The Effects Of Design-Based Learning In Teaching Augmented Reality For Pre-University Students In The ICT Competency Course

Ahmad Alif Kamal, Syahrul Nizam Junaini

Abstract:— Recent advances in learning approaches and technology made the teaching and learning process became more complex. While many researchers have examined the capabilities of empowering student learning and AR for the purpose of teaching and learning, quantitative evidence for its impacts is still scarce. To contribute to filling this research gap, we applied a two times post-test and collected an instructional materials motivation survey with 280 participants at a pre-university center to measure the effectiveness and motivational impact of design-based learning approach on acquiring practical AR knowledge in an immersive learning experience. We hypothesized that students gained more knowledge and interest on AR by participating in DBL. The theoretical rationale for our hypothesis is that DBL experiences promote higher order thinking skill and informal learning to happen. The empirical results we obtained show that students performed better academically and provided positive feedback in terms of motivation and interest.

Index Terms:— classroom technology practices, computer education, immersive participation, learning strategies

1 INTRODUCTION

Augmented reality (AR) is mainly known in the field of entertainment. This emerging technology is proven to be advantageous in the education field. The potential of incorporating AR into teaching practices had been studied in detail by researchers [1]. Implementing AR in education increases in the level of academic achievement [2], [3], by facilitating the teaching and learning process [4] as well as ensuring fun in learning [3], [4], [5]. However, the number of studies to examine the effect and impact of AR in education has yet to be suffice in embracing the age of Industrial Revolution 4.0 [6]. The full potential of AR in education is yet to be discovered, with the amount of study and research being scarce [7]. Other than that, there are issues arises in the suitability of content to be incorporated with AR to align with curriculum and pedagogy, as well as whether it is worth it to convert the content and invest into AR [8]. It is also reported that there are difficulties in terms of technicality in implementing AR for teaching [9]. The aim of this study is to measure the effectiveness and impact towards motivation in learning AR of a learning approach named design-based learning. From this, we come up with a hypothesis, that is can the teaching and learning method stated above, that is design-based learning, has a significant effect on pre-university students in learning and applying AR technology? To test this hypothesis, two research questions were raised, 1) what is the effect of design-based learning method in teaching augmented reality, AR for the pre-university students in the ICT Competency course, and 2) what is the impact of design-based learning towards students' motivation and interest in learning augmented reality technology as a part of the ICT Competency course?

- *Ahmad Alif Kamal is a lecturer at Centre for Pre-University Studies, Universiti Malaysia Sarawak, Malaysia. Email: kaalif@unimas.my*
- *Syahrul Nizam Junaini is a senior lecturer at Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak, Malaysia. Email: syahruln@unimas.my*

The remainder of this paper is as follows. First, a literature review on the background of AR and design-based learning. Next, the methodology which includes the research design and instruments is outlined. Then, the findings are recorded and analyzed. Finally, the summary of implications of the study and opportunities for further potential research.

2 LITERATURE REVIEW

2.1 Teaching of STEM courses

Issues have always been raised on how to improve the effectiveness in teaching science, technology, engineering and mathematics (STEM) courses. One issue highlighted on STEM is the difficulties in not only to attract but also retain the human capital [10]. The retention of STEM students' motivation is one of the challenges faced when they move from school into higher education especially in Malaysia [11]. Student-centered learning such as problem-based learning (PBL) is one of the many methods studied and employed to overcome some of the issues. PBL is stated to empower the process of learning by promoting motivation and creativity among learners [12], the key to attract future generations to pursue their studies in STEM fields. In addition, PBL have many other forms such as case-based learning, inquiry-based learning and many more in which an instructor can select the most suitable method accordingly [13].

2.2 Augmented reality in education

AR can strengthen teaching and learning process in universities. It is studied that the process of learning becomes highly satisfactory with the implementation of AR [14]. Due to its attractiveness, implementation of AR in educational activities is growing in popularity. This technology also offers exploration and simulation activities and its interactive nature can increase motivation, encourage active learning, provide beneficial experiences and promote student-centered learning [15]. A more innovative way of implementing AR is by making it a part of blended instructional strategies [16]. With the advancement of technology, the usability of AR into mobile devices especially smart phones has become easier, enabling more innovative techniques and tools to be implemented in teaching and learning process, but there are still more technical difficulties that need to be addressed [9]. By integrating AR technology into learning process really help to enhance lower order thinking skills by providing engaging experiences [17], but simply using it will not enable the learners to improve higher order thinking skills and their motivation as well as interest in the topic [18]. AR provides convenient and immersive experience for the students. Through augmented video or 3D animation, they have extended access to the learning content in many subjects such as engineering [19], chemistry [20], and mathematics [21].

2.3 Design-based learning

Design-based learning (DBL) is one of the forms of problem-based learning, with the focus of the learners taking on a task or assessment to design a solution for a given problem [13]. The solutions range from multimedia products, online or offline applications and tools. One example of DBL is an assessment to design and develop online instructional module. By taking part in the designing process, the learners receive positive impacts in the topic and subject matter [22]. Among the benefits include improvement of collaborative problem-solving skills, science process skills and self-confidence [23].

2.4 Design-based learning incorporating augmented reality

For this research, the assessment for the students in the ICT Competency course is set to implement DBL to help them learn both the content of the course itself as well as the skills needed to apply the content knowledge in new situations. The students' task was the development of AR learning materials that address their core science courses which are biology, physics, chemistry or mathematics. By going through the whole process of design and development, they are hoped to achieve the mastery of contents for the ICT Competency course, which is the AR technology, and, a better understanding of their core courses of choice as well. By nature, DBL can promote self-directed learning, hence, increasing motivation and interest towards all the subject matter involved [24]. Moreover, DBL that incorporates the AR technology promote higher order thinking skills [18]. In pre-university, a course named ICT Competency is taken by all students as one of the generic courses. Within the learning units, AR is one of the contents highlighted in the learning unit called “trends and emerging technologies”. However, learning new and difficult concept such as AR has caused problems among the students, which effects their results and morale in learning. Furthermore, learning process of exposure and using AR learning materials are found only able to promote lower order thinking skills [18]. If implemented correctly, AR should increase students' motivation and interest towards learning as it offers exploration and simulation activities [15].

3 Methodology

In this project, the students undertaking the course named ICT Competency participated in the DBL as a part of their continuous assessment. There is a total of 280 students that participated in this study.

3.1 Research instruments and data analyses

To answer the research questions stated, two instruments were used, which are 1) two post-tests, and 2) an Instructional Materials Motivation Survey (IMMS). Firstly, the post-test was used to measure the effectiveness of DBL. This post-test is divided into two sections of 10 questions per section. The first section addresses lower-order thinking skill (LOTS) and the second section addresses higher-order thinking skill (HOTS). The two post-tests produced two sets of data for both the LOTS and HOTS sections, analyzed using paired t-test. IMMS data was collected to measure the students' motivation, interest and receptacle towards AR technology and learning experience [25] data through a self-reporting mechanism. The IMMS has many variations. For this study, the original version consisting of 36 statements with 5-point Likert scale each was used to evaluate learners' attention, relevance confidence and satisfactory level (called the ARCS model) towards the learning instruction, process and materials [26]. The 36 statements belong to either one of the ARCS model factors as shown in Table 1. By answering the statements presented in this questionnaire, the student experienced a journey of making a self-reflection with the guidance of the statements to focus on specific criteria. The IMMS collected from the students is then analyzed using descriptive statistics.

TABLE 1
IMMS Scoring Guide for All 36 Statements [27]

Attention	*Relevance*	*Confidence*	*Satisfactory*
2	9	1	5
8	6	3 (reverse)	14
11	10	4	21
12 (reverse)	16	7 (reverse)	27
15 (reverse)	18	13	32
17	23	19 (reverse)	36
20	26 (reverse)	25	
22 (reverse)	30	34 (reverse)	
24	33	35	
28			
29 (reverse)			
31 (reverse)			

The numbers in each cell indicates the statement number in the IMMS

3.2 The design for DBL

There were 3 phases involved in conducting DBL; planning, implementation and evaluation.

3.2.1 Planning phase

The students attended a mini lecture session on the augmented reality topic and took their first post-test. Then, together with the instructor, the students performed a needs analysis among themselves to determine their AR project title to improve the learning contents of other science courses like Biology, Chemistry or Mathematics. The needs analysis is done by conducting an online poll (Google form), where the students voted among themselves for the most interesting topic. The result of the analysis is as shown in Fig. 1 below.

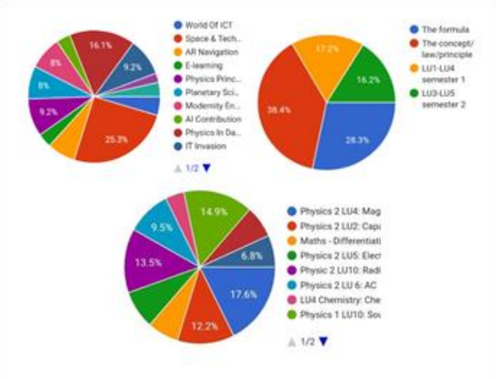

Fig. 1. The total 280 participants are divided into three groups. These needs analysis results were obtained by the voting among the group members

3.2.2 Implementation phase

The design and development of AR learning materials addressing the topic voted by the majority is carried out. The instructor plays the role as an advisor for the students on suitable resources like videos, images, animations and notes. Then, the students work together in designing relevant resources, programming the AR objects and completing the AR embedded learning material as a single, collective product.

3.2.3 Evaluation phase

The students presented their AR learning materials product, as shown in Fig. 2. They also undertake the second post-test and fill the IMMS to complete the full cycle of DBL.

4 Results

4.1 Post-Test

For the post-tests, the marks from each of the sections, LOTS and HOTS were analyzed separately.

4.1.1 LOTS

The paired t-test for the difference of means between the first and second post-test marks for LOTS questions was conducted with the following hypotheses.

H_0: There is no significant increase of mean marks between the first and second post-test (LOTS).

H_1: There is a significant increase of mean marks between the first and second post-test (LOTS).

The test is applied on Microsoft Excel 2016 to obtain the values as shown in Table 2.

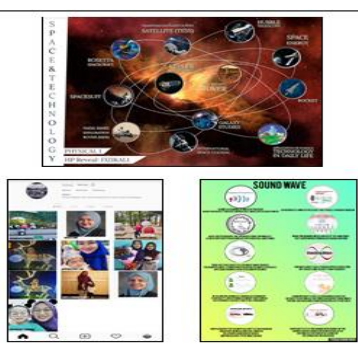

Fig. 2. The completed AR learning material by the three groups. The pictures in these A1-sized posters serve as the AR triggers (markers) for the related learning contents.

Based on the results shown in Table 2, in the sample obtained (n = 280) there is an increase of mean marks from mean = 2.88 (SD = 1.17) to mean = 3.94 (SD = 1.20), and the increase is significant with t (279) = –12.11 and p-value < 0.001.

TABLE 2

PAIR T-TEST FOR DIFFERENCE OF MEANS BETWEEN POST-TESTS (LOTS)
(LOTS)

	Post-Test 1	*Post-Test 2*
Mean	*2.88*	*3.94*
Standard deviation	*1.17*	*1.20*
df	*279*	
t (279)	*–12.11*	
t critical (one-tail)	*1.65*	
p-value	*< 0.001*	

4.1.2 HOTS

The paired t-test for the difference of means between the first and second post-test marks for HOTS questions is conducted with the following hypotheses.

H_0: There is no significant increase of mean marks between the first and second post-test (HOTS).

H_1: There is a significant increase of mean marks between the first and second post-test (HOTS).

The test is also applied on Microsoft Excel 2016 to obtain the values as shown in Table 3.

TABLE 3

PAIR T-TEST FOR DIFFERENCE OF MEANS BETWEEN POST-TESTS (HOTS)

	Post-Test 1	*Post-Test 2*
Mean	*2.07*	*2.59*
Standard deviation	*0.87*	*0.93*
df	*279*	
t (279)	*–8.12*	
t critical (one-tail)	*1.65*	
p-value	*< 0.001*	

Based on the results shown in Table 3, in the sample obtained (n = 280) there is an increase of mean marks from mean = 2.07 (SD = 0.87) to mean = 2.59 (SD = 0.93), and the increase is significant with t (279) = –8.12 and p-value < 0.001.

4.2 IMMS

For the IMMS, the mean and standard deviation for each ARCS component is tabulated as in Table 4 below.

TABLE 4

MEAN AND STANDARD DEVIATION FOR ARCS COMPONENT

	Attention	*Relevance*	*Confidence*	*Satisfactory*
Mean	*3.40*	*3.69*	*3.24*	*3.73*
SD	*0.07*	*0.04*	*0.05*	*0.05*

Based on the results shown in Table 4, the mean score for all components in ARCS model (attention: mean = 3.40, SD = 0.07, relevance: mean = 3.69, SD = 0.04, confidence: mean = 3.24, SD = 0.05, satisfactory: mean = 3.73, SD = 0.05) for students' motivational factor is above average and positively high. These results indicate that the DBL approach is efficient in terms of contributing towards students' learning motivation and interest.

5 Discussions

5.1 DBL effect on learning AR

The paired t-test results obtained from the post-tests suggests the effectiveness of DBL in promoting and enhancing higher order thinking skills [18]. An improvement of marks in the lower order thinking skill and higher order thinking skill sections can be observed due to as the students went through the learning process, they gain deeper understanding of the fundamentals knowledge and important experience in applying their theoretical into real-world practice [28], making the students' academic performance better. Furthermore, the DBL method provides more room and opportunities for students to perform self-learning activities and engage in self-development routine [29]. These factors help to increase the maturity of students in terms of prioritizing the importance to read, study and improve their knowledge as well as other primary and secondary skills related to the AR technology with the goals of achieving the learning outcomes, generally and solving the task presented to them in the planning phase of this research, specifically.

5.2 DBL impact on motivation

DBL activities empower learners to connect formal content such as AR technology and core science courses, as well as informal learning like teamworking, information management and lifelong learning skills [30]. Due to the phases of learning involved authentic elements, students' felt the importance of mastering the learning content, then applied the knowledge directly, hence, increasing overall motivation in achieving learning outcomes [31]. Also, positive results in IMMS enabled the clarification of how much AR technology really charmed the learners, supporting the findings in prior research [3]. In accordance to the ARCS model, attention factor corresponds to the perceptual arousal when learners engage in designing using AR technology; relevance factor measured the relevance of the pre-learning materials, in this case, the assessment guideline, instruction and related notes on AR; confidence factor indicated an establishment of positive expectations to achieve learning outcome among learners to produce AR embedded learning materials; satisfaction factor dictated the feeling and sense of achievement, praise or entertainment when the students completed their task in the assessment [6]. In overall, students felt very satisfied when the AR learning material was completed. They were able to feel the imperative relevance between their theoretical study and the real-world application of AR technology. The documents and face-to-face sessions provided enough but not too lengthy information to barely keep the learners' attention in the whole design-based learning phases as they were also restricted with other courses requirements and assessments as well. As the students were still new to the whole AR concept, they felt a very low confidence level in the beginning phase. Most of the students' academic background stems from pure sciences stream with no ICT or computer subject taught during their school days. But they slowly gain morale to finally be able to complete their task in developing the AR material by the end of the academic lecture weeks. All four factors contributing to their motivation and interest to be persistence in the completion of the assessment and strive to produce the product as perfect as possible.

6 Conclusions

The objective of this research was to understand the effect and impact of the design-based learning method in the teaching of AR technology for the ICT Competency course of the science stream pre-university students. The outcomes of this research showed an increased result for lower order thinking skills, higher order thinking skills and total scores in the second post-test. Also, above average mean values were measured in the IMMS for the corresponding attention, relevance, confidence and satisfaction factors in the ARCS model displayed the positivity in learners' motivation and interest towards AR technology. Further research and study should be conducted and resumed to determine an even better learning process and activities that would be more beneficial with the use of AR technology in the age of IR4.0 today.

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References

[1] Greenwood, A.T. and Wang, M., 2018. Augmented Reality and Mobile Learning: Theoretical Foundations and Implementation. In Mobile Learning and Higher Education (pp. 41-55). Routledge.

[2] Chiang, T.H.C., Yang, S.J. and Hwang, G.J., 2014. An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. Educational Technology & Society, 17(4), pp.352-365.

[3] Estapa, A. and Nadolny, L., 2015. The effect of an augmented reality enhanced mathematics lesson on student achievement and motivation. Journal of STEM education, 16(3).

[4] Carlson, K.J. and Gagnon, D.J., 2016. Augmented reality integrated simulation education in health care. Clinical simulation in nursing, 12(4), pp.123-127.

[5] Yilmaz, R.M., 2016. Educational magic toys developed with augmented reality technology for early childhood education. Computers in Human Behavior, 54, pp.240-248.

[6] Khan, T., Johnston, K. and Ophoff, J., 2019. The Impact of an Augmented Reality Application on Learning Motivation of Students. Advances in Human-Computer Interaction, 2019.

[7] Di Serio, Á., Ibáñez, M.B. and Kloos, C.D., 2013. Impact of an augmented reality system on students' motivation for a visual art course. Computers & Education, 68, pp.586-596.

[8] Radu, I., 2014. Augmented reality in education: a meta-review and cross-media analysis. Personal and Ubiquitous Computing, 18(6), pp.1533-1543.

[9] Akçayır, M. and Akçayır, G., 2017. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. Educational Research Review, 20, pp.1-11.

[10] McDonald, K.S. and Waite, A.M., 2019. Future Directions: Challenges and Solutions Facing Career

Readiness and Development in STEM Fields. Advances in Developing Human Resources, 21(1), pp.133-138.

[11] Dyrberg, N.R. and Holmegaard, H.T., 2019. Motivational patterns in STEM education: a self-determination perspective on first year courses. Research in Science & Technological Education, 37(1), pp.90-109.

[12] Kuo, H.C., Tseng, Y.C. and Yang, Y.T.C., 2019. Promoting college student's learning motivation and creativity through a STEM interdisciplinary PBL human-computer interaction system design and development course. Thinking Skills and Creativity, 31, pp.1-10.

[13] Moallem, M., 2019. Effects of PBL on Learning Outcomes, Knowledge Acquisition, and Higher-Order Thinking Skills. The Wiley Handbook of Problem-Based Learning, pp.107-133.

[14] Wu, P.H., Hwang, G.J., Yang, M.L. and Chen, C.H., 2018. Impacts of integrating the repertory grid into an augmented reality-based learning design on students' learning achievements, cognitive load and degree of satisfaction. Interactive Learning Environments, 26(2), pp.221-234.

[15] Kugelmann, D., Stratmann, L., Nühlen, N., Bork, F., Hoffmann, S., Samarbarksh, G., Pferschy, A., von der Heide, A.M., Eimannsberger, A., Fallavollita, P. and Navab, N., 2018. An augmented reality magic mirror as additive teaching device for gross anatomy. Annals of Anatomy-Anatomischer Anzeiger, 215, pp.71-77.

[16] Ibáñez, M.B. and Delgado-Kloos, C., 2018. Augmented reality for STEM learning: A systematic review. Computers & Education, 123, pp.109-123.

[17] Coffman, T.L. and Klinger, M.B., 2019. Mobile Technologies for Making Meaning in Education: Using Augmented Reality to Connect Learning. In Mobile Technologies in Educational Organizations (pp. 64-84). IGI Global.

[18] Bower, M., Howe, C., McCredie, N., Robinson, A. and Grover, D., 2014. Augmented Reality in education–cases, places and potentials. Educational Media International, 51(1), pp.1-15.

[19] Phade, G., Goverdhane, K., Vaidya, O.S. and Gandhe, S., A Novel ICT Tool For Interactive Learning For Electronics Engineering Based On Augmented Reality. International Journal of Scientific & Technology Research Volume 8, Issue 08, August 2019

[20] Dave, I.R., Chaudhary, V. and Upla, K.P., 2019. Simulation of Analytical Chemistry Experiments on Augmented Reality Platform. In Progress in Advanced Computing and Intelligent Engineering (pp. 393-403). Springer, Singapore.

[21] R. N. Farah, F. N. Hanani, and R. L. Zuraida, 2019. LINPROT: Linprot: A Multimedia Courseware For Optimization Methods With Integration Of Augmented Reality. International Journal of Scientific & Technology Research Volume 8, Issue 10, October 2019

[22] Akinci-Ceylan, S., Baran, E. and Ceylan, H., 2019, March. Integrating Learning by Design into a Flipped Civil Engineering Design Course. In Society for Information Technology & Teacher Education International Conference (pp. 1286-1291). Association for the Advancement of Computing in Education (AACE).

[23] Fuad, A., Alfin, J., Fauzan, F., Astutik, S. and Prahani, B.K., 2019. Group Science Learning Model to improve collaborative problem solving skills and self-confidence of Primary Schools Teacher candidates. International Journal of Instruction, 12(03).

[24] Wu, H.K., Lee, S.W.Y., Chang, H.Y. and Liang, J.C., 2013. Current status, opportunities and challenges of augmented reality in education. Computers & education, 62, pp.41-49.

[25] Briggs, N., 2015. Motivational value of mobile-based communicative tasks as coursebook supplements. Multimedia-Assisted Language Learning, 18(2), pp.11-36.

[26] Keller, J.M., 1987. Development and use of the ARCS model of instructional design. Journal of instructional development, 10(3), p.2.

[27] Keller, J.M., 2009. Motivational design for learning and performance: The ARCS model approach. Springer Science & Business Media.

[28] Zhang, Z., Hansen, C.T. and Andersen, M.A., 2015. Teaching power electronics with a design-oriented, project-based learning method at the Technical University of Denmark. IEEE Transactions on Education, 59(1), pp.32-38.

[29] Gómez Puente, S.M., van Eijck, M. and Jochems, W., 2015. Professional development for design-based learning in engineering education: a case study. European Journal of Engineering Education, 40(1), pp.14-31.

[30] Won, S.G., Evans, M.A., Carey, C. and Schnittka, C.G., 2015. Youth appropriation of social media for collaborative and facilitated design-based learning. Computers in Human Behavior, 50, pp.385-391.

[31] Solak, E. and Cakir, R., 2015. Exploring the Effect of Materials Designed with Augmented Reality on Language Learners' Vocabulary Learning. Journal of Educators Online, 12(2), pp.50-72.