Augmented Reality to Teach Human Heart Anatomy and Blood Flow

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ABTRACT
This research aimed to develop the augmented reality (AR) in teaching human heart anatomy and blood flow has been designed and developed an AR to study the anatomy of the heart. The AR was evaluated by five experts, who analysed its content consistency by using the Index of Item Objective Congruence (IOC). The content was rated at 0.8. Simultaneously, via Diffusion of Innovation (DOI), the arithmetic mean was determined to be 4.04 with the standard deviation of 0.35; indicating that the AR can be used for publicizing the innovation at a high level. Subsequently, diffusion of the AR teaching tool was tested by sample group of thirty students. These subjects were evaluated pre-test and post-test by the five experts via the content validity index (CVI), with a score of 0.83. Furthermore, when the learning results of the sample groups was evaluated after the training, it showed that the learning result received higher ratings when compared with the ratings prior to using AR tool. The before and after AR learning results were for statistical significance at p value < 0.001 with the use of a T-Test. Then, the effectiveness of the tool was evaluated by users focusing on the acceptance of the AR for teaching the anatomy of the heart; the evaluation of which was based on the theory of Unified Theory Acceptance and Use of Technology (UTAUT) in which the results of the arithmetic mean and the standard deviation were 4.38 and 0.49, respectively. It showed that the users generally accepted the AR for teaching about the heart at a high level. Moreover, when there was a comparison of the learning results of the thirty students who learned about the heart from using hardcopy media, pictures, and videos, and the thirty students using the AR received better scores. The learning results of the two sample groups, tested by the statistical test called T-Test, were statistical significant at p value < 0.001. Hence, it could be concluded that, the AR for teaching heart function can promote more effective learning proficiency while being unanimously accepted by the users.

KEYWORDS: Augmented Reality, Human Heart, Teaching, Biology.

INTRODUCTION

The use of modern learning tools in education assists instructors in improving their quality of teaching, and thus improve the educational experience of the students. Modern technology helps in the production of multifunction and userfriendly media, which assists in developing the learners' proficiency in all aspects (Kaufmann, 2013). The learners tend to understand the content via memorization of pictures and gain visual perception.

Biology, as one important knowledge to learn, being the science of living organisms and consisting of a wide range in content detailing molecular, cellular, and ecological factors. This leads the learners to have a negative attitude towards the subject. Moreover, the teachers might use the methods or media that cannot promote learning. There is a lot of knowledge content to learn, however the fundamentals of biology could be considered the most important in the human body, particularly with the heart and blood system, that is the center of this learning content.

Humans are multicellular living organisms. They made of many tissues, organs and complex systems. The heart is one of many vital organs, supplying nutrients and oxygen by continuously circulating blood to other organs. Any abnormality within the heart can be fatal. Heart disease is one of the main causes of death among the Thai population with the average death rate of one per seven people, annually. Thus the heart, its structural characteristics, and its functions, should be well studied. Generally, the visual presentation of living organism organs can help the learners in better understanding (Jiravarapong, 2010). Heart's shape and function as an internal organ is difficult to illustrate to students. Most textbooks and other resources presented in two

dimensional images in which its characteristics or functions cannot be clearly seen (Tieranabunjong, 2001). Therefore, this potentially affects the proficiency of the learners. Thus, an appropriate form of instructional media can be a good choice for effectively enhancing a student's perception in learning about the heart and blood system.

Computer software can be good instructional media to promote higher efficiency in learning by facilitating the data processing system and the presentation of information, pictures, sound, and messages effectively. For example, virtual technology (Augmented Reality: AR) is one of the innovations that can be applied to the area of education to stimulate, support, and promote learning experiences (Volkan, Bradford & Ruzena, 2016) Lin et al. (2011). In this regard, Izzurracmanhas used virtualization technology applications in chemistry. The chemical bonds with 3D models which allowed students to learn the chemistry fast and easy with the use of the graphic and imaginative content (Izzurrachman, 2012). Ditcharoen et al. used virtualization technology to facilitate the learning of atomic structure and chemical bonding, improving the accuracy and speed of learning when compared with traditional classroom lessons using twodimensional images (Ditcharoen, Polyiam, Vangkahad & Jarujamrus, (2014). Kiourecidou et al has developed a web application which enhances the user's medical knowledge with regard to the anatomy of the human heart by means of augmented reality which helped increase understanding and experiential learning methods aiding online education of anatomy courses (Kiourexidou, Natsis, Bamidis, Antonopoulos, Papathnasion, Sgantzos & Veglis, 2015).

This paper presents the development the AR to teach the human heart anatomy and blood flow, especially the functioning of the heart, with the use of Android operating system which is available on smartphones and tablets. It can assist the students and the interested people in studying about the human body with visual aids and without limitations in location. The tool can enable the students to gain more knowledge and understanding, and ultimately increase their interest in the subject. This study also aims to increase the learning potentiality for the learners to catch up with the digital era. In addition, it can reduce the longterm expenses and contribute to the learning society that stimulates, supports, and promotes education through media. It may also further expand the proficiency of the learners.

METHODOLOGY

The research methods for studying the development of the augmented reality to teach the human heart anatomy and blood flow include the following steps:

1. Preparation of questionnaires and the pre-test and post-test.

1.1 The questionnaires for sample selection were evaluated by five experts who were specialized in the field of information technology and biology using the analysis of Index of Item Objective Congruence (IOC to measure the appropriate sampling of the content validity of items in a questionnaire or at the item development stage.) (Turner & Carlson, 2002) by which the experts to provide scores. If the criteria determined by the IOC value of each indicator was higher than 0.5 (the highest IOC value is 1), it means the questionnaires met the objective, possessed content suitable for educational purposes, and that the questionnaires worked effectively. The IOC value of each indicator was 0.8, indicating that the questionnaires met the objective in content consistency and is suitable for use in sample selection.

1.2 The research team had developed the pre-test and post-test to obtain learning results. The tests had passed the content validity index: CVI (CVI using ratings of item relevance by content experts. which an instrument has an appropriate of the content domain of items for the construct being measured and is an important procedure in content validity of development for questions.) (Polit & Beck, 2008) evaluated by the five experts from the assessment of CVI evaluated by all the experts, it was determined that the CVI value was 0.83 as there were ten questions out of twelve questions receiving the scores at 3 or 4. As the result was higher than 0.8 (the highest CVI value was 1), ten questions had passed the CVI. Pre-test questions 1-5 are related to human heart anatomy and question 6-10 related to blood flow. post-test questions had the same questions as the pre-test, but the order of questions and the answers were changed. IOC value by using the formula as shown in the equation.

$$CVI = \frac{Nc}{N}$$

Nc is the sum of the scores that the experts rated.

N is the number of the experts.

T
he experts were able to rate by using the assessment criteria as in Table 1.

Table 1: The rating criteria for the CVI

Rating criteria	Meaning
4	Very consistent: Can be used to test.
3	Quite consistent: Can be used to test.
2	Some consistent: Can be used to test.
1	Not very consistent: Can not use the test

2. Demographic survey and sample selection. The research team surveyed the need for training and the qualification questionnaire for students who wanted to attend primary school in Bangkok Metropolitan Region. The deadline for submitting the survey is 1 month. Research has defined sampling criteria. Selected samples were 30 primary schools.

3. Documentary Research. The analysis and the data collection on human heart function were performed by the research team by reviewing related theories and previous studies on human function. The human heart is comprised of four chambers (Noonchu, 2016): 1) The chamber on the top right (Right Atrium) 2) The chamber at the bottom right (Right Ventricle) 3) The chamber on the top left (Left Atrium) 4) The chamber at the bottom left (Left Ventricle). The human heart anatomy and blood flow such as heart components, heartbeat and the circulation of blood is shown in Figure 1.

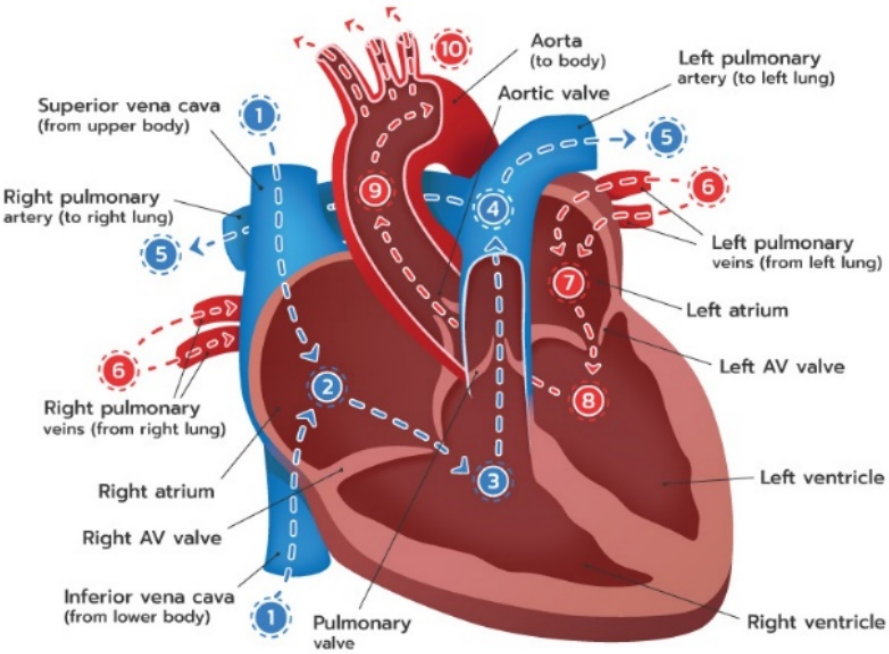


Figure 1: The human heart anatomy and blood flow

4. The design, development and implement the augmented reality to teach human heart anatomy and blood flow. 4.1 Based on collected information about human heart function, the heart components, heartbeat, and the blood circulation, the AR model was constructed and installed in the system (Noonchu, 2016). The subjects were able to use their smartphones or tablets to scan the images used for enhancing the memorization process on the heart structure. After scanning, the heart structure showed up in the form of 3D picture. The flow chart illustrating the design of the AR showed in Figure 2.

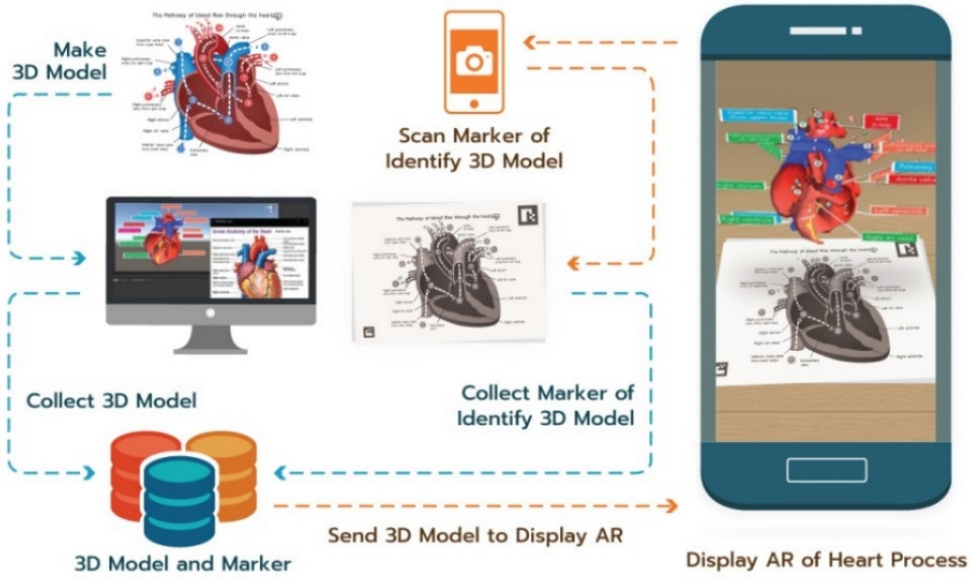


Figure 2: The Design of the augmented reality to teach the human heart anatomy and blood flow

4.2 Based on the design of the augmented reality to teach the human heart anatomy and blood flow, the information about the heart components, the heartbeat and the blood circulation in each chamber were used for constructing the model of the AR as a tool to teach about the heart anatomy (Dreamstime, 2016) show in Figure 3

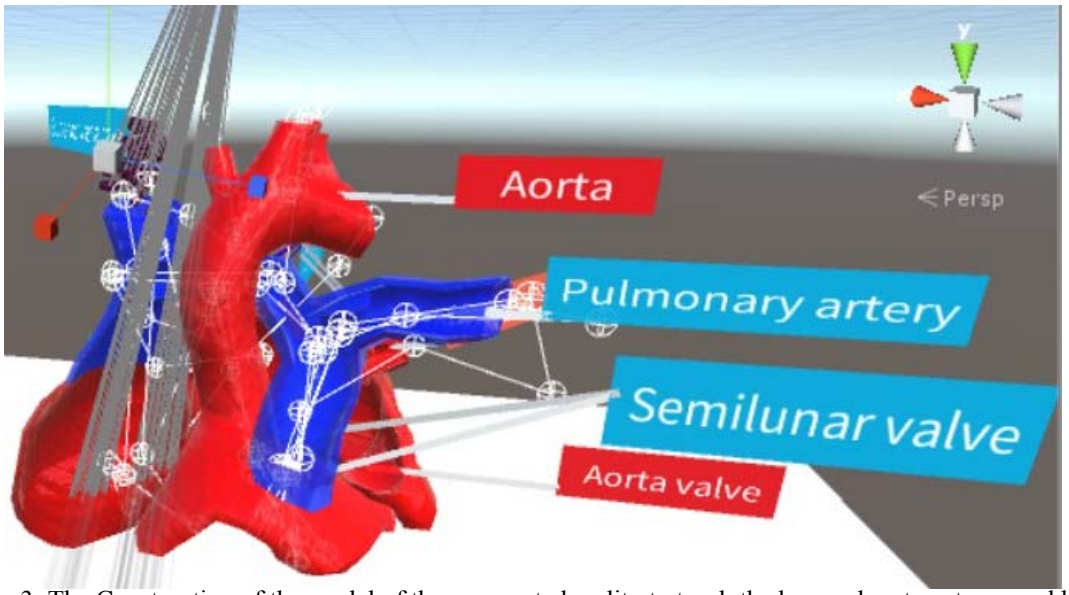


Figure 3: The Construction of the model of the augmented reality to teach the human heart anatomy and blood flow

4.3 Subsequently, there was a construction of the contents promoting memorization skills by linking pictures together into the model of a heart. The users could use the AR via smartphones or tablets with a scanning application to scan the heart pictures for virtual memorization the structure, the heartbeat in each chamber, the blood circulation, and other functions of each chambers show in Figure. 4

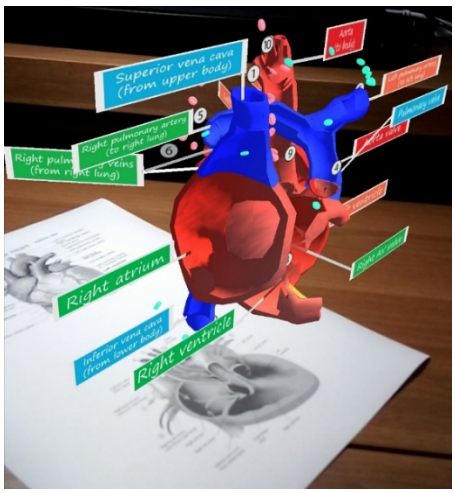


Figure 4: Display 3D of the augmented reality to teach the human heart anatomy and blood flow

4.4 The effectiveness of the augmented reality to teach the human heart anatomy and blood flow was evaluated by five experts who specialized in the field of information technology and biology. The evaluation used content consistency (IOC) to give scores. If the criteria determined by the IOC value of each indicator was higher than 0.5 (the highest IOC value is 1), it means the AR met the objective, possessed content suitable for education purposes, and therefore, the AR worked effectively. The IOC value of each indicator was 0.8, indicating that the developed AR met the objective and is suitable for using in education about the heart. The experts were able to rate by using the assessment criteria as in Table 2.

Table 2: The rating criteria for the content consistency

Rating criteria	**Meaning**
+1	sure that there is content consistency and it can work
0	not sure that there is content consistency and not sure if it can work
1	sure that there is not content consistency and it cannot work

Subsequently, take the information from the consideration of the experts and find IOC value by using the formula as shown in the equation:

$$IOC = \frac{\Sigma R}{N}$$

ΣR is the sum of the scores that the experts rated.
R is the score that the experts rated.
N is the number of the experts.

4.5 Subsequently, the experts also used the diffusion of innovation theory (DOI) (Roger, 1995) to evaluate five parameters, 1) more advantageous or have better performance, 2) usability, 3) noticeability, 4) consistency with the demand or experiences of the learners who would potentially adopt the innovation and 5) the result of which could be shown in advance (Agarwal & Prasad, 1997). It was necessary to find out if the innovation could be adopted by the sample group (Chaveesuk & Jaturapa, 2012). The data was analysed to find the mean value and the standard deviation value in order to assess the innovation dissemination of the AR to teach about the heart according to the scoring criteria of Likert Scale to rate the DOI form as shown in Table 3.

Table 3: The scoring criteria of the DOI form

Scoring Criteria		Meaning
Quantitative	Qualitative	
4.51 - 5.00	the highest	The AR can be published at the highest level
3.51 - 4.50	the high	The AR can be published at the high level
2.51 - 3.50	the medium	The AR can be published at the medium level
1.51 - 2.50	little	The AR can be published at the little level
1.00 - 1.50	the least	The AR can be published at the least level

The evaluation results of the DOI in all five aspects evaluated by the experts were: 1) the arithmetic mean and the standard deviation of "more advantages or better performance" were 4.00 and 0.00, respectively. It showed that this criterion was rated at a high level. 2) The arithmetic mean and the standard deviation of "usability" were

4.20 and 0.45, respectively. It showed that this criterion was also rated at a high level. 3) The arithmetic mean and the standard deviation of "noticeability" were 3.80 and 0.45, respectively. It showed that this criterion was rated at a high level. 4) The arithmetic mean and the standard deviation of "the consistency with the demand or experience of the subjects who would potentially adopt the innovation" were 4.20 and 0.45, respectively. It showed that this criterion was rated at a high level. 5) The arithmetic mean and the standard deviation of "the result which could be shown in advance" were 4.00 and 0.00, respectively. It showed that this criterion was rated at a high level. The arithmetic mean and the standard deviation of the overall image of the innovation dissemination were 4.04 and 0.35, respectively. It showed that the augmented reality to teach the human heart anatomy and blood flow was accepted to be used at a high level.

4.6 The dissemination of the augmented reality to teach the human heart anatomy and blood flow to Samples. The research team tested the augmented reality to teach the human heart anatomy and blood flow with 30 students. The students were at elementary level. Research Permission was obtained prior to the study. Training was provided via a lecture and workshop presentation (Nuanmeesri & Jamornmongkolpilai, 2018) to use the AR tool.

5. The evaluation of the effectiveness of the augmented reality to teach the human heart anatomy and blood flow.

5.1 Before being trained, the sample group had to finish ten question pre-test . Subsequently, they would enter the training session with the AR. It took three hours. After the training, the subjects did the post-test. After collecting the post-test, the trainers provided the subjects with the correct answers. Completed tests were assessed, scores recorded, and data analysis were performed by using the T-Test to find comparisons between the pre-test and post-test learning results. Moreover, when there was a comparison of the learning results of the thirty students (control group) who learned about the heart from the use of hardcopy pictures and videos, and the thirty students using the AR by using the T-Test.

5.2 To evaluate the effectiveness of the augmented reality to teach the human heart anatomy and blood flow based on the unified theory of acceptance and use of technology (UTAUT is a technology acceptance model for user feedback of information technology: Toward a unified view. The UTAUT aims to explain user acceptance, decisions and intentions to use technology.) (Chaveesuk, & Jaturapa, 2012). The research team developed a questionnaire on the acceptance of the AR to teach the sample group about the heart and evaluate the four aspects of the tool which are: 1) the anticipation on the performance, 2) the anticipation on the effort, 3) the social influence, and 4) the condition of facilities in the application. There were two questions for each aspect in the test. Subsequently, the data was analysed to find the arithmetic mean and the standard deviation values to determine the assessment effectiveness on the acceptance of the AR according to the scoring criteria of Likert Scale to rate the UTAUT form as shown in Table 4.

Table 4: The scoring criteria of the UTAUT form

Scoring Criteria		Meaning
Quantitative	Qualitative	
4.515.00	the most	The user has the most acceptance
3.514.50	much	The user has the much acceptance
2.513.50	moderate	The user has the moderate acceptance
1.512.50	little	The user has the little acceptance
1.001.50	the least	The user has the least acceptance

RESULTS

1. The result of the data analysis of the sampling group, the sampling group who were used in this research was sixty persons. The profile of the survey respondents was established from the demographics section of the survey with the following general information shown in Table 5 and Table 6.

Table 5: Sampling Group Demographics

Gender	**n**	**Percent**
sampling group		
Male	18	60%
Female	12	40%
control group		
Male	16	53.33%
Female	14	46.67%

Table 6: The scoring criteria of the satisfaction evaluation form

Age	n	Percent
sampling group		
below 13 years	25	83.33%
equal or more than 13 years	5	16.67%
control group		
below 13 years	23	76.67%
equal or more than 13 years	7	23.33%

2. The Test Results of the augmented reality to teach the human heart anatomy and blood flow. The pre-test and post-test results after training, using the augmented reality to teach human heart anatomy and blood flow revealed that the post-test results of the sample group after training was better than their pre-test results. The results were analysed by comparing the number of the students who could answer the questions correctly with their individual results. The learning results showed that the subjects had more correct answers after the training. The comparative test results collected before and after the training, showed that there was a statistically significant difference at the level of 0.05 according to the statistical test of the following hypothesis:
The hypothesis was assumed as followed:

H0: The learning result before and after using the AR were not different.

H1: The learning result before and after using the AR were different.

Statistically tested by T-Test, the main hypothesis (H0) was rejected because the significance value was lower than the significance level (α) which was previously determined. In this study in which $\alpha = 0.05$, the H0 was rejected and the H1 was accepted. The efficiency of the developed model was different in their methods. From the table of the pair sample testing, the significance value was analysed to consider whether the mean values of the two groups were different. In fact, it was found that the significance value was lower than the predetermined significance value. Therefore, the mean values of the two groups were different. Considering the comparative differences of the learning results both before and after the use of the AR, it was found that the statistical significance p value < 0.001.

Subsequently, the learning results were assessed by comparing the scores between the post-test results of the thirty students (control group) who had learned about the human heart from the hardcopy media, pictures, and videos and the post-test results of the thirty students that had learned using the AR. The learning results of the sample group that used the AR were clearly better than the sample group that learned from the use of hardcopy media, pictures, and videos show in Figure 6. It was found that there were differences at the statistical significance level of 0.05 according to the statistical test of the following hypothesis:
The hypothesis was assumed that:

H0: The learning results of the subjects who learned from hardcopy media, pictures, and videos and the subjects who learned via AR were not different.

H1: The learning results of the subjects who learned from hardcopy media, pictures, and videos and the subjects who learned via AR were different.

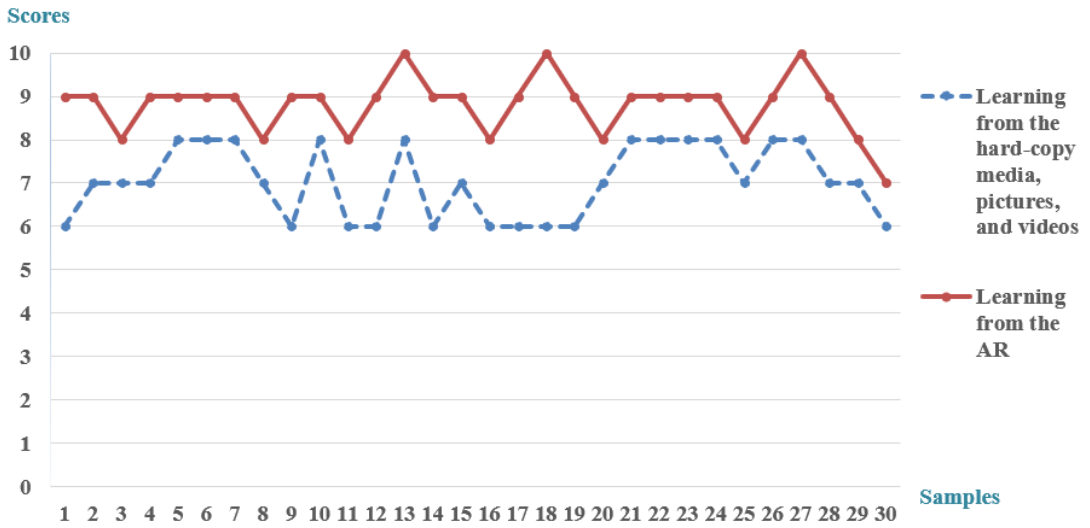
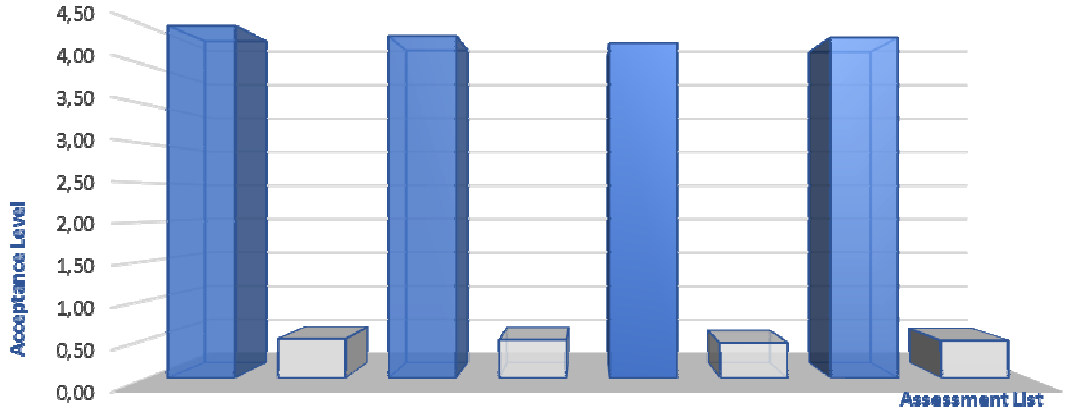


Figure 6: Comparing the scores between the post-test results of the thirty students (control group) who had learned about the human heart from the hardcopy media, pictures, and videos and the post-test results of the thirty students that had learned using the AR

Statistically tested by T-Test, H0 was rejected because the significance value was lower than the predetermined significance level (α). In this study, it was determined that $\alpha = 0.05$, so the H0 was rejected while the H1 was accepted. The efficiency of the developed models was different in their methods. From the Table of the Pair Samples Testing, the significance value was analysed to consider whether the mean values of the two groups were different or not. In fact, it was found that the significance value was lower than the predetermined significance value. Therefore, the mean values of the two groups were different. the comparative differences of the learning results before and after the use of AR, were different at the statistical significance of p value < 0.001.

3. The evaluation results of the acceptance and the use of the augmented reality to teach the human heart anatomy and blood flow. The results of the acceptance and the use of the augmented reality to teach the human heart anatomy and blood flow were evaluated in four aspects which were: 1) the anticipation of the performance; its arithmetic mean was 4.50 and the standard deviation was 0.50which showed that the acceptance of the performance was rated at a high level; 2) the anticipation of the effort; the arithmetic mean was 4.37 and the standard deviation was 0.49. It showed the anticipation of the effort was rated at a high level; 3) the arithmetic mean and the standard deviation of the social influence were 4.28 and 0.45, respectively. It showed that the social influence was accepted at a high level. 4) The arithmetic means and the standard deviation of the condition of facilities for the application were 4.35 and 0.48, respectively. So, the acceptance of facilities in application was rated at a high level. The overall image of the evaluation effectiveness results on the acceptance of the users in regard to the AR had the arithmetic mean value of 4.38, and its standard deviation was 0.49. this revealed that the users accepted the augmented reality to teach the human heart anatomy and blood flow at high level show in Figure 7.



	The Anticipation on the Performance		The Anticipation on the Effort		Social Influence		The Condition of the Facilities during the Application	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Results	4,50	0,50	4,37	0,49	4,28	0,45	4,35	0,48

Figure 7: The evaluation results of the acceptance and the use of the augmented reality to teach the human heart anatomy and blood flow

CONCLUSION AND DISCUSSIONS

In this research, the augmented reality (AR) to teach the human heart anatomy and blood flow. It was evaluated by five experts who had the experiences in teaching and researching about the virtual biological technology using the content consistency analysis (Index of Item Objective Congruence: IOC). The IOC value of each content was 0.8. The results indicated that the constructed AR was consistent with the objective and correspondent with the anatomy of the heart. The results with the arithmetic mean valued at 4.04 and the standard deviation at 0.35. clearly showed that the AR was accepted for the dissemination at a high level. Furthermore, the results of the study showed that the students who used the AR got better understanding than those who used other media for learning at the statistical significance of p value < 0.001. Comparing the learning results of sample group base on the post-test with control group (learned about the heart with hardcopy media, pictures, and videos) showed that the learning results of the sample group were better than the control group at the statistical significance of p value < 0.001. Correspondingly, there are four aspects of the effectiveness evaluation focusing on the acceptance of the AR as a tool to teach about the human heart measured by the theory of Unified Theory Acceptance and Use of Technology (UTAUT). The overall image of the effectiveness assessment results on the acceptance of the users was rated at a high level as the arithmetic mean and the standard deviation were 4.38 and 0.49, respectively. To conclude, the development of the augmented reality to teach human heart could contribute to the effective learning process and better results in understanding. Finally, it could increase the proficiency of the learners.

The augmented reality to teach the human heart anatomy and blood flow: from the research result, it showed that the virtual technology helped in disseminating and promoting the learning which caused the learning to be easier and also quicker to understand. It promoted the participation and the creation of imagination which was correspondent to the research work of Lin et al. (2011), Izzurrachman (2012), Ditcharoen et al. (2014). Kiourexidou et al. (2015). In the near future the augment reality and virtual technology will not be limited only to the creating of interest but also to be a part of the elaboration of knowledge, the survey exploration, and the collaborative learning which were also correspondent to the learning of this century.

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