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Implementation of Student-associated Game-based Open Inquiry in Chemistry Education: Results on Students' Perception and Motivation

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Abstract: Educational computer game refers to the use of digital technology to promote learning performance and experience through game-based activity. Currently, researchers mentioned that digital game-based learning can promote students' interest and enhance learning outcomes. As such, this study aims to develop inquiry-based learning process with the support of digital game for chemistry learning about ionization energy. This paper reports research findings on two studies. First, a digital game regarding chemistry concept of ionization energy has been created and 29 twelfth-grade students participated to play the game. The students' perceptions towards the game were measured and results showed that the game have significant effect in fostering their perceptions. Another, 87 tenth-grade students were recruited in this study, and they were divided into an experimental group (N=43) and a control group (N=44). The experimental group participated with student-associated game-based open inquiry, called SAGOI, class and another were assigned to conventional class. The results indicated that students in SAGOI class have changed science motivation over the SAGOI learning experience. This could be implied that the student-associated game-based open inquiry could be an alternative way for promoting chemistry learning in school science.

Keywords: Digital game, inquiry-based learning, ionization energy, science motivation

1. Introduction

Edutainment is an educational concept which aims to make a combination between education and entertainment. As such concept, educational computer game could be considered as an alternative form of edutainment that learners can learn lessons of subject matter by playing the game. By the way, researchers mentioned that educational game is different from other edutainment by its nature in requiring strategies, proving hypothesis, solving problems, and it usually use higher-order thinking rather than memorization. The main characteristics of educational game are the challenging to achieve the objectives, and providing a specific situation and reward for engaging and motivating learners which act as the players (Prensky, 2001; Papastergiou, 2009). A recent study reported about how digital game support learners' motivational and cognitive processing. Huang (2011) indicated that learners have more confident in learning after playing with educational game. In an addition, using game in education increased students' perceived learning, enjoyment and flow of learning experience (Barzilai and Blau, 2014).

For chemistry class, not many study investigated influence of educational game on students' learning outcomes. In fact, chemistry knowledge is often abstract, complex, and complicate in representations of the chemistry knowledge. The use of digital game may be help student increasing learning interest in chemistry, motivation, and attitude towards chemistry learning. Therefore, this study aims to create educational computer game as an inquiry tool to learn chemistry in concepts of ionization energy.

2. Research Questions

Based on the above mentioned rationale, the goals of this study was a couple: (i) to investigate students' perceptions towards an educational computer game, called "The IE War"; and (ii) to investigate students' science motivation delivered in a proposed open-inquiry learning process with support by an educational computer game, called "Student-associated Game-based Open Inquiry (SAGOI)". Specifically, the following questions were answered:

- Do the students interacted with "The IE War" perform significantly better by perceptual constructs i.e. perceived learning, flow, enjoyment, and satisfaction?
- Do the students engaged in "SAGOI" perform significantly better by motivational constructs towards science learning i.e. intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation?

3. Backgrounds and Research Hypotheses

2.1 Educational Computer Game and Students' Perceptions

2.2.1 Perceived Learning

Perceived learning relates to a retrospective evaluation of the learning experience and can be defined as a set of beliefs and feelings one has regarding the learning that has occurred (Caspi and Blau, 2011). The perceived learning is about the new information was obtained and person can get the new understanding, subjective evaluation of learning by learners themselves. Researchers mentioned that perceived learning is connected to emotion as flow, enjoyable, and satisfaction (Chu and Hwang, 2010). Regarding in context of educational computer game, when learners are immersed in game-based learning environment, they can judge themselves in the learning process and quality of how to get the knowledge from game, so game can help learned and practiced (Giannakos, 2013). According to the abovementioned, a research hypothesis was set to examine in this study as following.

H1. Students' perceived learning between pre- and post-interacting with educational computer game has development.

2.1.2 Flow

Flow is a state of deep concentration in which thoughts, intentions, feelings, and all of the senses are focused on the same goal (Csikszentmihalyi, 1990; Barzilai and Blau, 2014). The experience of flow would happen when person who take part in challenge situations or activities that need skills. Flow depends on a chance to concentrate, an immediate feedback, a sense of control, and a clarify goal (Barzilai and Blau, 2014). As such, if learners concentrate with the learning experience of educational computer game, the flow of learning would occur during playing the game. According to the abovementioned, a research hypothesis was set to examine presented as following.

H2. Students flow between pre- and post-interacting with educational computer game has development.

2.1.3 Enjoyment

Enjoyment is the condition of having and using technology, e.g. educational computer game that is good or pleasant. The enjoyment of player is a key goal, related with an easy to use of game and enjoyment was found to have valuable in explaining objective to use applications (Giannakos, 2013).

When learners which act as players of game fail to pass the game task, they would get disappointment and attempt to replay again. As such, the enjoyment can help reduce worry to learn and feel more confident when learners success. Accordingly, if the educational computer game can enjoy learners, then they would like to learn more and think positive to the subject. Based on this aspect, below is a research hypothesis for examining the impact of educational computer game on enjoyment.

H3. Students' enjoyment between pre- and post-interacting with the educational computer game has development.

2.1.4 Satisfaction

Satisfaction is the individual awareness of how well a learning environment supports academic success (Lo, 2010). It is relevant to instructional method that learners can think and learn, so their satisfaction can help to get how academic success. At the moment to learn with educational computer game, if it gets positive response from learners that means they reach to positive learning experience with also. In an addition, satisfaction can yield positive of learning performance and can improve learning outcome (Giannakos, 2013). To investigate an impact of educational computer game, a hypothesis was set as the following.

H4. Students' satisfaction between pre- and post-interacting with the educational computer game has development.

2.2 Student-associated Game-based Open Inquiry and Science Motivation

Science motivation refers to the motivation of students to learn science within their emotional which stimulate, control and support in science learning behavior. Therefore, science motivation could be achieved to learners when activate their behaviors by asking the questions, doing experiments, and collaborative learning (Schunk, Pintrich and Meece, 2008; Glynn et al., 2011). Researchers stated that science motivation consists of five motivational constructs: *intrinsic motivation*, an internal state of satisfaction to learn science because it will be good for itself; *self-determination*, the controlling of students' belief that they have when learning science; *self-efficacy*, students can bring their belief connect and manage to achieve learning science; *career motivation*, students learn science to get a good work in the future; and *grade motivation*, learning science to have a good score (Glynn et al., 2011). The following research hypothesis was another one which the researchers expected to examine in this study.

H5. Students' science motivation between pre- and post-participating in the student-associated game-based open inquiry has development.

4. Research Design

This study used two different research designs: one-group pretest-posttest design to examine impacts of the proposed digital game, The IE War, on students' perception and a simple two-group comparison to examine the effects of an instructional intervention, The SAGOI, on students' science motivation, as study 1 and 2 respectively.

5. Study 1

5.1 Participants

The subjects of this study were 29 twelfth-grade students in a public school at the northeastern region of Thailand. The age range of the students was 17-18 years, and all of them were females. 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.

5.2 Learning Materials

The digital game on chemistry of ionization energy was designed to comprise three stages and ten levels of playing. The IE War is the first stage and it was created in style of shooting game. The goal of this educational game is to facilitate student getting the definition of ionization energy. To complete The IE War, there were five playing levels as followings. Figure 1 illustrates a flow chart of The IE War game.

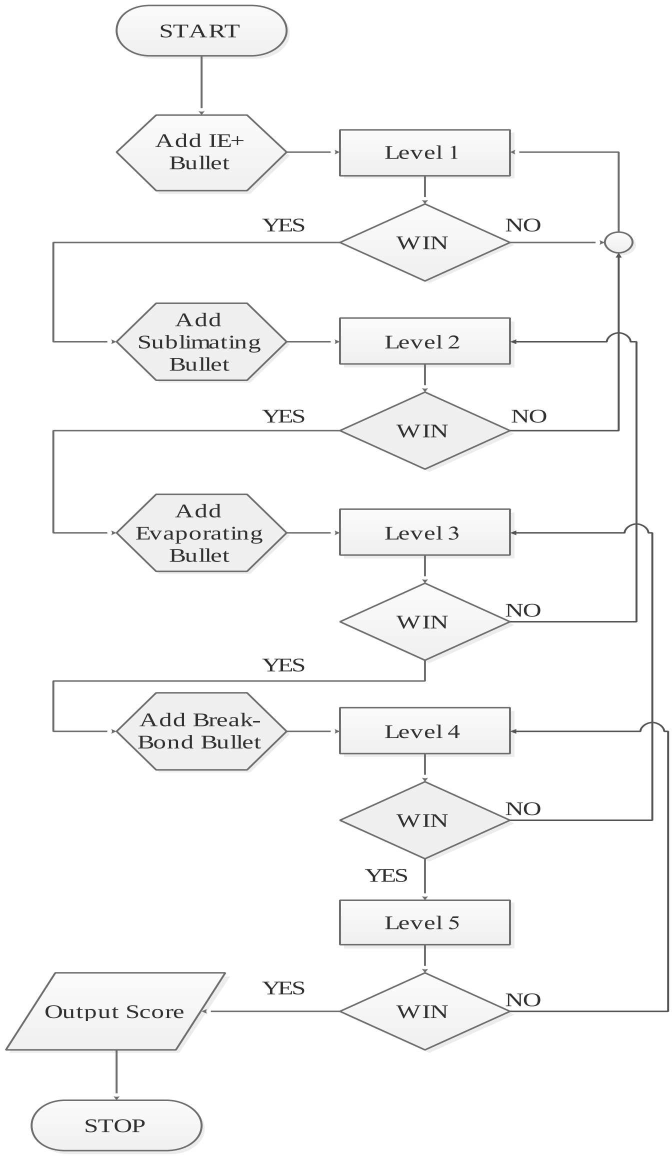

Figure 1. Flow chart of The IE War game.

Level 1: The players have only two bullets, which are IE and IE++ bullet and various gaseous atoms fall down to the ground. The players are able to shoot the atoms by the IE bullet, and then the atom changes its state to be gaseous ion if its energy is corrected. For one round, the players have only three hearts power and they must play to get 10 points for passing any level. Finally, the players who can pass this level would get another bullet, a sublimating bullet.

Level 2: The players have three bullets, which are IE, IE++, and sublimating bullet. In this level, various solid atoms fall down to the ground. The players must choose the sublimating bullet to sublimate solid into a gas, before using IE and IE++ respectively. In the end of this level, the players who complete this level would get the evaporating bullet for the next level.

Level 3: The players have four bullets, which are IE, IE++, sublimating, and evaporating bullet. Likewise, various liquid atoms fall down to the ground and the players must use the evaporating bullet to shot the liquid into a gas, before using IE and IE++. Finally, the players who complete this level would get another bullet called break bond.

Level 4: The players have five bullets, which are all previous four and the break bond bullet. Gaseous molecules fall down and the player must shot them by the break bond bullet to break the gaseous molecules into gas, before using IE and IE++ in next.

Level 5: In this level, all state of matter including gas, solid, liquid, and gaseous molecules fall down to the ground. The players have all five bullets, and must think how to use the bullet correctly and then if the points are high enough, the players would finish this game.

5.3 Instrument

An 18-item perception questionnaire was used to measure students' perception on four subscales: perceived learning, flow, enjoyment, and satisfaction. All of these 5-point Likert scale items obtained from Chu and Hwang (2010) and Barzilai and Blau (2014). From the English version, an identical version in Thai was constructed and two experts were recruited to identify communication validity. For the Thai version, reliability for the overall items was 0.902. There were four items on perceived learning subscale and its reliability was 0.754. The five items on flow subscale indicated that its reliability was 0.661. For enjoyment and satisfaction subscales, the reliability for them was 0.751 and 0.857 respectively.

5.4 Data Collection and Analysis

The participants were asked to complete the perception questionnaire to measure their pre-perceptions on perceived learning, flow, enjoyment, and satisfaction for 10 minutes. After completing the instrument, they were exposed to play The IE War game for 20 minutes. After finishing the game, the students' post-perceptions were examined by the same questionnaire for 10 minutes. To compare the pre-post perceptions on each subscale, paired t-test in SPSS was used to indicate the difference.

5.5 Results and Discussion

Compared to pre-perception scores, the results of post-perception indicated significant higher of students' perception scores on perceived learning ($t = 3.324$, $p < .01$), flow ($t = 5.158$, $p < .01$), enjoyment ($t = 2.480$, $p < .01$), and satisfaction ($t = 4.297$, $p < .01$). This indicated that students have increased their positive perception towards playing the game. Figure 2 illustrates a graphical representation on students' pre- and post-perception scores. The figure showed that the IE War game can affect students' perceived learning, flow, enjoyment, and satisfaction to learn science effectively.

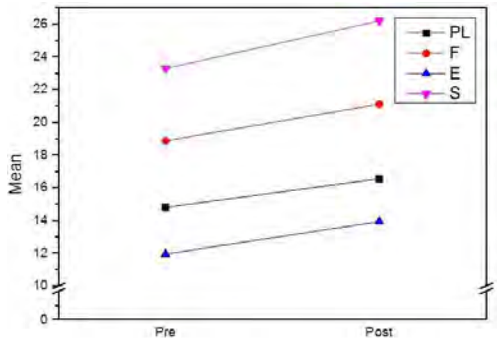

Figure 2. Compare mean scores between pre- and post-questionnaire of four scales.

6. Study 2

6.1 Participants

A total of 81 tenth-grade students were recruited into this study. They were divided into an experimental group (N=43) and a control group (N=44). The experimental group participated with SAGOI class and another was assigned to conventional class as a control group. 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 before.

6.2 Learning Materials and Activity

The IE War game and another two game related factors that affect to ionization energy were incorporated as instructional tool into open-inquiry learning process, called SAGOI. In this learning process, students will collaborative work together in small groups of three to five members. This pedagogy begins with an open-ended driving question targeted to alternative conceptions about ionization energy commonly found in students. To assist the process of hypothesis generation addressed the question, essential scientific backgrounds are provided to students. Then, students are required to perform generating testable hypotheses, designing an investigation with the games. During playing the game, each group was assigned to access Google Drive spreadsheet, preparing by instructor, for recording scores and what they found into a predetermined table. In an addition, each group was assigned to analyze the recorded data by comparing individual score and also use Google Chat for discussing in the group. When they finished the game, all groups have to communicate findings among groups by creating a PowerPoint presentation via Google Drive presentation. Finally, instructor induces students into a forum for drawing a conclusion based on evidence and collaborative explaining the result of hypotheses testing.

6.3 Instrument

A 25-item science motivation questionnaire was used to measure students' motivation to learn science on five subscales: intrinsic motivation (IM), self-determination (SDT), self-efficacy (SEC), career motivation (CM), and grade motivation (GM) (Glynn et al., 2011). From 25 items English version, the translation an identical version in Thai was constructed and Cronbach’s alpha of Thai version were 0.79, 0.81, 0.89, 0.81 and 0.85 for IM, SDT, SEC, CM and GM respectively (Srisawasdi, submitted).

6.4 Data Collection and Analysis

Students were investigated science motivation by the 5-point Likert-scale questionnaire before giving SAGOI intervention for 10 minutes. In the SAGOI class, students participated biology learning of ionization energy using the developed digital game for 230 minutes. After the instruction, students were administered by the same questionnaire again as post-test. The statistical data techniques selected for analyzing students' science motivation was repeated-measures MANOVA in SPSS.

6.5 Results and Discussion

A repeated-measures MANOVA was conducted to determine students’ science motivation scores on the five 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 = .313). The results for the repeated-measures MANOVA indicated significant main effect for group (Wilks’ lambda =0.713, F (5, 75) =6.029, $p<0.001$, $\eta^2=0.287$), and time [Wilks’ lambda=0.663, F (5, 75) = 7.634, $p<0.001$, $\eta^2=0.337$], but interaction effect of time and group were not significant. Thus, these results indicated that students in SAGOI class have changed science motivation over the SAGOI learning experience. Univariate MANOVA on each subscale was conducted as follow-up tests to the one-way MANOVA. The results of the univariate test for control- and experimental group students are summarized in Table 1.

Table 1: The students' subscale means of science motivation by time and univariate MANOVA.

Subscale	Time				F	Sig.	η^2
	CG Pre-test: Mean (SD)	CG Post-test: Mean (SD)	EG Pre-test: Mean (SD)	EG Post-test: Mean (SD)			
Intrinsic motivation (IM)	17.10 (2.73)	17.61 (2.95)	17.95 (2.64)	19.23 (2.51)	8.96	0.004	0.10
Self-determination (SDT)	15.39 (3.71)	16.54 (3.20)	15.65 (2.91)	18.00 (2.92)	26.27	0.000	0.25
Self-efficacy (SEC)	13.17 (3.29)	14.56 (3.65)	15.83 (3.99)	16.98 (3.36)	21.11	0.000	0.21
Career motivation (CM)	17.39 (3.30)	18.07 (3.25)	18.12 (2.86)	19.73 (3.17)	14.87	0.000	0.15
Grade motivation (GM)	17.44 (3.38)	17.44 (3.67)	20.00 (2.70)	20.72 (2.26)	1.15	0.285	0.01

In Table 1, the univariate MANOVA from pre- to post-questionnaire of four subscale scores consists of IM, SDT, SEC and CM were significant differences across time. The univariate results pointed out a significant effect on IM ($F_{1,79} = 8.960$, $p < 0.01$, partial $\eta^2 = 0.102$), SDT ($F_{1,79} = 26.273$, $p < 0.001$, partial $\eta^2 = 0.250$), SEC ($F_{1,79} = 21.113$, $p < 0.001$, partial $\eta^2 = 0.211$) and CM ($F_{1,79} = 14.873$, $p < 0.001$, partial $\eta^2 = 0.158$), but another one GM, the univariate result displayed insignificant ($F_{1,79} = 0.285$, $p < 0.01$, partial $\eta^2 = 0.014$). The result suggested that the increase of science motivation regarding intrinsic motivation, self-determination, self-efficacy, and career motivation from the pre- to post-questionnaire was different between control group and experimental group after participating with the learning instruction. Grade motivation was no effect of time difference on science motivation in learning.

These findings confirm with previous studies (Tuan et al., 2005) that inquiry lessons can increase students' learning motivation. In addition (Erhel and Jamet, 2013) found that game can support motivation and learning which offer it with features that immediate learners to actively procedure in the content and (Ebner and Holzinger, 2007) also found that learning will not be successful if there is a lack of motivation. Therefore we needed some tactics to motivate the students to play the game repeatedly.

5. Conclusion

This study reported impacts of educational computer game on students' perceptions and effects of student-associated game-based open inquiry on students' science motivation. The findings revealed successful of improving students' perceptions and science motivation in context of digital game-based learning experience. This implies that the student-associated game-based open inquiry can be effective in fostering chemistry learning of ionization energy. The results from this study could lead us to conclude that the student-associated game-based open inquiry could be an alternative way for promoting chemistry learning in school science.

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