The Effect of Pedagogy-embedded Digital Game in Primary Science Education: A Comparison of Students' Understanding of Vitamin

Marisa HIANGSA[a], Niwat SRISAWASDI[b*] & Witcha FEUNGCHAN[c]
[a]*Science Education Program, Faculty of Education, Khon Kaen University, Thailand*
[b]*Division of Science, Mathematics, and Technology, Faculty of Education, Khon Kaen University, Thailand*
[c]*Department of Computer Engineering, Faculty of Engineering, Khon Kaen University, Thailand*
*niwsri@kku.ac.th

Abstract: Recently, effective instructional interventions are needed to enable primary school student to increase conceptual understanding in science. To archive the mentioned, well-designed instructional materials regarding appropriate pedagogy is an important platform for students' learning in primary school science. In this study, an educational digital game regarding fruit and vegetable consumptions, particularly called "The Fruit Eater", has been pedagogically designed concerning problem-based learning strategy and then collaboratively created in android application platform, under the cooperation by computer engineering, science educator, and in-service science teacher at Khon Kaen University, in order to transforming traditional learning environment into constructivist-based learning environment. To investigate the effect of the intervention, a study has been conducted with 104 primary school students, classifying into three different groups, in order to verify the value of the game app. The results showed that the game demonstrated good performance (as compared to regular traditional (problem-based) instruction, and problem-oriented game-based inquiry learning) concerning the gain of conceptual understanding of vitamins, and health benefits of fruits and vegetables, even though the pedagogy-embedded digital game was used independently by students for learning. To this end, this study concluded that the use of pedagogy-embedded digital game could facilitate students' development of scientific understanding as well as teacher-centered instruction, and well-designed digital game regarding appropriate pedagogy might be a key factor associated to this effect in science learning.

Keywords: Problem-based learning, pedagogy, digital game, science learning, primary education

1. Introduction

In the 21st century, tools for acquiring knowledge are more important than content knowledge. The advancement of technology has made the students to find their own knowledge from various sources and whenever they want, and make a transformative change from the traditional classroom. The growth of educational games in the last years has largely impacted learning procedures (Shin, Sutherland, Norris, and Soloway, 2012; Virvou, Katsionis and Manos, 2005). Researchers mentioned that educational games have enhanced the value of instruction (Meesuk and Srisawasdi, 2014: Nantakeaw and Srisawasdi, 2014). In additions, educational computer games embrace the characteristics of the new pedagogy in terms of providing authentic and increasing learners' autonomy. For examples, Tüzün et al. (2009) reported that educational computer game can used as learning tool to support students learning and increase their learning motivation while making the learning fun. This is consistent with Dorji, Panjaburee and Srisawasdi (2015) who reported that game-based inquiry learning approach can enhance students' learning in physics better than the traditional teaching approach.

In recent decades, the integration of digital games as learning tools has been studied at the primary, secondary, and college levels, and they has been applied in different disciplines, such as mathematics (Lee and Chen, 2009), history (Watson et al., 2011), biology (Annetta et al., 2009;

Kanyapasit and Srisawasdi, 2014; Lokayuth and Srisawasdi), chemistry (Meesuk and Srisawasdi, 2014: Nantakeaw and Srisawasdi, 2014), physics (Dorji, Panjaburee and Srisawasdi, 2015a, 2015b), and social sciences (Cuenca and Martin, 2010), to effectively achieve various educational goals. Regarding the fostering of learning by digital game, the digital games have colorful pictures and sounds that are interesting to make players happy, enjoy and be challenged. During the process of learning a challenge and hence the incentives encourage the learning of students (Nelson, Erlandson and Denham, 2011). In additions, the digital games allow players to interact in the game world, and players will gain knowledge and skills in education beyond school books (Castell, Jenson and Taylor, 2007).

In context of Thai science education, digital game-based learning is not a famous pedagogy in school science. It is sometimes, though rarely, used in the classroom setting to promote 21st century skills. However, the use of computer games has continually increased in educational settings in Thailand because the educational game transformed pedagogical strategies about learning and teaching (van Eck, 2006). In 2012, Thai government distributed tablet PCs to public school around the country by a project called One Tablet Per Child (OTPC). A challenge for researchers and educators around the country is how to make usefulness for the OTPC tablets in teaching and learning. We are a team who are thinking about development of digital game in OTPC tablets for Thai learners. In this study, we are developing "The Fruit Eater" game and it is implemented into the OTPC tablets in a primary school. "The Fruit Eater" has been created in android app platform with the aim to enhance construction of scientific knowledge and induce behavioral change in fruits and vegetable consumptions for primary school students. The purpose of this study was to use a pedagogy-embedded serious game in teaching to facilitate the construction of scientific understanding about vitamins and benefits of fruits and vegetable through game playing.

2. Literature Review

2.1 Educational Digital Games

With the rapid improvement of technology, video game play has become popular entertainment. Due to the features of video games, such as excellent interaction and attractive entertainment, most of today's children have the experience of playing video games. As such, educational researchers, developers, and innovators trend to consider the probabilities of using video games in education (Griffiths, 2002; Squire, 2008).

Digital games have sophisticated and dazzling images and sound, and bring players' enjoyment and challenge. The educational digital games keep players immersed in the game world because animations, sounds, and sophisticated graphics of games offer players an immersive environment in where they might ignore changes and forget everything at their surroundings; moreover, they might feel like they are the leading role of the game, and therefore put their whole concentration, thoughts, and even emotions into the game (Hsu and Cheng, 2014). Players may get knowledge, information, and skill in context of non-formal education (Castell, Jenson and Taylor, 2007). Researchers mentioned that the educational games could provide positive effectiveness on students both cognitive and affective domains of learning. Resulted on this, students get positive learning attitude and create learning curve in the meantime (Giannakos, 2013).

2.2 Digital Game-based Learning (DGBL)

Games consist of challenge, control, curiosity and fantasy, which can be created persistence and enjoyment (Toro-Troconis and Partridge, 2010). According to its features, educational researchers and developers have developed games for teaching and learning in three goals included: (i) students can learn from playing the game; (ii) the component of game can be supported the learning's ability; and (iii) students have motivate to learn via playing the game (McNamara, Jackson and Graesser, 2010). Digital game-based learning (DGBL) is an instructional method that incorporates educational content or learning principles into video games with the goal of engaging learners. Applications of digital game-based learning draw upon the constructivist theory of education. Regarding to the important of

DGBL, researchers developed effective pedagogy to implement the game into classroom. For instances, Meesuk and Srisawasdi (2014) reported that the use of digital game following student-associated game-based open inquiry (SAGOI) pedagogy can increase students' chemistry understanding, by revising inaccurate conception in chemistry, and promote their motivation to learn chemistry. Nantakeaw and Srisawasdi (2014) reported that students' science attitude did not correlate with motivation toward digital game-based learning, and their conceptual understanding, mental model, and science motivation have been increased after interacting with collaborative game-based learning.

2.3 Problem-based Learning (PBL)

There are many different types of learning environments that are based on constructivist theories. One of the best exemplars of a constructivist learning theory based environments is ones called problem-based learning (PBL). PBL promotes students' confidence in their problem solving skills and strives to make them self-directed learners. These skills can put PBL students at an advantage in future courses and in their careers. Savery and Duffy (1995) considers PBL environments to have the three primary underlying constructivist propositions: (i) understanding is in our interactions with the environment, as posited by cognitive constructivists, (ii) cognitive conflict is the stimulus for learning and determines the organization and nature of what is learned, as posited by cognitive constructivists, and (iii) knowledge evolves through social negotiation and by the evaluation of the viability of one's understanding, as posited by social constructivists. According to the PBL environments, it promotes activation of prior learning, self-directed learning, and motivation (Barrows, 1996; Barzak et al., 2002).

Currently, design of educational computer games with the constraint that all game play activity embedded within the game be aligned with the instructional objectives has been suggested by educators and developers (DeCastell and Jenson, 2003; Shelton, 2007). The game uses simulated scenarios that are representative of the real-world situation, and the activity itself is useful for progression toward and designed around a learning goal. As such, the use of problematic scenario may engineer students learning to balance authenticity with alignment to the educational task and objectives. Therefore, educational games may benefit a great deal from incorporating the traits of PBL, and the combination of educational games and PBL may help bridge the gap between the enticements of a commercial game designed purely for entertainment and an educational game that holds no allure for learners (Walker and Shelton, 2008)

3. Research Question

In this study, we developed an educational digital game that intends to facilitate students' intuitive understanding of vitamins. The purpose of the game was to examine the effects of different instructional settings, namely traditional (problem-based) instruction, pedagogy-embedded digital game, and problem-oriented game-based inquiry learning, on students' conceptual learning scores. This study conducts an experiment to answer the research question: How do students in the individual mode with pedagogy-embedded digital game and in the collaborative mode with problem-oriented game-based inquiry learning differ from students who experienced traditional instruction of problem-based learning with respect to acquiring scientific understanding?

4. Methods

4.1 Study Participants

A total of 104 student-respondents aged ranging from 10 to 15 years old in a local public school at the northeastern region of Thailand were recruited in this study. Two classes were assigned to be the experimental groups and one the control group. The first experimental group (EG#1, N = 39) interacted with the pedagogy-embedded digital game, and the second experimental group (EG#2, N = 32) participated with problem-oriented game-based inquiry learning, and the control group (CG, N = 33) was exposed to traditional (problem-based) instruction.

4.2 Instruments

A series of conceptual question were created regarding scientific knowledge about vitamins, types and the benefits of fruits and vegetables by the researchers. There were ten items, and five items were matching test items and another five items were open-ended items. For the test, the maximum score is 15 points. The question items were content validated by a science educator and two science teachers.

4.3 Learning Material

In this study, we designed and developed a digital game-based learning environment, called "Fruit Eater" that emphasizes the promotion of fruits and vegetables consumptions and promote students' scientific understanding of vitamins and types and the benefits of fruits and vegetables in two versions. For the first version, we did not embed the problematic scenarios into the game while the problematic scenarios and a series of QR code card game has been developed and embedded into the second version. For both versions, the entertainment goal of the game is to get the highest score by controlling a monster to consume appropriate fruits and vegetables. The educational goals of the game were (1) to understand the effects of necessary and unnecessary foods and drinks, (2) to understand the types of vitamins, (3) to describe the benefits of fruits and vegetables, and (4) to understand the impact of not eating fruits and vegetable. The examples of activities embedded in the game are illustrated in Figure 1 and 2.

Figure 1. Screen shot of the main interface: player can select one of three monsters (Left) and player can select mode of playing controller (Right)

Figure 2. Screen shot of the gameplay: player can control the selected monster to eat fruit and vegetable (Left) and the amount of fruit and vegetable consumed will be displayed (Right)

To promote the players' enjoyment and flow of learning experience, we designed and developed a series of QR code digital card being the vitamin card for improving the players' challenge and their understandings about types and the benefits of fruits and vegetables consumptions. Figure 3 displays the QR code digital card and scientific information obtained from the card.

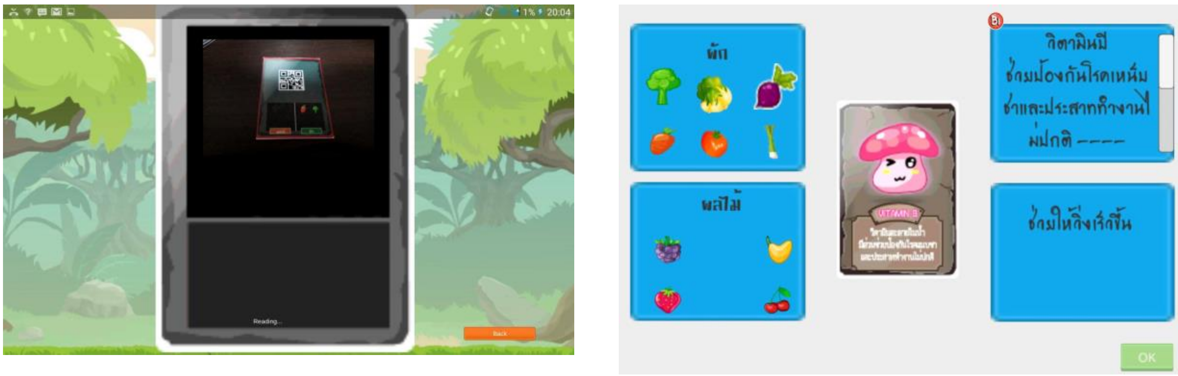

Figure 3. Screen shots of the QR card: QR code digital card displayed on the OTPC tablet screen (Left) and scientific information about type of fruit and vegetable, name of vitamin, and its benefit (Right)

4.4 Data Collection and Analysis

All three groups were examined for conceptual understanding by using the ten question items for 30 min, both pretest and posttest. They were also given an orientation to the learning activity and familiarized with the Fruit Eater game during 20 min after the pretest. The students in each group undertook the intervention for 200 minutes within two weeks. For answering the research question, one-way analysis of covariance (ANCOVA) was used to compare the scores of the three groups in terms of conceptual understanding among the experimental and control groups. Paired t-tests were also used to examine difference in the scientific understanding scores for each group, before and after instructional intervention.

5. Results and Discussions

To reduce the threats of sample error, one-way ANCOVA was utilized to test the main effects for the experiment groups and the control group on scientific understanding, controlling the effects of prior conception. The dependent variable, covariates, and independent variable were posttest measurement of scientific understanding, pretest measurement of scientific understanding, and teaching condition, respectively. Before the ANCOVA was done, the homogeneity test within groups regression coefficient was executed, and the result suggested that the homogeneity test has not reached statistical significance. It means that there is no significant difference in variances among the three groups. Therefore, the ANCOVA could be done. Table 1 reports the result of the ANCOVA analysis.

Table 1: ANCOVA results the experimental groups and the control group on conceptual understanding scores

Source	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial η2	Observed power (a)
Group	2.388	2	1.194	.262	.770	.108	1.000
Error	459.249	100	4.562				

R2 = .108 (adjusted R2 = .081)
* $p < .05$; ** $p < .01$: ***$p < .001$

The result of the ANCOVA indicates that there is a no statistically significant difference ($F(2,100) = .262$, $p = .770$) between the experimental groups and the control group after the intervention as shown in Table 1. After eliminating the influence of covariance (pretest), the CG group had an adjusted mean of 8.42 (SD = .38) EG#1 group had an adjusted mean of 8.08 (SE = .41); and the EG#2 group had an adjusted mean of 8.56 (SE = .41), for the posttest measure of conceptual understanding. That means, students who participated in the problem-oriented game-based inquiry learning group outperformed others; and students in the traditional instruction group were better than the pedagogy-embedded digital game group. In other words, after the instruction, the students in the individual mode with pedagogy-embedded digital game can learn as well as students in the collaborative mode with problem-oriented game-based inquiry learning and in traditional instruction.

To determine where the differences among the teaching methods were, Bonfferoni's Post Hoc Test was employed to test for significance. All tests were conducted using the adjusted means, controlling for any differences in prior conception. Table 2 reports the result of the Bonfferoni's pairwise comparisons.

Table 2 : Bonferroni Post Hoc Test results by teaching condition

Group	(J) Group	Mean difference (I-J)	Sig.
CG	EG#1	.330	.585
	EG#2	-.133	.805
EG#1	CG	-.330	.585
	EG#2	-.463	.477
EG#2	CG	-.133	.805
	EG#1	.463	.477

* $p < .05$; ** $p < .01$; *** $p < .001$

The evidence from Table 2 indicated that students in the individual mode with pedagogy-embedded digital game did not significantly differ than students in the collaborative mode with problem-oriented game-based inquiry learning and students who experienced traditional instruction of problem-based learning with respect to acquiring scientific understanding. In addition, Table 3 reports the results of the paired t-test between pretest and posttest for all groups.

Table 3 : Descriptive statistics and paired t-test on the pretest and posttest for the experimental groups and the control group

Group	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*
CG	5.06 (1.54)	8.12 (1.64)	-7.000	$.000^{***}$
EG#1	7.87 (2.18)	8.73 (2.36)	-2.559	$.015^{**}$
EG#2	4.44 (1.58)	8.03 (2.54)	-8.009	$.000^{***}$

* $p < .05$; ** $p < .01$; *** $p < .001$

The results from Table 3 indicated that there is a statistically significant difference between pretest and posttest for the CG group (t = -7.000, p = .000) EG#1 group (t = -2.559, p = .015), and EG#2 group (t = -8.009, p = .000). It indicated a significant difference in students' scientific understanding change over time in for all three groups. This finding is consistent with Dorji, Panjaburee, and Srisawasdi (2015a, 2015b) and Giannakos (2013) that the enactment of digital game-based learning could complement the inquiry-based learning process in order to develop collective conceptual understanding of the scientific phenomena.

In overall conclusion, these results suggest that the use of pedagogy-embedded digital game is beneficial for students' scientific conceptual learning as well as the problem-oriented game-based inquiry learning and traditional instruction.

6. Conclusions

This study reported impacts of pedagogy-embedded digital game and problem-oriented game-based inquiry learning on students' scientific understanding of vitamins, comparing with traditional instruction. The findings revealed that students' development of scientific understanding of vitamins, and types and benefits of fruits and vegetable consumption in the individual mode with pedagogy-embedded digital game did not differ than students in the collaborative mode with problem-oriented game-based inquiry learning and students who experienced traditional instruction of problem-based learning. That means, the pedagogy-embedded digital game called Fruit Eater demonstrated good performance (as compared to regular traditional (problem-based) instruction, and problem-oriented game-based inquiry learning) concerning the gain of scientific understanding. The finding of this study implied that well-designed digital game regarding appropriate pedagogy, i.e. problem-based learning, might be a key factor associated to this effect in science learning.

Acknowledgements

This work was supported by Graduate School, Faculty of Education, Khon Kaen University, Thailand. The authors would like to express sincere thanks to Mr. Theerawat Maturos for his supports in development of the Fruit Eater game.

References

Annetta, L., Minogue, J., Holmes, S. Y., & Cheng, M. (2009). Investigating the impact of video games on high school students' engagement and learn–ing about genetics. *Computers and Education, 53*(1), 74-85.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: a brief overview. *New Directions for Teaching & Learning, 68*(3), 3-12.

Barzak, M. Y., Ball, P. A., & Ledger, R. (2002). The Rationale and Efficacy of Problembased Learning and Computer Assisted Learning in Pharmaceutical Education. Pharmacy Education, 1(2), 105-113.

Cheng, M., Su, T., Huang, W., & Chen, J. (2013). An educational game for learning human immunology: What do stu-dents learn and how do they perceive?. *British Journal of Educational Technology, 45*(5), 820-833.

Chan, C., Burtis, J., & Bereiter, C. (1997). *Knowledge building as a mediator of conflict in conceptual change. Cognition and Instruction*, *15*, 1-40.

Cuenca, L. J. M., & Martin, C. M. J. (2010). Virtual games in social science education. *Computers & Education, 55*(3), 1336- 1345.

Debbe, T. (2012). *A serious video game to increase fruit and vegetable consumption among elementary aged youth (Squire's Quest! II): Rationale, design, and methods.* JMIR Research Protocols, 1(2), DOI: 10.2196/resprot.2348

DeCastell, S., & Jenson, J. (2003). Serious play. Journal of Curriculum Studies, 35(6), 649-665.

Dorji, U., Panjaburee, P., & Srisawasdi, N. (2015a). A learning cycle approach to developing educational computer game for improving students' learning and awareness in electric energy consumption and conservation. *Educational Technology & Society, 18*(1), 91-105.

Dorji, U., Panjaburee, P., & Srisawasdi, N. (2015b). Gender differences in students' learning achievements and awareness through residence energy saving game-based inquiry playing. *Journal of Computers in Education*, *2*(2), 227-243.

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2014). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Educational Technology & Society, 17*(1), 42-53.

Giannakos, M.N. (2013). Enjoy and Learn with Educational Games: Examining Factors Affecting Learning Performance. *Computers & Education, 68*, 429-439.

Griffiths, M. (2002). The educational benefits of videogames. *Education and Health*, 20(3), 47-51.

Hakan,T., Meryem,Y., Turkan,K., Yavuz,l., and Gonca,K. (2009). The effects of computer games on primary school students' achievement and motivation in geography learning. *Computers & Education, 52*(1), 68-77

Hsu, M., & Cheng, M. (2014). Bio Detective: Student science learning, immersion experience, and problem-solving patterns. In *Proceedings of the 22nd International Conference on Computers in Education*, Asia-Pacific Society for Computers in Education, 171-178.

Huang, W. (2011). Evaluating learners' motivational and cognitive processing in an online game-based learning environment. *Computers in Human Behavior, 27*, 694-704.

Kanyaprasit, K., & Srisawasdi, N. (2014). Development of digital game-based biology learning experience on cell cycle through DSLM instructional approach. In *Proceedings of the 22nd International Conference on Computers in Education,* Asia-Pacific Society for Computers in Education, 857-866.

Lee, C. Y., & Chen, M. P. (2009). A computer game as a context for non-routine mathematical problem solving: The effects of type of question prompt and level of prior knowledge. *Computers & Education*, *52*(3), 530-542.

Lokayut, J., & Srisawasdi, N. (2014). Designing educational computer game for human circulatory system: A pilot study. In *Proceedings of the 22nd International Conference on Computers in Education*, Asia-Pacific Society for Computers in Education, 571-578.

Meesuk, K. & Srisawasdi, N. (2014). Implementation of Student-associated Game-based Open Inquiry in Chemistry Education: Results on Students' Perception and Motivation. *Proceedings of the 22nd*

International Conference on Computers in Education. Asia-Pacific Society for Computers in Education, 219-226.
Nantakaew,N., and Srisawadi,N. (2014). Investigating correlation between attitude toward chemistry and motivation within educational digital game-based learning. *Proceedings of the 22nd International Conference on Computers in Education.* Asia-Pacific Society for Computers in Education, 316-323.
Nelson, B.C., Erlandson, B., & Denham, A. (2011). Global channels of evidence for learning and assessment in complex game environments. *British Journal of Educational Technology, 42*(1), 88-100.
Savery, J. R., & Duffy, T. M. (1995). Problem Based Learning: An Instructional Model and Its Constructivist Framework. In B. Wilson (Ed.), *Constructivist Learning Environments: Case Studies in Instructional Design* (Vol. 35, pp. 31-38). Englewood Cliffs, NJ: Educational Technology Publications
Shelton, B. E. (2007). Designing instructional games for activity-goal alignment. In B. E. Shelton & D. Wiley (Eds.), *The Design and Use of Simulation Computer Games in Education.* Rotterdam, The Netherlands: Sense Publishers.
Shin, N., Sutherland, L. M., Norris, C. A., & Soloway, E. (2012). Effects of game technology on elementary student learning in mathematics. *British Journal of Educational Technology*, 43, 540-560.
Squire, K. D. (2008). Video games and education: Designing learning systems for an interactive age. *Educational Technology Magazine: The Magazine for Managers of Change in Education*, 48(2), 17-26.
Ugyen, D., Patcharin, P.,& Srisawasdi, N. (2015). Gender differences in students' learning achievements and awareness through residence energy saving game-based inquiry playing. *Computers & Education, 2,* 227-243
van Eck, R. (2006). It's not just the digital natives who are restless. Retrieved December 10, 2011, from http://net.educause.edu/ir/library/pdf/erm0620.pdf
Virvou, M., Katsionis, G., & Manos, K. (2005). Combining software games with education: evaluation of its educational effectiveness. *Educational Technology and Society, 8*(2), 54-65.
Walker, A., & Shelton, B. E. (2008). Problem-based educational games: Connections, prescriptions, and assessment. *Journal of Interactive Learning Research, 19*(4), 663-684.
Watson, W., Mong, C., & Harris, C. (2011). A case study of the in-class use of a video game for teaching high school history. *Computers & Education, 56*(2), 466-474.