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Designing Educational Computer Game for Human Circulatory System: a Pilot Study

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Abstract: Recently, digital games have been becoming popular and integral part of our society. The benefit of digital games is not only for fun but also for supporting learning by adding educational purpose into the games called educational games. In this study, we identified 12th grade students' alternative conceptions of human circulatory concept by using two-tier test to design a game served as their alternative conceptions-based learning material. The tests consist of multiple-choice and confident scale. The results show that the students hold alternative conceptions (false-positive and false-negative group) in every concept of human circulatory system, especially homeostasis. From students' alternative conception findings, in this study, an educational computer game was designed and developed, for example the Blood Donor game. To study the effectiveness of Blood Donor game, we explored the 11th grade students' motivation and perception of learning before providing them game (pre-test) and perception after taking game (post-test). The results show that game can enhance students' perceptions. Moreover, students' motivation did not correlate to their perception, indicating that the developed game could be used for students who have low or high motivation in science.

Keywords: Game-based learning, digital games, alternative conceptions, science motivation, perception to learn

1. Introduction

Digital games or computer games are programs or software that created for entertainment purpose (Rollings and Adams, 2003). Recently, digital games have been becoming popular and integral part of our society, especially children or younger generation who like to play game as a favorite activity. To apply the game to educational system, teachers and educators have attempted to find the new ways of teaching by adding educational purpose into the games which is called educational games, this approach namely game-based learning (Tang, Hanneghan and Rhalibi, 2009).

The benefit of digital games is not just for fun, it can be used to support learning. Papastergiou (2009) reported that using game in high school can promote students' of computer concepts and more motivational than non-game approach. Another study also reported that educational games can promote engagement and learning for students with special learning needs (Ke and Abras, 2013). The comparison effect of games indifferent course showed that students and teachers in the game-based course provided more reasons for student motivation along with more desirable, more helpful and less hindering aspects than students and teachers in the non-game-based course (Gunter and Hess, 2013). In addition, students who play an educational video game expressed all of the projected twenty- first century skills while being engrossed in the embedded science content (Annetta, Cheng and Holmes, 2010).

Human circulatory system, which is one topic in biology course, is difficult to learning due to its complex, too much information, and sometimes students' alternative conception come from textbook illustrations (Buckley, 2000). This is a reason why educators have attempted to seek a new approach to teach biology, such as active learning and student-centered pedagogy (Armbruster, Patel, Jhonson and Weiss, 2009). Oblinger (2003) suggested that actively engaged students insist that education must be more than the conventional PowerPoint classroom lecture where information is poured into their heads

and regurgitated onto worksheets. To this end, knowing students' alternative conception is useful when designing the learning material. Consequently, students' alternative conceptions of human circulatory system are needed to investigate for served as an input to designing a digital game. The developed game is served as a tool for supporting students' learning on human circulatory system topic. Therefore, the students' perception and the correlation between students' science motivation and perception are challenging to examine in this study.

2. Study 1

2.1 Participants

A total of 31 students in the twelfth grade from local public school at the northeastern region of Thailand were recruited to respond their conceptual understanding about human circulatory system by taking a conceptual test including 16 items for 40 minutes. All of them are women and age ranging from 18-19 years old. They learned about human circulatory system before participating in this study. They did not prepare themselves for taking this test. Such that, it is reasonable for seeking their alternative conception on the topic.

2.2 Research Instrument

The two-teir concept test about human circulatory system was used in this study. We developed frist teir as a multiple-choice by applying the study of Sungur and Tekkaya (2003) to investigate students' alternative conceptions. The second teir is confidence scale (McClary and Bretz, 2012), ranging from 0% (just guessing) to 100% (absolutely confident), to examine students' confident in their response and facilitated an analysis about students' alternative conceptions. Our concept test consist of 16 items and main concept is classified into 4 concepts including blood, heart, blood vessels, and homeostasis.

2.3 Data Collection and Analysis

To design and implement the games, we investigated students' alternative conceptions about human circulatory system at first step. Students were tested by taking two-tier conceptual test including 16 items for 40 minutes without preparing themselves for taking an examination. The students have to select only one correct answer form four options and make "X" mark on the scale to assign their confidence about answer in each item. Students' answer and their confidence were classified into 4 groups, true-positive (TP) for correct answer with confidence more or equal 50%, true-negative (TN) for correct answer with percent of confident below 50%, false-positive (FP) for incorrect answer with confidence more or equal 50%, and false-negative (FN) for correct answer with percent of confident below 50%.

2.4 Results and Discussion

The aim of developing two-tier test is to identify alternative conceptions in which students have about human circulatory system concept. The results from this test show that the students hold alternative conceptions for every concept such as blood, heart, blood vessels, and homeostasis. List of students' alternative conceptions was shown in Table 1. Considering Table 1, students' alternative conceptions about blood concept shows that 80.65% of them hold alternative conceptions in which biconcave shape allows red blood cells to be in close contact with body cells, 32.26% of them believed that some of the blood stays inside blood tube and some of it leaves the blood tubes and baths the cells. In other concepts, 38.71% of them thought that blood goes into the heart on one side and leaves the other sides and goes to all parts of the body, low blood velocity in capillaries is due to material exchange through capillaries (58.06%), in systemic circulation, percentage of blood volume in the arteries and capillaries is equal, which is greater than that of veins (29.03%), all plasma proteins catalyze reactions in blood under normal physiological conditions. Similar to the study of Özgür (2013), he found that student hold

alternative conceptions about blood circulatory system, such as heart, blood, blood circulation, and blood transfusion.

Table 1. List of students' alternative conceptions about human circulatory system.

Concept	Students' alternative conceptions	% (n=31)
Blood	Fat is not found in plasma.	22.58
	Vitamins uric acid is not found in plasma.	29.03
	Uric acid is not found in plasma.	16.13
	Biconcave shape allows red blood cells to hold more hemoglobin.	16.13
	Biconcave shape allows red blood cells to be in close contact with body cells.	80.65
	Serum is plasma to which necessary nutrients for a patient.	16.13
	Serum is storage from of plasma.	29.03
	Serum is house's plasma.	12.09
	Blood stays inside blood tubes that go to and from the cells.	22.58
	Blood leaves the blood tubes and bathes the cells.	3.23
	Some of the blood stays inside blood tube and some of it leaves the blood tubes and baths the cells.	32.26
Heart	Ventricular filling occurs mostly during atrial contraction.	35.48
	Ventricular filling occurs mostly during contraction of atrioventricular valves.	25.81
	Blood goes into the heart on one side. Blood leaves the other side and goes to all part of the body.	38.71
Blood vessel	Low blood velocity in capillaries is due to their small diameter.	9.68
	Low blood velocity in capillaries is due to material exchange through capillaries.	58.06
	Low blood velocity in capillaries is due to their long distance from the heart.	22.58
	In systematic circulation, percent of blood volume in the arteries, capillaries, and veins is equal.	9.68
	In systemic circulation, percent of blood volume in the arteries and capillaries is equal, which is greater than that of veins.	29.03
	In systemic circulation, the percent of blood volume in the arteries is the highest, while the blood volume in the veins is the lowest.	25.81
Homeostasis	Under normal physiological conditions, all plasma proteins are used to meet cells' amino acid needs.	6.45
	Under normal physiological conditions, all plasma proteins help material transport across capillaries.	19.35
	Under normal physiological conditions, all plasma proteins catalyze reactions in blood.	38.71
	Glucose leaves the blood in capillary mainly by diffusion through endothelial cells.	29.03
	Glucose leaves the blood in capillary mainly by fluid movement through endothelial cells at arteriole end.	41.94
	Glucose leaves the blood in capillary mainly by diffusion through narrow opening between endothelial cells.	19.35

From analysis of students' answers shown in Table 2, we found that 18.55% and 33.07% were classified as FP and FN group respectively, this suggests that half of students hold alternative

conceptions and 14.49% hold incomplete scientific conceptions about blood concept. In the same way, more than half of students hold alternative conceptions about heart, blood vessel, and homeostasis concept.

Table 2. Students report self-confidence in each item on multiple-choice and scale of 0% to 100% of confident.

Content	Item	TP		TN		FP		FN	
		N	%	N	%	N	%	N	%
Blood	1	4	12.90	6	19.25	9	29.03	12	38.71
	3	22	70.97	3	9.68	3	9.68	4	9.68
	4	5	16.13	7	22.58	6	19.35	13	41.94
	16	11	35.48	2	6.45	5	16.13	13	41.94
		Mean	33.87	Mean	14.49	Mean	18.55	Mean	33.07
Heart	8	8	25.81	4	12.90	11	35.48	8	25.81
	9	6	19.35	3	9.68	10	32.26	12	38.71
	13	3	9.68	8	25.81	3	9.68	17	54.84
	15	17	54.84	2	6.45	11	35.48	1	3.23
		Mean	27.42	Mean	13.71	Mean	25.81	Mean	30.65
Blood vessel	5	1	3.23	1	3.23	25	80.65	4	12.90
	10	6	19.35	3	9.68	10	32.26	12	38.71
	11	2	6.45	1	3.23	11	35.48	17	54.84
	12	3	9.68	8	25.81	3	9.68	17	54.84
		Mean	9.68	Mean	10.49	Mean	39.52	Mean	40.32
Homeostasis	2	1	3.23	10	32.26	4	12.90	16	51.61
	6	1	3.23	1	3.23	11	35.48	18	58.06
	7	3	9.69	3	9.68	7	22.58	18	58.06
	14	1	3.23	3	9.68	8	25.81	19	61.29
		Mean	4.85	Mean	13.71	Mean	24.19	Mean	57.26

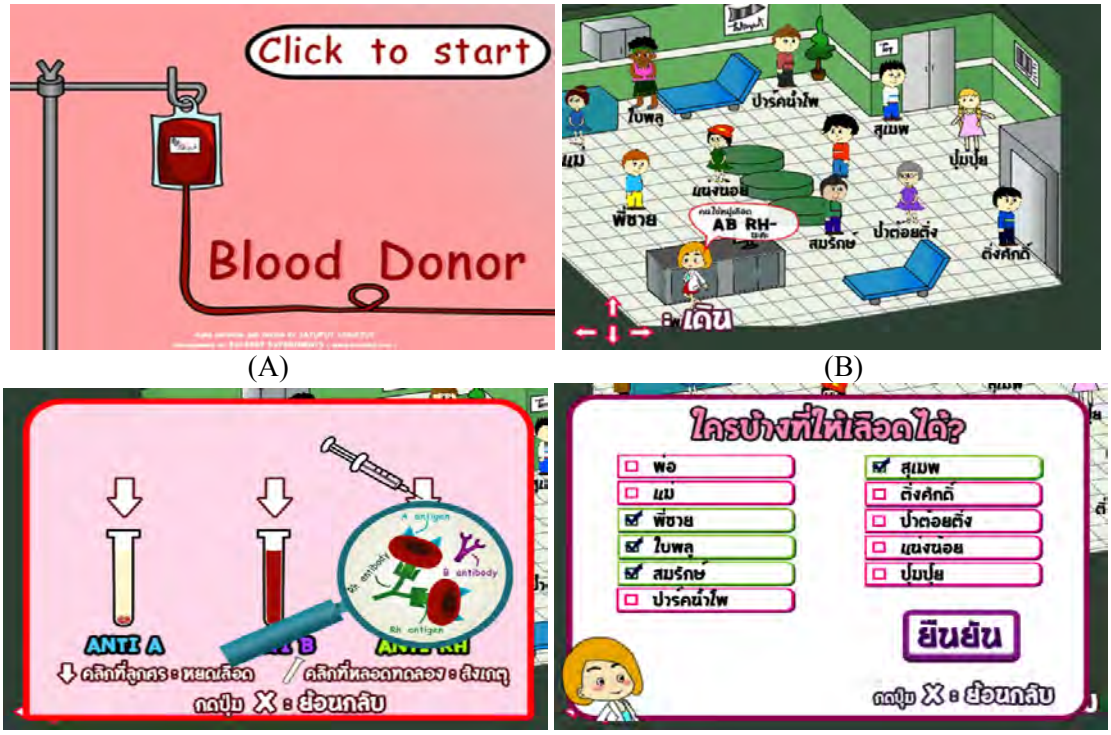
3. Study 2

3.1 Participants

To examine student's science motivation and perception, the participants were 50 eleven-grade students who never learned about human circulatory system before and lack of experience of learning through educational computer game.

3.2 Material about Game

To construct a game as a learning material, we classified the main concept into 3 concepts such as heart, component and flowing of blood, and blood group. We have developed a digital game for assisting learning in each concept. The Blood Donor is an example of game in this study. The overall of this game is shown in Figure 1. In this game, the students get the mission to find who can give their blood for the patient in the scenario. Patient's blood group is random at the beginning of the game. Students have to type blood group everybody in the hospital to know and decide whether the patient can receive blood from this person by dropping blood into test tube of which antibody. Students can click at the test tube for get more details of molecular level. After typing blood group, the students have to check a list of name of people in the hospital with the nurse. The mission will be completed until the students can check list of name for all blood donor correctly.



(A) (B)

(C) (D)

Figure 1. Illustrate example of game "Blood Donor" for teaching about concept of blood type: (A) shows home screen of the game; B shows people in the hospital that need to know their blood group; (C) shows typing blood by dropping blood into test tube; (D) shows checking list of people in the hospital.

3.3 Research Instruments

3.3.1 Student's Perception

To study students' perception of the educational computer game, we develop the questionnaire with 6 scale, such as perceived learning (PL), flow (FL), enjoyment (EJ), ease of use (EU), usefulness (UF), and satisfaction (SA) (Cheng, 2014, Barzilai and Blau, 2014), see Table 3.

Table 3: Scale and sample items of the perception questionnaire.

Scale	α	Example of item
Perceive learning (PL)	0.80	I learned a lot from the game. The game added to my knowledge.
Flow (FL)	0.82	I learned a lot from the simulation. The game added to my knowledge.
Enjoyment (EJ)	0.75	I enjoyed the game. I had fun playing the game.
Perceive ease of use (EU)	0.74	It is easy for me to learn how to use game. The user interface of game is easy to use.
Perceive of usefulness (UF)	0.84	Game can help me learn more effectively. Game can improve my course performance.
Perceive of satisfaction (SA)	0.77	I feel comfortable to use game. I enjoy the experience of using game.

Participants were required to consider each possible reason for educational game and rate how important it was for them by using a 5-point Likert scale (1-strongly disagree; 2-disagree; 3-neutral; 4-agree; 5-strongly agree). For overall items have a very good reliability.

3.3.2 Student's Science Motivation

A science motivation questionnaire was developed from the study of Glynn, et al. (2011) by translated into Thai version. They are 5 categories of this questionnaire and 5-point Likert scale, such as intrinsic motivation (IM), self-determination (SDT), self-efficacy (SEC), career motivation (CM), and grade motivation (GM). Reliability of the questionnaire was tested Cronbach's alphas in each category which were 0.79, 0.81, 0.89, 0.81 and 0.85 for IM, SDT, SEC, CM and GM, respectively, indicating that Thai version's Science motivation questionnaire was found a good reliability.

3.4 Data Collection and Analysis

3.4.1 Students' Perception

Students were investigated by perception questionnaire before providing the educational games (pre-test). After that, students were asked to play the game Blood Donor for 20 minutes and were investigated perception again by using the same questionnaire (post-test). To compare both pre- and post-test, the pre- and post-test scores were analyzed by using pair *t*-test using SPSS program.

3.4.2 Students' Science Motivation

To explore students' science motivation, the questionnaire was used before providing the educational games. There are 25 questions on the questionnaire and each item rates the students' perceptions of the game using five-point scale ranging from "least" (1 point) to "most" (5 points). Students' science motivation was determined the correlation with post-test of students' perception by using the educational computer game.

3.5 Results and Discussion

3.5.1 Students' Perception

After playing game, students' perception before and after were analyzed by using pair *t*-test. The result shows that post-test score is higher than pre-test significantly in each scale as shown in Table 4.

Table 4: Students' perception in each scale.

Scale	IM	CM	SDT	SEC	GM	PL	FL	EJ	EU	UF	SA
IM	1										
CM	0.49**	1									
SDT	0.56**	0.52**	1								
SEC	0.63**	0.34*	0.43**	1							
GM	0.52**	0.42**	0.22	0.43**	1						
PL	-0.26	-0.12	-0.20	-0.09	-0.11	1					
FL	-0.10	-0.23	0.02	0.10	0.15	0.61**	1				
EJ	-0.22	-0.07	-0.25	-0.01	-0.36	0.77**	0.57**	1			
EU	0.07	0.18	0.14	0.08	-0.03	0.24	0.43**	0.16	1		
UF	-0.10	-0.28	-0.14	0.07	0.03	0.42**	0.55**	0.47**	0.20	1	
SA	-0.24	-0.26	-0.22	-0.01	-0.14	0.33*	0.40**	0.56**	0.15	0.57**	-
Mean	17.36	16.28	15.72	14.00	16.76	13.90	15.96	10.60	9.45	10.14	10.82
SD	3.15	2.87	2.42	2.55	3.01	1.81	2.10	1.77	1.73	1.44	1.76

$^{*}p < 0.05$, $^{**}p < 0.01$

This indicates that the progression of students' perception increase after playing the developed educational computer game. This finding conforms to the study of Srisawasdi (2012) that using technology can improve students' perception of learning.

3.5.2 Correlation between Students' Science Motivation and Perception

Pearson's correlation was used to investigate correlation between science motivation (IM, SDT, SEC, CM, and GM) and perception (PL, FL, EJ, EU, UF, SA) in this study as shown in Table 5. Regarding Pearson's correlation analysis of each scale in science motivation, we found that all scale related together except self-determination which do not relate to grade motivation. This results reveal that grade in science subject is important for them even though they have different level of self-determination. From the analysis of perception, perceived learning showed significantly related to flow, enjoyment, usefulness, and satisfaction. In addition, students' perception of flow was positively related to their change in enjoyment, ease of use, usefulness, and satisfaction.

The analysis of correlation between students' science motivation before playing the developed educational computer game and perception after playing the game showed that intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation were related to their perceived learning, flow, enjoyment, ease of use, usefulness, and satisfaction. These results indicate that the developed game, The Blood Donor, could be used for all students who have low or high motivation in science. In addition, game tasks can improve students' motivation, engagement, and problem-solving performance (Eseryel, Law, Ifenthaler, Ge, & Miller, 2014).

Table 5: Descriptive statistic and correlation for perception and science motivation

Scale	Mean (SD)		*t*
	Pre-test	Post-test	
Perceived Learning	11.52 (2.37)	13.90 (1.81)	5.79*
Flow	14.04 (2.59)	15.96 (2.10)	4.41*
Enjoyment	9.06 (1.92)	10.60 (1.77)	3.92*
Ease of use	8.18 (1.99)	9.52 (1.79)	3.60*
Usefulness	8.70 (2.10)	10.14 (1.44)	4.01*
Satisfaction	9.04 (2.47)	10.82 (1.76)	4.12*

* $p < 0.01$

4. Conclusion

This study surveys students' alternative conception about human circulatory system. After that the educational computer game was designed and developed based on those alternative conceptions. The finding of this study show that (1) students still hold alternative conception about the concept of human circulatory system even if they learned before; (2) our educational computer game, the Blood donor, can be used for improving students' perception to learn; (3) students' perception dose not relate to science motivation. To this end, the Blood Donor game which is designed based on students' alternative conceptions can assist students who have low or high motivation in science to learn. However, to address students' learning performance we are going to study about the effect of using educational computer game on students' conceptual understandings.

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