Implementation of Mario-like Digital Game in Chemistry Education: Results on Students' Perception

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Abstract: This paper presents the effectiveness of a Mario-like digital game, called "The Functional Group Game 1" on students' perceptions on six subscales: perceived learning, perceived ease of use, flow, perceived playfulness, enjoyment, and perceived satisfaction. The game was designed based on levels of the cognitive process dimension of the revised Bloom's taxonomy. This study was conducted on 74 twelfth-grade students to investigate students' perceptions toward the game. The results revealed that the student increased their perceptions after experiencing the game. In additions, gender difference has no effect on students' perceptions toward game-based learning of chemistry. Obviously, both females and males increased their perceptions on perceived learning, perceived ease of use, flow, perceived playfulness enjoyment, and perceived satisfaction after interacting with the Functional Group Game 1. It led us to conclude that the Functional Group Game could be an alternative way for promoting chemistry learning in Thai school science.

Keywords: Digital game, chemistry education, perception, Bloom's taxonomy, individual differences

1. Introduction

In 21st century, educational environment has been changed rapidly. Many advanced technologies make the learner finding knowledge from any source for anytime and anywhere such as laptop computer, computer tablet, or smart phone. In additions, visual representation technologies have become increasing important for facilitating students' learning in science (Suits and Srisawasdi, 2013). Digital media technologies have been applied for 21st century learning to make learner learning easier and to attract learner to learn with interesting things, especially the digital games. Because the digital games are used to make relaxation for most people, so learning with the games can promote of students' chemistry motivation. Sung and Hwang (2013) pointed out that combining games with educational objectives could not only trigger students' learning motivation, but also provide them with interactive learning opportunities. Previously, the study about using educational digital game in instructional chemistry such as Meesuk and Srisawasdi (2014) indicated that using educational game to support student' inquiry learning process named student-associated game-based open inquiry (SAGOI) could be an effective way in improving students' science motivation for fostering chemistry learning in the ionization energy topic. Moreover, using of educational digital game-based learning could support student' motivation even they have a positive or negative attitudes in learning (Nantakaew and Srisawasdi, 2014). However, there have been only a few reports of using such learning materials on organic chemistry learning in the functional group topic. Welsh (2003) reported that both chemistry majors and non-chemistry majors struggle with their first attempts to recognize the basic organic functional groups. Moreover, the instruction based on Bloom's taxonomy could encourage students' learning (Krathwohl, 2002). Such that it would be benefit for students' chemistry learning if they receive the attractive learning material as the digital game with Bloom's taxonomy.

Consequently, this study applied the Mario-like digital game to develop "The Functional Group Game 1" grounded by Bloom's taxonomy. Specifically, the research questions were answered:

1) Do the students interacted with The Functional Group Game 1 perform significantly better by perceptual constructs of perceived learning, perceived ease of use, flow, perceived playfulness enjoyment, and perceived satisfaction?
2) Do the gender differences effect on students' perceptions within the Functional Group Game 1?

2. Related work

In chemistry learning, both chemistry majors and non-chemistry majors struggle with their first attempts to recognize the basic organic functional groups (Welsh, 2003).They are required to make connections between the macroscopic properties of organic molecules. The organic functional group card deck was created to help visually oriented students recognize the names and structures of 13 common functional groups. However, it the students might have less motivation to learn the topic. In other words, in an effort to make learning chemistry more enjoyable, chemistry instructors have devised and used a wide variety of excellent games in the classroom.

Digital games consist of dazzling and sophisticated images and sounds, alongside textual communication. Players get engagement, which is both pleasurable and challenging. The educational digital game keep players immersed in digital worlds, knowledge, information, and skill development become increasingly accessible outside confines of formal education (Castell, Jenson and Taylor, 2007). In addition, several studies have shown that educational computer games can enhance the perceptions, learning motivation and learning performance of students in science learning. For example, Meesuk and Srisawasdi (2014) surveyed 29 twelfth-grade students in a public school at the northeastern region of Thailand after playing The IE War game, and found that the students increased their perceptions towards playing the game. They further investigated effects of student-associated game-based open inquiry on 81 tenth-grade students' science motivation. The findings revealed successful of improving students' science motivation in context of the digital game-based learning environment. Furturmore, Nantakaew and Srisawasdi (2014), Lokayut and Srisawasdi (2014) and Kanyapasit and Srisawasdi (2014) developed The Pipe, The Blood Donor and The Cell Cycle Game respectively and found that the students' perceptions and motivations were increase.

3. Method

3.1 Participants

The participants of this study were 74 twelfth-grade students in a local public school at the northeastern region of Thailand (male = 25 and female = 49). The age range of the students was 17-18 years. They were attending a chemistry course for basic education level and all of them have satisfactory skills on basic computer and information and communication technology, but they have no experience yet using educational computer game in chemistry learning.

3.2 Learning Materials

Based on the previous work, the research (Meesuk and Srisawasdi, 2014; Nantakaew and Srisawasdi, 2014; Lokayut and Srisawasdi (2014) and Pinatuwong and Srisawasdi, 2014), they created the game to support science leaning based on the open inquiry pedagogy. However, they did not use the revised Bloom's taxonomy to design the difficulty of the game. So, in this study we decided to apply the revised Bloom's taxonomy as the ground framework to create Mario-like digital game. According to the researchers mention that the revised Bloom's taxonomy can be used to design each level of game. Generally, computer game focus on remembering but on our research carries out higher-order level of the revised Bloom's taxonomy (Remember, Understand, Apply and Analyze)

The Mario-like digital game on organic chemistry of functional group was designed to include five games including The Functional Group Game 1-4 which have four levels of playing. Each game will have an interesting problem involving real-life context in the theme of a medicine used in the treatment of various diseases. The chemical structure of medicine consists of the functional groups of different types and each level of the game was designed based on levels of the cognitive process dimension of the revised Bloom's taxonomy (i.e., Remember, Understand, Apply, and Analyze) (Krathwohl, 2002) and Evaluate was used to design the last game,The Functional Group Game 5,

In this pilot study, The Functional Group Game 1 was used as an exploratory research to examine impacts of the Mario-like digital game idea on students' perception. The game was related to content of classes of organic compounds (i.e., alkene, alkyne, alcohol, and ketone). The game provides interesting problem situation to students. It can trigger the students to link the three levels of representation in chemistry including macroscopic, sub-microscopic, and symbolic level (Treagust, Chittleborough & Mamiala, 2003). Figure 1-4 illustrates examples of user interface of The Functional Group Game 1.

Figure 1. Illustrate playing The Functional Group Game 1 in the first level.

Figure 1 show an example of the game in Level 1. In this level, the game was designed based on the first level of the cognitive process dimension of the revised Bloom's taxonomy that is Remember. The students are provided the opportunity to retrieve relevant knowledge from long-term memory and recognize the knowledge (Krathwohl, 2002).

Figure 2. Illustrate playing The Functional Group Game 1 in the second level.

Figure 2 show an example of the game in level 2. In this level, the game designed based on the second level of the cognitive process dimension of the revised Bloom's taxonomy that is Understand level. The students are provided the opportunity to determining the meaning of instructional messages, including oral, written, and graphic communication and classifying such knowledge (Krathwohl, 2002).

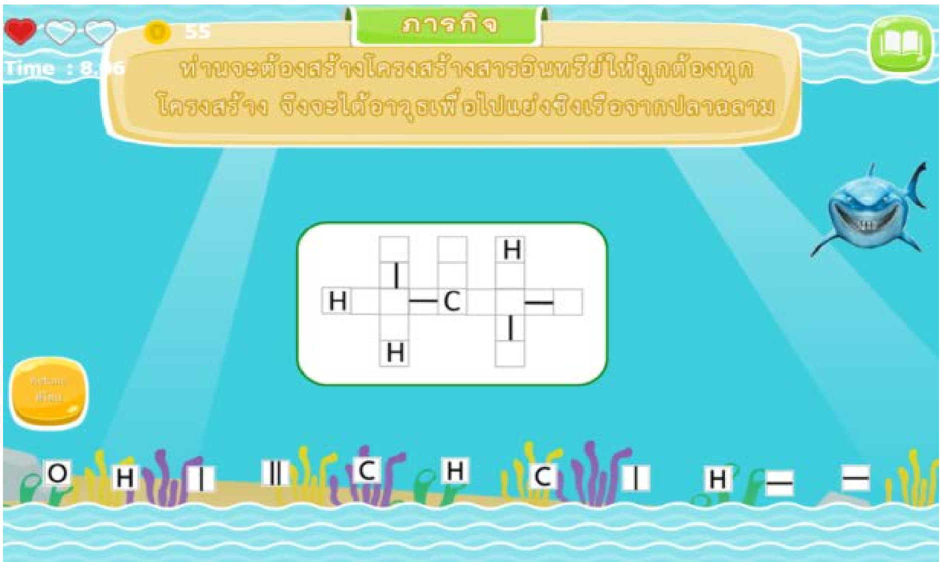

Figure 3. Illustrate playing The Functional Group Game 1 in the third level.

Figure 3 show an example of the game in level 3. In this level, the game was designed based on the third level of the cognitive process dimension of the revised Bloom's taxonomy that is Apply level. The students are provided the opportunity to carry out or use a procedure in a given situation and execute the situation (Krathwohl, 2002).

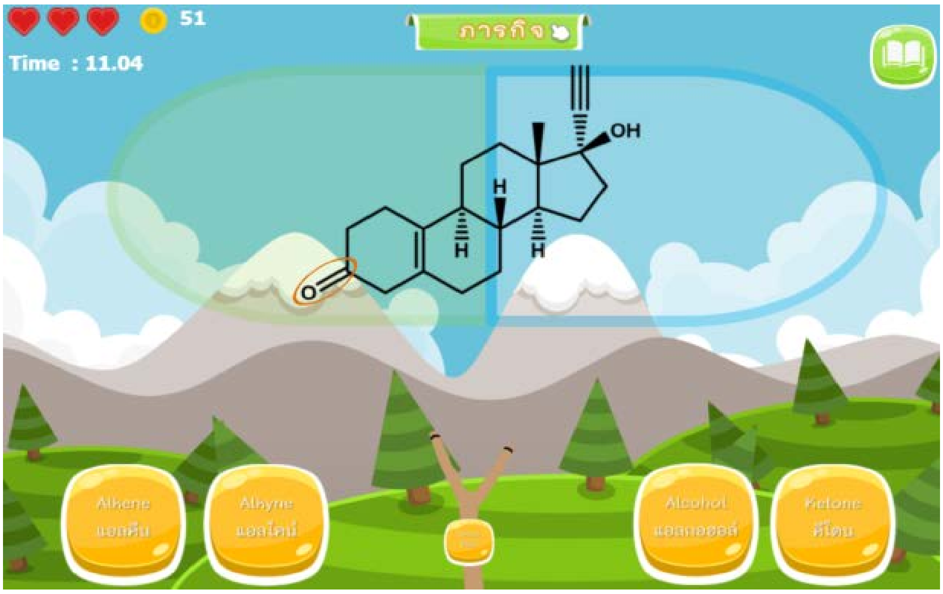

Figure 4. Illustrate playing The Functional Group Game 1 in the fourth level.

Figure 4 show an example of the game in Level 4. In this level, the game was designed based on higher order the fourth level of the cognitive process dimension of the revised Bloom's taxonomy that is Analyze level. The students are provided the opportunity to breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose, and also differentiating such parts (Krathwohl, 2002).

3.3 Research Instrument

An 18-item perception questionnaire was used to measure students' perceptions on six subscales: perceived learning, perceived ease of use, flow, perceived playfulness enjoyment, and perceived satisfaction. All of these 5-point Likert scale items obtained from Cheng (2014) and Barzilai and Blau (2014), developed and validated in Thai by Meesuk and Srisawasdi (2014) and Pinatuwong and Srisawasdi (2014). On each item, respondents were assigned to rate how much the respondent agree with in to five scale, from 1-strongly disagree to 5-strongly agree.

Table 1: Example items of perception questionnaire for each construct.

Subscale	Sample items
Perceive learning	The game will help me understand the things I learned. The games increase my learning efficiency. The games allow me to complete my studies faster.
Perceived ease of use	The games are easy to use. Using the games to complete course related tasks are easy.
Flow	I was very involved in the game. I lost track of time when I played. When I played I did not think of anything else.
Perceived playfulness	It is interesting to use games. I feel like exploring more information when I use games. I was totally immersed in the game.
Enjoyment	I had fun playing the game for learning science. I feel relaxed to use games for learning science.
Perceived satisfaction	The use of the system makes this learning activity more interesting I like to learn new skills by using business simulation games. I would like to learn with the system in the future. I would like to know if the innovative approach could be applied to other courses to improve my learning performance. I would recommend this learning system to others.

3.4 Data Collection and Analysis

The regular class consists of 74 students. Students were surveyed to complete the perception questionnaire of the 5-point Likert-scale, to measure their pre-perceptions on perceived learning, perceived ease of use, flow, perceived playfulness enjoyment, and perceived satisfaction for 10 minutes. After completing the instrument, they were exposed to play The Functional Group Game 1 for 20 minutes. After finishing the game, students were administered by the same questionnaire again as post-test for 10 minutes. The statistical data techniques selected for analyzing students' perceptions was repeated-measures MANOVA in SPSS to compare effect of intervention considering gender (female/male) and time (pre-test/post-test).

4. Results

The results for the repeated-measures MANOVA were conducted to determine students' perceptions scores on the six subscales. The assumption of homogeneity of variance-covariance was tested with Box's M Test which was not significant and indicated that homogeneity of variance-covariance was fulfilled (*p* =.517). The results for the repeated-measures MANOVA indicated significant main effect for gender (Wilks' lambda =.973, $F_{(6,67)}$ =.304, *p*=.932, η^2=.027) and time (Wilks' lambda =.413, $F_{(6, 67)}$ =15.897, *p*=.000, η^2=.587). Also, there was no significant interaction effect between time and gender (Wilks' lambda =.895, $F_{(6, 67)}$ =1.305, p=.267, η^2=.105). Univariate analyses of variances (ANOVA) on each subscale were conducted as follow-up tests to the one-way MANOVA. The results of the univariate test for time are shown in Table 2.

Table 2: The students' subscale means of perceptions by time and univariate MANOVA.

Subscale	Digital Technology		F	Sig.	η^2
	Pre-test Mean (SD)	Post-test Mean (SD)			
Perceived learning (PL)	9.28 (1.810)	12.43 (1.952)	75.747	.000*	.513
Perceived ease of use (PEU)	6.91 (1.284)	8.32 (1.415)	35.685	.000*	.331
Flow (PF)	9.34 (1.995)	11.99 (2.084)	59.758	.000*	.454
Perceived playfulness (PP)	10.01 (1.898)	12.28 (1.955)	49.815	.000*	.409
Enjoyment (PE)	6.92 (1.487)	8.31 (1.364)	36.070	.000*	.334
Perceived satisfaction (PS)	18.05 (3.448)	21.26 (3.184)	34.911	.000*	.327

*$p < .001$

In Table 2, the univariate MANOVA from pre- to post-questionnaire of six subscale scores of perceptions were significant differences across time. The univariate results pointed out a significant effect on perceived learning ($F_{(1,72)} = 75.747$, $p < .001$, partial $\eta^2 = .513$), perceived ease of use ($F_{(1,72)}= 35.685$, $p < .001$, partial $\eta^2 = .331$), flow ($F_{(1,72)}= 59.758$, $p < .001$, partial $\eta^2 = .454$),perceived playfulness ($F_{(1,72)}= 49.815$, $p < .001$, partial $\eta^2 = .409$), enjoyment ($F_{(1,72)}= 36.070$, $p < .001$, partial $\eta^2 = .334$), and perceived satisfaction ($F_{(1,72)}= 34.911$, $p < .001$, partial $\eta^2 = .327$). These results indicated that the students have increased their positive perception towards playing the game. Furthermore, the results show that there were no significant difference between females and males for their perceptions. In other words, perceptions toward learning chemistry through The Functional Group Game 1 between females and males were not difference. It indicates that females and males satisfied equally in the in the end of The Functional Group Game 1. In addition, Figure 5 illustrates a graphical representation on students' pre- and post-perception scores. It indicates that the developed game could affect students' perceived learning, perceived ease of use, flow, perceived playfulness enjoyment, and perceived satisfaction to learn science effectively.

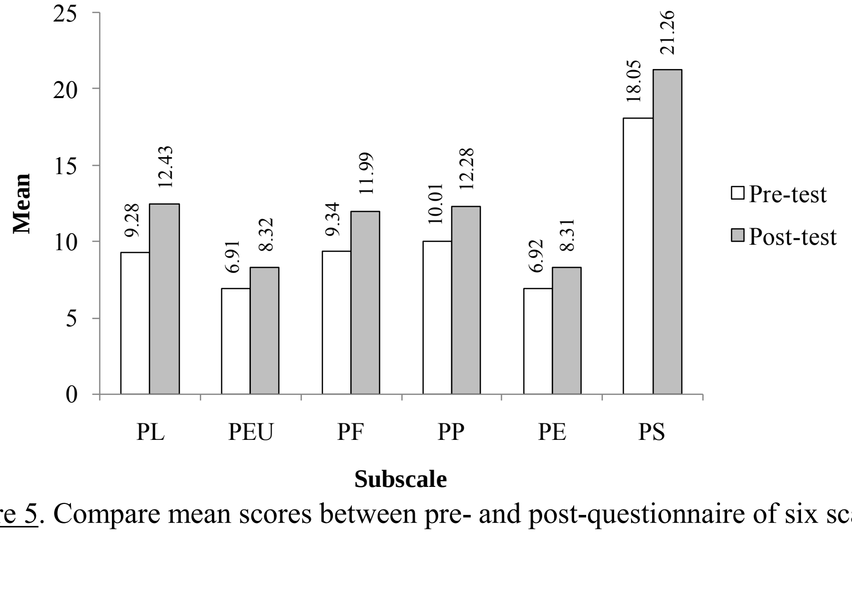

Figure 5. Compare mean scores between pre- and post-questionnaire of six scales.

5. Conclusion and Future work

This study reported impacts of educational computer game on students' perceptions. The findings revealed successful of improving students' perceptions in context of digital game-based learning experience. In additions, the finding showed that gender difference has no effect on students' perceptions towards learning of chemistry through The Functional Group Game 1. As such, it is clear that both females and males increased their perceptions on perceived learning, perceived ease of use, flow, perceived playfulness enjoyment, and perceived satisfaction after interacting with The Functional Group Game 1.This implies that The Functional Group Game 1 can be effective in Organic Chemistry Learning about the Functional Group. The results from this study could lead us to conclude that The Functional Group Game 1 based on the Mario-like game and Bloom's taxonomy could be an alternative way for promoting chemistry learning in Thai school science.

Although there are many researches indicated that teaching and learning via game improve student' motivation, we should collect pre- and post-motivation for comparing motivation before and after learning. In and addition, the challenge is how to immerse the digital game into classroom instruction. A previous study by Meesuk and Srisawasdi (2014) used the educational game to support student' inquiry learning process by integrating with student-associated game-based open inquiry (SAGOI) approach, and they found that the SAGOI can be effective in improving students' science motivation for fostering chemistry learning (ionization energy). Consequently, in further study, based on the findings of this study and successful SAGOI, we will implement The Functional Group Game 1-5 with SAGOI approach for enhance students' conceptual understanding and also chemistry motivation in quasi-experimental design. The mix research methodology will combine quantitative method of non-equivalent control group design with qualitative method of phenomenological research design to carry out chemistry conceptual understanding and motivation.

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References

Barzilai, S., & Blau, I. (2014). Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences. *Computers & Education*, 70, 65-79.

Cheng, G. (2014). Exploring students' learning styles in relation to their acceptance and attitudes towards using Second Life in education: A case study in Hong Kong, *Computers & Education*, 70 (2014),105-115.

Castell, D. S., Jenson, J., & Taylor, N. (2007). Digital game for education: When meanings play. *Intermedialities*, 9, 45-54.

Kanyapasit, P., & Srisawasdi, N. (2014). Development of digital game-based biology learning experience on cell cycle through DSLM instructional approach. In Liu, C.-C.et al. (Eds.). *Proceedings of the 22nd International Conference on Computers in Education* (pp. 857-866). Nara: ICCE 2014 Organizing Committee, Japan

Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview, *Theory Into Practice*. 41(4), 212-218.

Lokayut, J., & Srisawasdi, N. (2014). Designing education computer game for human circulatory system: a pilot study. In Liu, C.-C.et al. (Eds.). *Proceedings of the 22nd International Conference on Computers in Education* (pp. 571-578). Nara: ICCE 2014 Organizing Committee, Japan

Meesuk, K., & Srisawasdi, N. (2014). Implementation of Student-associated Game-based Open Inquiry in Chemistry Education : Results on Students' Perception and Motivation. In Liu, C.-C.et al. (Eds), *Proceedings of the 22nd International Conference on Computers in Education* (pp.219-226). Nara: ICCE 2014 Organizing Committee, Japan

Nantakaew, N., &Srisawasdi, N. (2014). Investigating Correlation between Attitude toward Chemistry and Motivation within Educational Digital Game-based learning.In Liu, C.-C.et al. (Eds.). *Proceedings of the 22nd International Conference on Computers in Education* (pp. 316-323). Nara: ICCE 2014 Organizing Committee, Japan

Pinatuwong, S. & Srisawasdi, N. (2014). An investigation of relationships between biology attitudes and perceptions toward instructional technology in analogy-based simulation on light reaction. In Liu, C.-C.et al. (Eds.). *Proceedings of the 22nd International Conference on Computers in Education* (pp. 149-152). Nara: ICCE 2014 Organizing Committee, Japan

Suits, J. P. & Srisawasdi, N. (2013). Use of an interactive computer-simulated experiment to enhance students' mental models of hydrogen bonding phenomena. In J.P. Suits & M.J. Sanger (Eds.) *Pedagogic roles of* *animations and simulations in chemistry courses* ACS Symposium Series 1142, American Chemical Society: Washington, DC.

Sung, H., & Hwang, G. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education*, 63, 43-51.

Treagust, D. F., Chittleborough, G. & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, 25(11), 1353–1368.

Welsh, M. J. (2003). Organic Functional Group Playing Card Deck.*Journal of Chemical Education*, 8(4), 426-427.