and followed by researchers from the UK (20 articles). These studies focused primarily on the achievements, motivation, and attitude of students involved in learning various subjects and most of the researchers in Taiwan investigated the issue of learning achievements (Liu, Lin, Hsiao, Chen et al., 2009). Game-based learning has been applied in many science-related school subjects. Yien, Hung, Hwang, & Lin (2011) used game-based learning in a nutrition course, discovering that this approach was more effective in enhancing the learning effectiveness and attitudes of students than traditional PPT teaching and even influenced their dietary habits. Using a game similar to Monopoly to teach students about the area of circles (Lin, Liu, Chen, Liou, Chang, Wu, & Yuan, 2013) and obtained similar results. Through game-based learning, participants learn more actively and with greater interest, enabling the learned content to leave a deeper impression than would be possible using conventional methods (Papastergiou, 2009).

Most studies on game-based learning have focused on digital game-based learning. Digital games provide animated graphics and audio effects as well as immersive stimulation. Lin and Liu (2009) included game mechanisms in typing practice, inviting learners to beat their rivals. Although the progress of these learners was not significantly greater than that of learners using conventional teaching techniques, their typing skills were significantly better than before the experiment. Lin and Liu also observed that learners in the game mechanism group spent considerably more time practicing typing than their counterparts in the regular class, thereby demonstrating that multimedia can influence the learning motivation of students. Chiang, Lin, Cheng, and Liu (2011) explored the influence of various computer games on the flow experience and positive emotions of students and discovered that violent games did not induce violent emotions or conduct in students. Moreover, they found that both violent and non-violent games were capable of eliciting flow experience and positive emotions. As shown in these studies, digital games can enhance learning motivation and arouse positive emotions in students; however, a digital game environment cannot provide face-to-face interaction.

In a classroom situation, teacher-student interactions and student-student interactions exert a profound impact on learning. Unlike interactions in digital games via computers, face-to-face interaction exposes people to human expressions, physical action, and verbal tones (Billinghurst & Kato, 2002). Thus, using educational card games as a medium for game-based learning could enhance the direct interpersonal interaction between teachers and students as well as among students to a degree unmatched by the sound and audio effects of digital games. This study designed a science lesson using an educational card game. By handling the cards and moving the character pieces themselves and competing or cooperating with peers through direct verbal communication, students can interact with one another and learn happily from within.

In recent years, research on learning with card games has made a substantial contribution to the discipline. Siegler and Ramani (2008) speculated that a lack of skills in the use of numbers among children from low-income households might be due to their limited opportunities to play number games during their childhood. Thus, a series of number card games for children from low-income households was designed to narrow the differences between poor children and those from middle-income households. Their results demonstrate that the learning effectiveness of high-priced equipment for digital games can be matched by using inexpensive or even self-handmade card games. Alexander, Sevcik, Hicks, and Schultz (2008) designed a card game to teach students the symbols of chemical elements and gain subject knowledge. Kirikkaya, Iseri, and Vurkaya (2010) designed a card game to assess one's knowledge of

galaxies and space; the game is also applicable in areas other than learning. Through semi-structured interviews, they discovered that this educational card game not only increased the learning motivation of students but also assisted them in the formation of higher conceptual abstractions. The use of such a card game for assessment purposes could help to reduce test anxiety and promote better learning effectiveness. Using thematic cooperative learning, Huang, Liu, Liu, and Lin (2012) had participants in a teacher education program divide into groups to design card games with subject knowledge for secondary level students. Their results showed that the process of designing educational card games significantly increased self-efficacy.

Few Taiwanese studies have explored game-based learning in the form of educational card games. It is hoped that the achievements of this study will demonstrate the effectiveness of card games in promoting interpersonal interaction during the process of learning.

2. Methodology

2.1. Research participants

This study recruited 18 students from an elementary school in northern Taiwan, of which 10 were male and 8 were female. In age distribution, the participants comprise 3 third graders, 2 fourth graders, 7 fifth graders, and 6 sixth graders.

2.2. Procedure

The total duration of the teaching experiment was 120 minutes. Prior to the formal learning activity, a 20 minute pre-test was administered to assess science knowledge according to a standard assembled by the authors. Following the pretest, the participants were randomly divided into groups of 4 or 5 students. The rules of the game, Conveyance Go, were outlined in a 10 minute explanation. The formal learning activity with educational card game then proceeded for 60 minutes. After the learning activity, a a post-test (containing the same questions as the pre-test but reordered) as well as a learning satisfaction questionnaire were administered. The post-test and questionnaire required 30 minutes for completion.

2.3 Design of science educational card game Conveyance Go

This study referred to the revised Bloom's Taxonomy established by Anderson and Krathwohl (2001) as the design standard for the educational card game. In the knowledge dimension of the revised Taxonomy, knowledge is divided into four levels from concrete to abstract: factual knowledge, conceptual knowledge, procedural knowledge, and meta-cognitive knowledge. Cognitive processes are divided into six levels from low complexity to high: remember, understand, apply, analyze, evaluate, and create. The primary scientific concepts selected for development in the card game were found in the "Means of Transport and Energy" unit of a fourth grade science text. The subject knowledge was divided as follows (Chen, Liu, Lin, Chang, Hsin, & Shih, 2012):

1. Remember – Factual knowledge: Pictures and text on the game cards present the appearances and names of various forms of transport.

2. Remember – Conceptual knowledge: Game cards explain the amount of energy required by each type of transport.

3. Understand – Conceptual knowledge:

(1) If a given form of transport consumes petroleum products (oil), then the game card will also show a pollution value, demonstrating the principle that the use of oil produces pollution. Transport modes that use electricity, wind power, or solar power, do not produce pollution.

(2) Solar power energy cards can be used to replace other energy cards such as oil to demonstrate the convenience and wide applicability of solar power.

(3) Two types of terrain are included in the game (land and sea) and three forms of transport travel by land, sea, or air. This helps students to understand the differences among various modes of transport with regard to their appearance and the environment in which they operate. In the game, ship transports can only travel by sea, land transports can only travel by land, and aviation transport is not limited by terrain. This helps students to understand the limitations of each form of transport.

(4) Problem cards require that students group transport modes according to energy source, appearance, or function. Based on the answers provided by the students, appropriate feedback may be given.

4. Understand – Meta-cognitive knowledge:

(1) Event cards integrate daily environmental concerns (such as vehicle emissions testing) into the content of the game.

(2) The event cards also include an 'Oil Crisis' card. When this card appears, all oil energy cards are useless, demonstrating that oil depletion will occur someday.

5. Apply – Procedural knowledge: Once the students understand the rules of the game, they can play the game smoothly according to a given procedure.

6. Analyze – Procedural knowledge: Two strategies are provided to score the games and students may adjust their tactics according to the circumstances of the game.

7. Evaluate – Meta-cognitive knowledge: During the game, students learn via self-discovery by evaluating the pros and cons of each transport mode.

In designing the educational card game in this study, we referred to the seven design principles proposed by Liu (2011): Analyze the traits of the learners and understand their prior knowledge; establish clear teaching objectives and select appropriate gaming equipment, combine the teaching objectives with the game content; remember that teaching is the primary goal and that the game is a supplementary tool; take advantage of game characteristics to arouse student interest; enable students to enjoy learning while they take control of learning; and periodically assess learning effectiveness and improve teaching.

We also evaluated the game design according to the five indices proposed by Liu and Lin (2009): Whether the game information is in accordance with the game descriptions of the learners and the game includes a learning theme; whether the pictures in the game are associated with the learning theme and can arouse student interest; whether the structure of the game is simple and operations are easy to learn; whether the overall content of the game is interesting, and include many pictures for presentation; and whether the game provides instant feedback. By referring to these principles, we ensured that the card game designed in this study is capable of conveying subject knowledge that is easy to learn and elicits the interest of participants.

2.4 Learning satisfaction scale

We developed a satisfaction scale according to the structure of the technology acceptance model (TAM) to evaluate the degree to which students accepted the educational card game according to four constructs: Perceived usefulness, perceived ease-of-use, attitude towards usage, and intention to use (Davis, Bagozzi, & Warshaw, 1989). Each construct included five question items. To improve scale validity, we enlisted the aid of three experts (two elementary school science teachers and a scale development expert), to revise the descriptions in the question items. A pilot test was administered to twenty students. Reliability analysis of the pilot test results returned a Cronbach's α and remaining number of question items in each construct after item elimination were α=.84 and 4 items in perceived usefulness, α=.66 and 3 items in perceived ease-of-use, α=.78 and 4 items in attitude towards usage, and α=.63 and 3 items in intention to use. The questionnaire included 14 question items after item elimination, with a reliability of α=.82. We employed a five-point Likert scale in which the students answered strongly agree (5 points), mostly agree (4 points), agree (3 points), disagree (2 points), or strongly disagree (1 point) based on their learning satisfaction.

2.5 Science assessment

The primary objective of the science assessment tool was to gauge the comprehension of elementary school students with regard to scientific concepts associated with transport modes and energy. The content of the assessment was based on the learning content in the unit. In the development of the assessment, we referred to problems and questions in textbooks compiled by Ministry of Education and made revisions according to suggestions provided by three elementary school science teachers. The assessment included eight true or false problems, six multiple choice problems, and six matching problems, each contributing points for a total score of 100 points. The assessment was given to the participants before and after the learning activity, with the problems from the pretest reordered in the posttest to reduce the effects of repeated exercise.

3. Results

3.1 Acceptance of elementary school students towards educational card game

Mean and standard deviation derived for each construct of the satisfaction scale are presented in Table 1. The results show that the students exhibited consistently positive responses for all constructs. Perceived usefulness and intention to use received particularly high scores, indicating that the students felt they could gain scientific knowledge by learning with the card game and that it was useful to the learning of science knowledge. These results also show that game-based learning aroused student interest. The results in future intention to use and perceived ease-of-use show that the students readily accepted this learning method, felt that it facilitated learning, and hoped to continue using this method in the future.

Table 1 Mean and standard deviation of scores in the student satisfaction scale

	Mean	Standard deviation
Perceived usefulness	4.14	1.08
Perceived ease-of-use	3.85	1.16

Attitude towards usage	4.00	1.10
Intention to use	3.85	1.21

3.2 Influence of educational card game on science learning achievement among elementary school students

We performed a dependent sample t-test to examine whether the participants improved in the science assessment after playing the educational card game. The results indicate that the posttest scores of the students (M=92.13, SD=8.80) were significantly higher than the pretest scores (M=83.33, SD=11.43) (t=-3.319, p<0.01), as shown in Table 2. According to these results, we can infer that the scientific card game designed in this study, Conveyance Go, can assist students in gaining knowledge regarding transport modes and energy.

Table 2 Results of paired sample t-test on science assessment for elementary students

	Mean	Standard deviation	t
Pretest	83.33	11.43	-3.32**
Posttest	92.13	8.80	

** p<0.01

4. Discussion

The purpose of this study was to determine whether game-based learning using cards could assist elementary school students in the acquisition of knowledge related to energy and transport. The participants displayed positive attitudes toward the use of the science card game and felt that the approach contributed to learning. The majority of students accepted this learning method and hoped to continue using this approach in the future. The students also expressed that learning with the educational card game could assist them to gain scientific knowledge and that the game-based learning method increased their interest in modes of transport and energy. The pretest and posttest results demonstrate that the card game significantly increased the student's scientific knowledge related to energy and means of transport. These results correspond to the use of digital games in game-based learning in previous studies (Lin et al., 2013; Papastergiou, 2009; Siegler & Ramani, 2008; Yien et al., 2011). Moreover, the use of the card game to promote game-based learning also enhanced learning motivation and learning effectiveness.

We suggest that future studies conduct in-depth surveys on student attitudes towards learning using card games to identify the elements that arouse interest and how knowledge is acquired from playing games. The authors and the homeroom teachers discovered that following the interactions elicited by the card game, the students became closer to their teacher and their peers. The students also preferred a grouped arrangement rather than single separated arrangement in rows. Thus, future studies could conduct further analysis on the learning process and student-student interaction during educational card games and

investigate how they influence game-based learning. Finally, this study focused on science; we suggest that future researchers create educational card games for other subjects such as English and mathematics.

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