The Effects of Learning Styles and Meaningful Learning on the Learning Achievement of Gamification Health Education Curriculum

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This study aims to discuss the correlations among learning styles, meaningful learning, and learning achievement. Directed at the rather difficult to comprehend human blood circulation unit in the biology materials for junior high school students, a Mobile Meaningful Blood Circulation Learning System, called MMBCLS gamification learning, was developed. In the study, the instructional design is based on meaningful learning and follows the principles of digital game-based learning models to design after-class multimedia materials, which allow learners to enjoy learning. With a quasi-experimental design, Kolb's learning styles scale and meaningful learning scale were utilized as research instruments. Taking a G8 class as the subject, 46 valid questionnaires were returned. The research findings show divergences in mobile game-based learning styles: students with convergent styles highly regarded the well-designed curriculum in meaningful learning; student gender presented no significant difference in curriculum design and learning achievement in meaningful learning; students with different learning styles revealed remarkable differences in learning achievement; and students in the experimental group apparently had a higher learning achievement than the students in the control group, with notable differences. The research outcomes could be cited by teachers for designing material and provide educators with a reference for the mobile as meaningful media material design..

Keywords: gamification, 3D mobile game education, meaningful learning, learning styles, learning achievement

INTRODUCTION

In recent years, researchers have begun to emphasize differences in student learning styles. Various factors in the learner's learning process should be considered, including personal factors of motivation, personality and ability, as well

as the external learning environments of instructional media and course content. Research results have pointed out that the learning style is the key factor and affect academic performance in learning (Clariana & Smith 1988; Scoest & Kruzich 1994; Jorge, Rebecab & Ana 2013; Shaw 2012).

In the traditional learning environment, it has often been found that different pupils presented distinct learning approaches to the same question. Such learning differences mainly resulted from students' learning styles. Learning style refers to the personal preference that a student brings to bear in a given learning situation; such preferences were the variable learning processes and strategies affecting personal learning outcomes. For this reason, personal learning styles were a consideration in the teacher's teaching strategy and course activity design. Teaching strategy, the motivation of curriculum design, played a critical role in the learning process. Meaningful learning was a teaching strategy, which allowed traditional curriculum design to be tuned to the learner's willingness to actively and positively face learning in order to enhance learning benefits and learning achievement.

State of the literature

- Meaningful learning and follows the principles of digital game-based learning models to design as a multimedia material, which allow learners to enjoy learning.
- Kolb's learning styles scale and meaningful learning scale were utilized as research instruments.
- Students with convergent styles highly regarded the well-designed curriculum in meaningful learning.

Contribution of this paper to the literature

- The authors develop a game as the learning approach to establish the gamification mobile learning system and enhance the learning achievement.
- Finding out the differences in learning outcomes with distinct instructional strategies.
- Finding out differences in unit level learning outcomes with distinct instructional strategies.

Both learning styles and meaningful learning are key factors in the learner's learning process. Much research has been done on learners' learning styles and meaningful learning, with results that varied, depending on the research theory, sample or instruments. This study also ascertained that learning styles and meaningful learning might show slight correlations. Nevertheless, research on the correlations between learning styles and meaningful learning has been limited, and literature on this issue is scant.

This study, therefore, is devoted to the development of digital games, which can be used to improve the resources of junior high school teachers, teaching the human blood circulation unit. The circulation system is an important unit. In the research on the human blood circulation system, domestic and international researchers were in agreement with regards to the students' difficulty in comprehending it (Chi, Chiu & deLeeuw 1991). Although the human body contains a complete blood circulation system, the heart, capillaries and blood cells cannot be observed with the naked eye, and circulatory system diseases are, typically, far removed from the realm of experience of these young students. It is, therefore, difficult for students to discuss this system, based on their real life experience alone, a conclusion with which Buckley (Buckley & Boulter 2000) agrees.

Past research considered that game-based learning could, effectively, attract pupils' attention. Quinn (2000) defined games as coming from intrinsic motivation and being interesting, so that the potential cognition process became easier to comprehend. The game-oriented teaching method of gamification, which presents the characteristics of challenge, curiosity and fantasy, could appeal to students' learning motivation. Furthermore, Ellington, Adinall and Percival (1982) proposed that games, with fun, allowed students to maintain longer attention spans and easily cultivated higher cognitive skills in the learning process.

Even though students are taught the blood cell curriculum through lectures, diagrams and texts, misconceptions are still, relatively, widespread, such that many students do not understand that the gap between the left and right atrium allows

blood flow, and that arteries and veins can be differentiated by size and thickness. With regards to teaching media, many teachers do not use interesting digital materials; conversely, digital games do not conform to their demands (Prensky 2001; 2003).

Consequently, instructional activities are designed through meaningful learning theory and combined with game-based learning characteristics in this study. Based on domestic and foreign research results on human blood circulation, the design principles for a game-based learning model and the activity design for meaningful learning are applied to understanding the following:

1. The use of games as a learning approach to establish the gamification mobile learning system and enhance the learning achievement.
2. Difference in learning outcomes with distinct instructional strategies.
3. Differences in unit level learning outcomes with distinct instructional strategies.
4. How to correlate analyses of meaningful learning and learning outcomes.
5. Effects of learning styles on learning achievement.

LITERATURE REVIEW

Game-based learning

Some research has indicated that students consider game-based learning easier than other learning approaches (DeVries & Edwards 1972). Prensky (2001; 2003) pointed out that the competitive/cooperative spirit, playfulness, achievements and the continued introduction of challenges into a game, in which rewards can be acquired, increases the amount of knowledge gained by students. Games could also provide continual practice, after which learners could acquire higher accuracy and improve their memory (Driskell , Willis & Cooper 1992). Dempsey, Lucassen, Haynes, and Casey (1996) pointed out several functions of games, such as teaching, entertaining, assisting in exploring new skills, promoting self-dignity, practicing skills, and changing attitudes, revealing that the application of games to education offered great value. Bork and King (1998) argued that video games allowed real-time brainstorming and stimulated inspiration. Considering the above viewpoints, it is concluded that the application of games to learning could induce a competitive/cooperative spirit, enhance memory, stimulate inspiration, and promote motivation among learners.

Learning styles

Learning styles refers to the way learners approach the learning process. During the interaction between the learning situation and the learning process, students generate special preferences to respond to external and internal environmental stimuli. In the Experiential Learning Theory, Kolb (1976) regarded learning activities as a continuous process, which was divided into four stages: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experience (AE). Such four stages formed a continuously repeated learning cycle, Figure 1.

These four learning styles were further composed to include: (1) an accommodator, who tended to deal in affairs with practical experiences and active verification; (2) a diverger, who presented stronger imagination and comprehension and was good at observing conditions from various aspects to organize a complete symbolic meaning; (3) a converger, who solved problems and made decisions, as well as practically applying theories and ideas; and (4) an assimilator, who
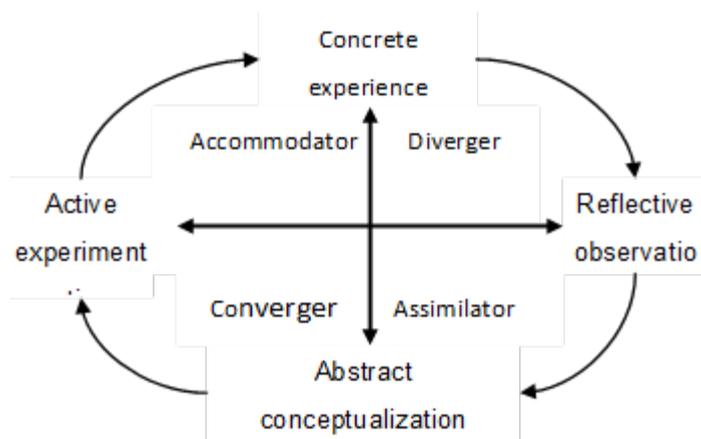
Figure 1. Kolb's learning styles

presented stronger deductive inferential abilities and the establishment of theoretical models, and could assimilate individually observed objects into a whole.

From the above mentioned literature, we derive that game-based learning could effectively enhance motivation, and can be conducted anytime, anywhere, without necessarily being in-school. In this case, appealing to learners to learn actively becomes an important consideration in promoting education. Past literature has proven that mobile game-based learning could reinforce learning achievement. The mobile game-based learning system design in this study is utilized for discussing the effects of learning styles on students' learning achievement through meaningful learning activity design.

Meaningful learning

Ausubel's (1963) research on cognition and learning demonstrated that forming meaningful learning approaches, such as integrating meaningful learning with a cognitive structure to teach students new knowledge, could have the students generate meaningful learning. Meaningful learning reinforced the students newly acquired knowledge and formed a personalized and unique comprehension with past experiences and knowledge (Renda , Fonseca & Pinto 2006; Viola,Giretti & Leo 2007). Ausubel (1963) explained cognitive structure as an organizational, stable and clear cognition of an individual about certain special information. Such a cognitive structure is constantly operating in order to integrate various sub-concepts or information into a systematic structure. In this case, all teaching preparations for learning activities should be focused on allowing students to engage in meaningful learning (Jonassen 1995). Some research has attempted to use mobile information technology to practice (Jonassen 1995) meaningful learning (Karppinen 2005; Rendas, Fonseca & Pinto 2006; Rick & Weber 2010). The meaningful learning scale in this study is based on Huang's (Huang, Chiu, Liu & Chen 2011) meaningful learning assessment structure and refers to experts' suggestions (Table 3).

Instruction in human blood circulation systems

For instructional reference, Arnaudin & Mintzes (1985) preceded with semi-structured clinical interviews of 46 G8 students, in order to understand what misconceptions they may have had regarding the cardiovascular system. Arnaudin & Mintzes (1986) investigated the blood circulation concepts of elementary, junior high, senior high and college students, and classified blood circulation into seven concepts. The results revealed that the elementary school students had misconceptions about all seven items and that the high school freshmen had misconceptions on three. Obviously, a change of instructional models is required for the circulation system concepts to be better understood. In the research on

understanding the effects of the circulation systems on homeostasis, Sungur, Tekkaya & Geban (2003) proposed 48 misconceptions related to human circulation systems.

Researchers have discovered several improvements for learning about the human blood circulatory system. The complexity of the systems caused the learners to step back, while its importance induced experts to invest in the studies, expecting to promote student learning achievement in circulation concepts and to rectify students' misconceptions.

Operation model of digital games

Game-based learning design closely resembles experience-oriented, individualized instruction, in which the instructional design focuses on students. Thus, game-based learning has become a popular research issue. In Digital Game-based Learning, Prensky (2001; 2003) pointed out six key game factors:

1. Rules: Games give players a structure to follow, e.g., game regulations and conditions for passing levels;
2. Goals or Objectives: each game provides certain objectives and the game design induces players' motivation to continue the game;
3. Outcomes and Feedback: designing proper feedback in games could create players' learning opportunities and outcomes in the games;
4. Conflict, Competition, Challenge and Opposition: players perceive physiological and psychological stimulation, self-challenge, self-competition or competition with others, and opposition in the game processes;
5. Interaction: players could share, support, and help each other by interacting and forming communities of like-minded game participants; and
6. Representation and Story: games create emotional identity to satisfy players, physically and mentally.

There are diversified computer games, most of which focus on game-based entertainment, while few of them have been applied to educational learning (Virvou & Katsionis 2008). Many researchers agree with the positive educational effects of applying digital games to education (Prensky 2001; 2003), as digital games present the characteristics of games in which the idea of learning by doing is regarded as a potent instrument. The powerful motivation behind games could enhance learning, turning it into an interesting affair (Kirriemuir & McFarlane 2004). Some researchers have even proposed digital games as a future learning style (Hsiao & Hui-Chun 2007). Other studies have indicated that a game itself could not result in learning, but required the assistance of instructional strategies to reinforce learning outcomes. In other words, game-based learning outcomes were deeply affected by instructional design.

Garris, Ashlers & Driskell (2002) proposed a learner's internal operation model, Model of Game-Based Learning, in game-based learning activities, where input, process and output were covered, Figure 2. Instructional content and game characteristics were included in input; proper game varieties in instructional content were selected based on the instructional requirements, the game situations were created, and the players had to integrate into the roles; and rules, goals or objectives, outcomes and feedback, conflict, competition, challenge, opposition, representation and story, curiosity, and control were followed and presented in game characteristics. System feedback, user behavior, and user judgment were contained in the process in which the player's behavior corresponded to the system and generated interactive responses. As players pursued challenges and revised their thoughts during the game process, the behavior models effectively changed. User judgment adhered to the following principles:
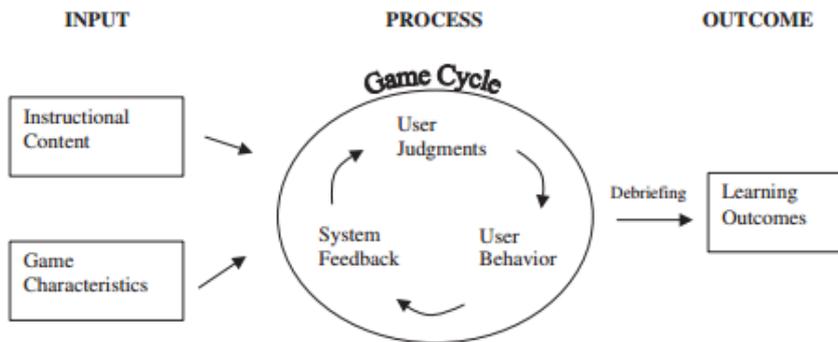
Figure 2. Model of game-based learning (Garris, Ahlers & Driskell 2002)

1. Interest: clear interest or preference for an activity;
2. Enjoyment: personal subjective fun or enjoyment level;
3. Task Involvement: focus or depth of educational activities; and
4. Confidence: perception of familiarity or self-efficacy.

Learning outcomes include specific achievements in learning goals or objectives. The game-based learning model and game characteristics, proposed by Garris (2002) et al., could be reference points for educational game designs (Thomas, Schott & Kambouri 2003), which digital games were applied to the educational design principles in this study, expecting to provide teachers with rich and lively teaching aids and enhance the students' learning motivation and attitudes through game characteristics.

MMBCLS SYSTEM DESIGN AND PRACTICE

Garris et al (2002) proposed the theoretical points of gamification learning activities, including the steps of input, processing and output for meaningful and focused curriculum design; each step was designed according to the points of meaningful learning and implied distinct gamification interaction, which was achieved through MMBCLS. Table 1 shows the teaching curriculum design completed by the combination of mobile game-based learning activities and the curriculum design steps in meaningful learning.

Meaningful learning activity design

Teaching activity design, based on Ausubel's (1963) meaningful learning and the model of game-based learning proposed by Garris et al. (2002), is used in the Red Attack-Human Blood Circulation System Learning game, with an explanation of the level-corresponding game design in Table 1. Meaningful learning activities and game-based model design stand for a learning activity table, which contains the operations of input, process and output, and combines them with meaningful learning activities (active, authentic, constructive, cooperative and personalized).

A. Input

I. Instructional Content
The data sources for Instructional Content contain two parts:
1. Pulmonary circulation: Blood starts from right ventricle, enters the pulmonary artery, the lung, and the pulmonary vein for gas exchange, and brings oxygenated blood back to the left atrium, Figure 3-1 Model of Game-Based Learning (Garris, Ahlers & Driskell 2002).
2. Systemic circulation: From the left ventricle, blood enters various parts of body through the main artery for gas exchange and nutrient delivery and

Table 1. Design of meaningful learning activities and model of game-based learning

Model	Meaningful learning	Learning objective	Level	Game characteristics	AS
Input	**Active**	1.Understanding the pulmonary circulation process	Cardiovascular zone	Rules/Curiosity	
		2.Self-learning the systemic circulation process	Cardiovascular zone		A
Process	**Authentic**	3.Keeping an active attitude while learning blood circulatory systems	Cardiovascular zone	Rules/Curiosity	A
		4.Observing real blood circulatory system learning objects	Liver zone	Conflict/Curiosity/Control/ Representation and Story	A
	Constructive	5.Learning blood circulatory systems in an authentic environment	Liver zone	Conflict/Curiosity/Control/ Representation and Story	A
		6. Understanding materials related to blood circulatory systems	Lung zone	Conflict/Curiosity/Control/ Representation and Story	A
		7. Connecting new concepts to the learning experiences in blood circulatory systems	Lung zone	Conflict/Curiosity/Control/ Representation and Story	A
	Cooperative	8. Effectively learning in the cooperative lesson	Spleen zone	Conflict/Curiosity/Control/ Representation and Story	B
		9. Completely understanding the cooperative lesson	Spleen zone	Conflict/Curiosity/Control/ Representation and Story	B
Output	**Personalized**	10. Completely understanding and learning blood circulatory systems	Assessment	Outcomes and Feedback	A
		11.Blood circulatory systems providing personalized services	Assessment	Outcomes and Feedback	A

(A=the system automatically collects assessment; B=the teacher collects assessment; AS=Assessment)

(a) Game start picture   **(b)** Game role selection picture

Figure 3. Game start picture and role selection picture

then flows back to the right atrium through superior and inferior vena cava for bringing deoxygenated blood back to the heart.

II. Game Characteristics

This game design covers the following game characteristics:

1. Rules: players have successively to assume the role of red blood cells, white blood cells and platelets at the proper time, so as to satisfy the game requirements.

2. Goals or Objectives: in the limited time, the players start from the right ventricle and pass to the left lung, left atrium, spleen, liver, right ventricle, right lung, and left atrium for a one-time human blood circulation.
3. Outcomes and Feedback: all questions asked by NPCs (Non-Player Characters) should be answered in the game process in order to pass through succeeding levels.
4. Conflict, Competition, Challenge and Opposition: different bacterial attacks are encountered along the various game routes and many wounds need to be healed, dictating that players use both hands and brains.
5. Representation and Story: players can play three roles (red blood cells, white blood cells, platelets) to deepen their sense of identity.
6. Curiosity: four organs – heart, liver, spleen and lung – are levels through players pass, so that they can view the internal organs; further, the games are animated to induce player curiosity.
7. Control: players can control their roles through interaction with mobile devices. Skills are required for coping with bacteria, big monsters and little monsters, and the players need rich blood circulation knowledge in order to pass the levels.

B. Process

I. System Feedback
1. The little map on the top left of the screen allows players to be aware of the current locations, so as to learn the correlations among blood circulation systems.
2. There are task prompts for the four organs (heart, liver, spleen and lung) e.g., requiring oxygen when starting from the left lung, or changing to red blood cells to absorb carbon dioxide.
3. NPCs ask questions in the blood cell/vessel zone, heart zone, liver zone, spleen zone, and lung zone. For example, players can be asked what delivers blood to the lungs, allowing the carbon dioxide in the blood to be changed into oxygen, and are requested to select a correct answer from (A) left ventricle, (B) right ventricle and (C) right atrium.
II. User Judgment
Players go through the organs and think of the functions that would most interest them when reading the relevant knowledge in textbooks, rather than looking at static pictures.
III. User Behavior
The relevant textbook lesson would be effectively connected to the lesson after the game, by which time students will have become acquainted with the human blood circulatory system and their learning motivation will have been enhanced.

C. Output

With game characteristics and auditory and visual stimulation, players are integrated into situations by constantly performing tasks, solving problems and answering questions; by seriously treating the knowledge delivered in the game process; and by adjusting their opinions about such issues; all of which further enhances their learning motivation.

System function design

The game interface and functions are completely introduced and demonstrated in this section. The players can log onto the system from the menu in Figure 3(a) and enter the unit practice from the menu in Figure 3(b). The main menu and role selection are shown in Figure 3(b), through which the players can enter the learning units of the cardiovascular, liver, spleen and lung circulatory systems.

The players start as white blood cells from the right atrium and go through the left lung, left atrium, spleen, liver, right atrium, right lung and left atrium. The blood circulatory system contains pulmonary circulation, systemic circulation, and back to pulmonary circulation. In addition to collecting oxygen and carbon dioxide on the way, oxygen and carbon dioxide are also released at specific locations. Various bacteria attacks are encountered and wounds need to be healed on the way. Before leaving each organ, NPCs' questions need to be correctly answered. The final destination is arrived at when the powerful Devil King is defeated. Figure 4(a)~(d) shows pictures of the players in the four organ games.

Ten unit questions are asked after completing the learning lesson of each level, and the system automatically records the learning process. Consequently, a player's learning is assessed as it corresponds to the four major human blood circulation assessment systems: cardiovascular, liver, spleen and lung, Figure 5(a)~(d).

Instrument

Gamification system comprehension and learning achievement pretest

Before the instructional experiment, the gamification system content comprehension test was preceded by a pretest. The learning achievement test aimed to evaluate the participants' learning achievement in the blood circulation course after the experiment. The content refers to the lessons taught about blood
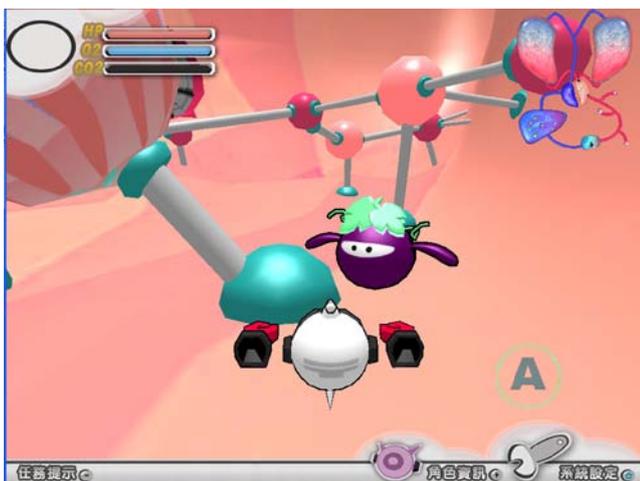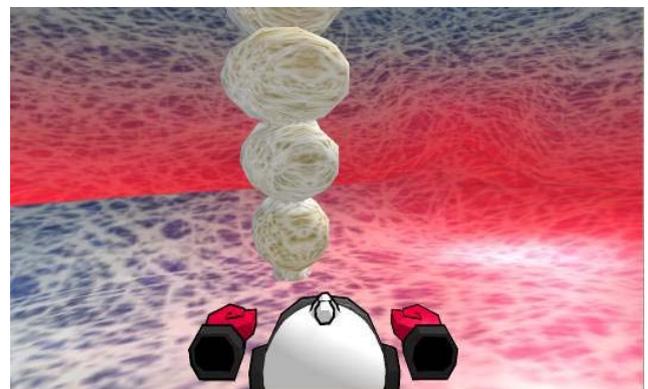

(a) Heart

(b) Liver

(c) Spleen

(d) Lung

Figure 4. Four major organs in the human blood circulation systems: heart, liver, spleen and lung

(a) Assessment 1. Cardiovascular circulation system

(b) Assessment 2. Liver circulation system

(c) Assessment 3. Lung circulation system

(d) Assessment 4. Spleen circulation system

Figure 5. Four assessment systems: heart, liver, spleen and lung

circulation in junior high school biology classes, as defined by the Taiwan Ministry of Education syllabus; the validity of the test paper was evaluated by a team of experts, and further revised to eliminate improper questions and refine semantic content.

Learning styles scale

The Kolb Learning Styles Scale refers to the one compiled by Kolb in 1976, which was revised in 1984 from KLSI-1976 to KLSI-1984. Four basic dimensions in this scale, CE (Concrete Experience)=0.85, RO (Reflective Observation)=0.83, AC (Abstract Conceptualization)=0.78, and AE (Active Experience)=0.88, present favorable internal reliability after the Cronbach alpha test, and the α coefficient of the overall scale appears as 0.84, revealing favorable reliability.

Meaningful learning scale

The meaningful learning scale was also collaboratively completed in a preliminary test by 5 biology teachers, randomly sampled from the school. A total of 51 students in two G8 classes were tested, with a valid sample of 46. The meaningful learning scale was divided into five parts: active, authentic, constructive,

cooperative and personalized. In regard to validity, a factor analysis was used for exploring the construct validity, confirming the valid factors, deleting potential indicators not conforming to the research, and reinforcing the construct validity of the scale. The α reliability presents 0.87, 0.83, 0.88, 0.82 and 0.81, and the α coefficient of the overall scale appears as 0.84, showing the favorable reliability of this scale.

SYSTEM ASSESSMENT

Four sections are covered in this chapter, including sample collection, experimental design, reliability and validity, and result. This study aims to understand: 1. the differences in learning outcomes with distinct instructional strategies; 2. the differences in unit level learning outcomes with distinct instructional strategies; 3. the correlation analyses of meaningful learning and learning outcomes; and 4. effects of learning styles on meaningful learning and learning achievement.

Sample collection

Forty-six students in a southern Taiwan G8 junior high school were selected randomly as the research sample in this study. By random distribution, the class was divided into an experimental group, composed of 12 male and 11 female students, and a control group, composed of 13 male and 10 female students.

Experimental design

The pretest-posttest nonequivalent-groups design in a quasi-experiment was selected in this study. The teacher and the 46 students participated in the experimental design, Table 2. The experimental group applied meaningful, mobile, game-based learning, while the control group utilized general, meaningful, material learning. Both groups used identical textbooks, and both groups took a human blood circulation learning outcome assessment pretest (X1, X3) and human blood circulation learning outcome assessment posttest (X2, X4).

Experimental procedure

The study took ten weeks to conduct the overall learning activity, and was designed in five stages, as shown in Figure 6. The implementation of the experimental procedure took place over six weeks. The first stage (1st week) consisted in studying the fundamentals of the blood circulation lesson in the natural science course. In the second stage (2nd week), the teacher explained the experimental objectives and evaluation methods, and the students were asked to take a pre-test. Subsequently, in the third stage, the three learning conditions were implemented. The learning activity was conducted in the blood circulation lesson area. To play the game, the students in the experimental group, in cohorts of 3 to 8, took field trips to the blood circulation lesson area. The students with smartphone devices could play the game. The MMBCLS helped students learn about the target blood circulation by easily allowing them to identify the blood circulation lesson they learned. In the fourth stage (week 9), all the students were asked to take a post-test and to answer a questionnaire (40 min.). Finally, the teacher interviewed students with different learning styles and followed up with some questions in order to evaluate individual student learning problems.

Table 2. Experimental design model

Group	Pretest	Experiment	Posttest
Experimental group	X1 X3	Meaningful mobile game-based learning	X2 X4
Control group		General meaningful material learning	

Reliability and validity

In order to achieve the confidence level in the measured scores, Cronbach's α was utilized for calculating the reliability of the questions and questionnaire. The reliability of the scales was first analyzed with Cronbach's α in order to confirm the reliability of the questionnaire. The reliability analysis of the service satisfaction scale is shown in Table 3. The five dimensions of active, authentic, constructive, cooperative and personalized for meaningful learning present the Cronbach's α as 0.875, 0.86, 0.87, 0.905 and 0.87, respectively; and, the Cronbach's α of the overall meaningful learning scale appears as 0.876. Such reliability is greater than the standard of 0.7, suggested by Hair et al., indicating that the scales present significant reliability and are suitable for future research.
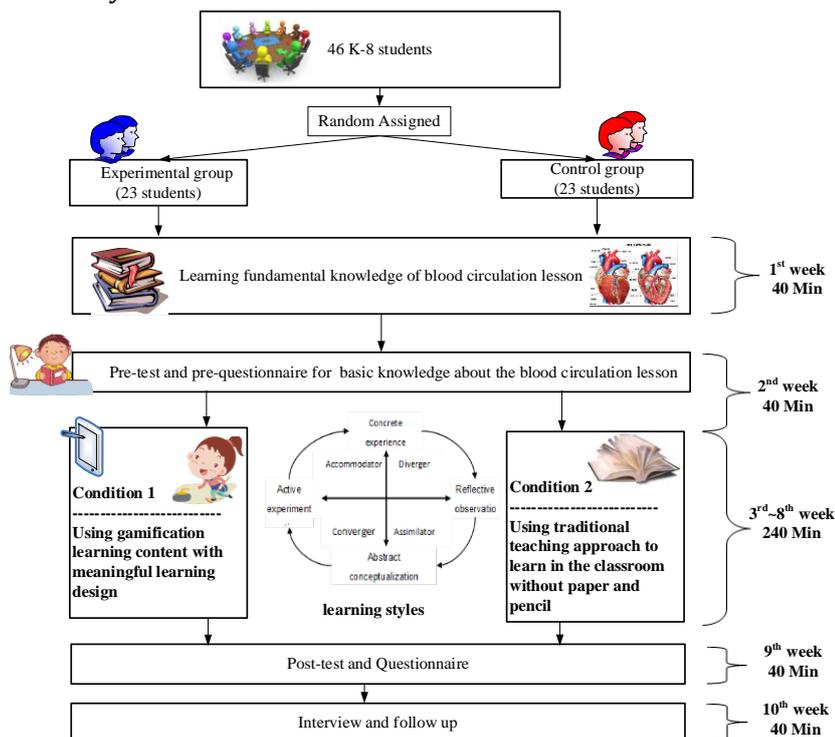

Figure 6. Experimental procedure

Table 3. Statistic data of meaningful learning questionnaire

Meaningful learning	Questions	Mena	SD	Cronbach α	
Active	1. I can self-learn without others' help	5.7	0.6	0.84	0.875
	2. I can monitor my current learning progress	5.2	1.1	0.91	
Authentic	3. I maintain a positive attitude towards learning activities	5.1	1.3	0.84	0.86
	4. I can observe real learning objects	4.2	1.0	0.88	
Constructive	5. I learn in an authentic environment	3.9	1.3	0.84	0.87
	6. I understand materials related to authentic environments	4.2	1.2	0.90	
	7. I can connect new concepts with previous experiences	5.9	1.5	0.87	
Cooperative	8. I can learn effectively with team cooperation	6.5	0.8	0.90	0.905
	9. I thoroughly understand the knowledge learned through team cooperation	6.1	0.6	0.91	
Personalized	10. The materials are understandable and suitable for learning	4.2	1.1	0.89	0.87
	11. The materials provide personalized services	5.7	1.2	0.85	

To achieve this accuracy, i.e., a valid scale, one reliable enough to measure all of the questionnaires is required. In other words, a scale achieves effectiveness when it is able to achieve the measuring objective. Content validity is utilized in this study for evaluating the validity. In this case, the scale was revised based on the suggestions derived from three experts, and the pretest results. The scale, therefore, reveals suitable content validity.

RESULT

The research result analysis, aiming at the research objective proposed in Chapter 1, contains data analyses of four sections, including: (1) the differences in learning outcomes with distinct instructional strategies; (2) the differences in unit level learning outcomes with instructional strategies; (3) the correlation analyses of meaningful learning and learning outcomes; and (4) the effects of learning styles on learning achievement.

Difference in learning outcomes with distinct instructional strategies

With ANCOVA of the differences in learning outcomes with distinct instructional strategies, Table 4, the mean pretest of the experimental group is 78, and of the control group, 75. There is no difference (F=0.32, P>0.5) in the pretest between the experimental group and the control group, but remarkable differences (F=27.30, P<0.001) in the posttest. Having applied the mobile, meaningful, learning strategy, the mean posttest of the experimental group appears as 88, obviously increased by 10, while the control group does not reveal any obvious differences on the posttest.

Differences in unit level learning outcomes with distinct instructional strategies

The analysis results of the differences in unit level learning outcomes with instructional strategies are organized in Table 5. On the posttest, the experimental group presents liver zone (92)>, spleen zone (89)>, lung zone (87)>, and cardiovascular zone (85), while the experimental group shows lung zone (80)>, spleen zone (77)>, cardiovascular zone (76)>, and liver zone (75). The spleen zone is the only one showing the same order.

4.5.3 Correlation analysis of meaningful learning and learning outcomes

The correlation analysis of meaningful learning and learning outcomes, organized in Table 6, present the correlation analysis of meaningful learning and learning outcomes of human blood circulation. Personalized shows the highest correlation at 0.780**, followed by constructive at 0.763**, while active appears the lowest at 0.584**. All dimensions in meaningful learning show significant correlations with learning outcomes.

Effects of learning styles on learning achievement

From the valid questionnaires, the experimental group's learning style scores are calculated. The four learning approaches score, as follows: a mean concrete

Table 4. Pretest and posttest ANCOVA of learning outcome

	Group	N	Mean	SD	Adjusted mean	Std. error.	F
Pretest	Experimental group	23	78	11	6.85	1.3	0.32^{ns}
	Control group	23	75	10	5.23	1.1	
Posttest	Experimental group	23	88	9	4.3	0.86	27.30^{***}
	Control group	23	76	12	5.11	1.2	

*** :p<0.001; ** :0.01; * :p<0.05

Table 5. Game level learning outcome analysis between experimental and control group

Unit level		Experimental group (grade)		Order	Control group (grade)		Order
		Pretest	Posttest		Pretest	Posttest	
Cardiovascular zone	Mean	75	85	4	78	76	3
	SD	11	9		10	11	
Liver zone	Mean	79	92	1	73	75	4
	SD	12	11		11	10	
Lung zone	Mean	80	87	3	79	80	1
	SD	10	10		12	11	
Spleen zone	Mean	78	89	2	74	77	2
	SD	11	8		9	10	

Table 6. Correlation analysis of meaningful learning and learning outcome

	Active	Authentic	Constructive	Cooperative	Personalized	LA
Active	1					
Authentic	.372*	1				
Constructive	.291	.794**	1			
Cooperative	.411*	.380*	.520**	1		
Personalized	.571*	.420*	.610**	.510**	1	
LA	.584**	.474**	.763**	.700**	.780**	1

LA (Learning Achievements)

Table 7. Effects of learning styles on learning achievement

Learning Style	Experiment Group		Control Group		Count	%
	Mean	SE	Mean	SE		
Concrete experience (CE)	91	6.3	83	9.2	30	65
Reflective observation (RO)	84	9.4	78	10.4	5	11
Abstract conceptualization (AC)	81	8.3	77	9.3	3	6
Active experience (AE)	85	7.2	81	8.5	8	18
(AE－RO)	0.76	6.8				
(AC－CE)	0.24	7.42				

experience of 91, with a standard deviation of 6.3; a mean reflective observation of 84, with a standard deviation of 9.4; a mean abstract conceptualization of 81, with a standard deviation of 8.3; and a mean active experience of 85, with a standard deviation of 7.2. Two learning style-scaled scores present a mean active experience－reflective observation（AE－RO）0.76, a standard deviation 6.80, and a mean abstract conceptualization－concrete experience（AC－CE）0.24 with a standard deviation 7.42, Table 7.

From Table 7, the learning approaches (CE, RO, AC, and AE) of the tested samples score about 100, without larger differences, presenting the balanced learning approach of the participants. Regarding the in-group variance of the four learning approaches, concrete experience (CE) appears to be the smallest and abstract

conceptualization (AC), the largest. Overall, the variance of the four learning approaches is not large, revealing the small differences among the tested students and the high homogeneity of learning styles of the sampled students. In terms of the distribution of the participants' learning styles, 65% are divergers, 11% assimilators, 6% convergers, and 18% accommodators. In this case, the order of population percentage shows diverger, accommodator, assimilator and converger, Table 7. Based on One-way Analysis of Variance, Table 8 shows that a different learning style could notably affect the awareness of a learning achievement, F=5.946, p=.000<.001, reaching a significance of .05, with post comparisons, P1(Diverger) > P2(Assimilator), P3(Converger), P4(Accommodator).

Divergent and accommodation learning styles cover 65% of the tested samples. According to Kolb's Learning Styles Theory, divergent learners prefer concrete experience and reflective observation, while accommodation learners prefer concrete experience and active experience. From the two dimensions in learning styles, both divergers and accommodators tend towards concrete experience in receiving information and prefer receiving it through the senses. According to Piaget's cognitive-development stages, G8 students are at the concrete operational stage, in which practical operation experiences replace abstract conceptualization thinking in the learning. The research results conform to the cognitive development learning theory. G8 students present rich creativity and imagination. The research results reveal that 65% of the participants with divergent learning styles have the characteristics which conform to the developmental characteristics of children at this stage. The research results further verify the favorable reliability and validity of Kolbs' Learning Styles Scale.

CONCLUSION AND SUGGESTION

Conclusion

Kolb's four learning styles are classified according to the learner's learning experiences; divergers prefer concrete experience and reflective observation; assimilators prefer reflective observation and abstract conceptualization; convergers prefer abstract conceptualization and active experience; and accommodators prefer concrete and active experience. Each type of learner presents a learning preference. Therefore, a meaningful mobile learning system was proposed in this study, through quasi-experimental design, to understand what assistance the mobile meaningful learning system offers to a student's learning

Table 8. ANOVA learning achievement of learning style with post compares

Level	Mean	SD	Count
P1= (Diverger)	91	6.3	46
P2=(Assimilator)	84	9.4	46
P3=(Converger)	81	8.3	46
P4=(Accommodator)	85	7.2	46

Source of Variation	SS	DF	MS	F	Compare
Between	8.204	3	2.735	5.946***	P1>P2
Within					P1>P3
					P1>p4
Group	136.267	45	2.781		
SD	67.609	147	0.460		
Total	212.089	199			

*n.s. no Significant p>.05 * P≦0.05 ** P≦0.01 *** P≦0.001*

outcome (Table 2). The experiment also proves the assistance of such a system in teaching the blood circulation system lesson, and the significant differences in distinct learning strategies. What is more, the mobile meaningful learning system is utilized for understanding the units and promoting the learning outcomes (Table 4). This study also reveals the positive correlations between meaningful learning and learning outcomes.

The research results disclose no remarkable difference between learning styles and meaningful learning, showing various factors in meaningful learning, but not including learners' learning preference; meaningful learning with distinct learning styles does not differ and they have no effect upon each other. Research in the area of curriculum design, aiming at learning styles and meaningful learning was not done. The results of this study, therefore, could be a point of departure for future research.

1. Differences of student learning outcomes in the blood circulation lesson

The learning assessment can be automatically collected through the system, thus, allowing for an analysis of a student's learning outcomes at various unit levels of circulation in the cardiovascular zone, circulation in liver zone, circulation in lung zone, and circulation in spleen zone. It is worth noticing that the research subjects in this study, both in the experimental and control group, present the spleen zone in the second order of the unit learning outcomes, while the rest appear in a different order. It also shows different media performance on the learning contents designed with MMBCLS: rich media design correlates with better learning outcomes. The experimental group shows the unit level result of the liver zone (92)>, spleen zone (89)>, lung zone (87)>, and cardiovascular zone (85), where the design contents in the liver zone include more challenges and game characteristics. As a result, it would appear that there is a correlation between the outcome of game-based learning and the number and function of game characteristics invested into the game.

2. Correlations between meaningful content design and learning outcome

The five learning dimensions for meaningful learning show positive correlations with learning outcomes, with personalized having the highest correlation of 0.780**, followed by constructive with 0.763** (Table 6). It shows that meaningful content design should put more emphasis on students' levels and that more adaptive learning designs should be required for the students with distinct levels, so as to acquire more learning satisfaction. Furthermore, a constructive 0.763** also indicates that the student learning material design should correlate to students' prior learning, so that new units are gradually integrated. By drawing from their previous experiences, students could then reduce the amount of time consumed in tangential explorations. It conforms to Vosniadou and Brewer's comprehensive model, which regarded students' daily experiences as the initial model, turning to a comprehensive model and further to a scientific model. In other words, knowledge is the continuous acquisition of new mental correlations.

Research implications and suggestions

1. Understand students' learning styles to develop distinct course activity designs

Each student has an independent and distinct learning style, and the unique composition of learning styles in any given class is different from that of any other. In deference to individual learning styles and in order to avoid teachers' treating all students with a single methodology, negating the maximization of individual student potential, teaching practitioners could organize students' learning styles into files for instructional reference.

2. Design various teaching strategies to cultivate students' integration of different learning styles

According to the research results, most G8 students present divergent and accommodative learning styles and prefer the learning approaches of concrete experience and reflective observation. It reveals a lack of learning experience in abstract conceptualization and active experience in the learning process. Teachers could reinforce their teaching strategies and increase the meaningful instructional activity contents to inspire students' learning potential. Teacher's guidance allows students, gradually, to become active learners, rather than passive recipients.

3. Importance of multimedia interactive teaching aids

The human body cannot actually be explored, internally. Essentially, the traditional teaching material was specific, but the functional operations of various parts of the human body could not be easily comprehended. Virtual 3D multimedia allows it to become specified, visualized and explored to assist students by attracting their attention. It is suggested that the convenience and interaction of mobile learning be promoted, because such technology-integrated instruction is expected to enhance students' overall learning achievement.

4. Meaningful and appropriate material design

The learning activities in this study were designed to reflect the five dimensions of meaningful learning, and several game-based learning concepts are included to stimulate students' absorption (conflict, competition, challenge, opposition, award, representation and story, and curiosity), so that the learning of biology is no longer dull and the instructions become diversified, vivid and more suitable for students' learning.

***Role of teacher*:** In meaningful instructional strategies, teachers play the role of constructing and guiding learning activities, assisting in team cooperation, and interpreting materials. Teachers have to design creative lesson plans, construct adaptive materials, plan materials clearly to be systematic and in stages, and guide and concisely interpret for students.

***Role of students*:** In the rote method of instruction, students become passive receptacles of knowledge. Such a teaching approach is obviously deleterious, because, in point of fact, students must learn to play the role of active learners. That is, despite the fact that course contents are narrated by teachers, students have to pay attention to the lessons, understand the meaning of the materials, try to internalize the lesson, and turn their prior experiences and knowledge into self-understandable structured knowledge. Such a process requires that students actively invest in their learning. Ausubel (1963), therefore, considered that such receptive learning could be turned into personal knowledge. Nonetheless, such a learning approach is not automatically generated by students; instead, it relies on the instructional design and guidance of teachers, so that students may actively and completely understand the learning outline.

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