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RESEARCH ARTICLE

The effectiveness of using digital applications for diabetes mellitus with augmented reality models as learning media in pharmacy education

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Abstract

Background: Learning in the fields of pharmacology and specialists requires experience or imagination in the material being studied. It has its own difficulties, especially understanding the introduction of diabetes mellitus treatment. Augmented Reality (AR) technology is one alternative to traditional teaching methods to show strong potential in improving the quality of learning. **Objective:** To design applications and provide information for using Android-based mobile AR technology as an interactive learning module about diabetes mellitus drug information. **Methods:** The application of AR in this study uses a marker-based method and a monitor-based system. The research design is to evaluate the function test and informational knowledge of Diabetes Mellitus of quasi-experimental. There were 60 pharmacy students who filled out a questionnaire on the use and knowledge of the DMAR (Diabetes Mellitus Augmented Reality) tool. **Result:** The application system was tested and found to work effectively. The results of the assessment of the response of DMAR media users on the aspect of usefulness with an average score of 4.35 (87.0%); Media design 4.23 (84.7%); ease of learning 4.40 (88.0%) and satisfaction 4.45 (89.0%). AR technology is able to support student learning on the chosen topic of 76.2% and showing effective way to improve student learning with *p*-value < 0.001. **Conclusion:** AR technology is an effective way to improve student learning about diabetes mellitus drug information. Instructional information can be presented in various attractive formats, and it is easier for pharmacy students to study independently anywhere and anytime (before, during, and after lectures) thereby improving performance and learning outcomes.

Introduction

Entering the era of technology and communication, many felt the need to improve learning quality by harnessing these new tools (Bacca *et al.*, 2014). Information technology develops in line with theoretical values and supports learning practices (Sung, Chang, & Liu, 2016). One of the greatest positive impacts of new technologies is technology in the field of education, where the presence of information technology means that there has been a change in methods towards a more student-centred learning approach (Elliott *et al.*, 2014).

In general, the use of immersive technologies, such as augmented reality and other virtual models, has generated new opportunities. Augmented reality (AR)-based educational media, is one of these new opportunities, it combines graphic technology, multimedia, and mobile applications (Zhang & Dang, 2020). Recently, there has been an increase and development in the use of information technology systems in the health sector, especially in medicine (Gerup, Soerensen, & Dieckmann, 2020). Some studies have applied AR to enhance learning experiences for students in medical education, one example is the trial by Mazzuco and colleagues (2022) in medical

chemistry teaching. Research shows that AR can help students learn, understand the material and increase learning motivation (Stojšić *et al*., 2020). In the study conducted by Manrique-Juan and colleagues (2017), the results show that AR learning media received an excellent response of 85.4%. Another study by Gierwialo and colleagues (2019) shows that with the use of AR media, medical students can be taught how to correctly insert a syringe, which can reduce the ratio of installing a failed needle from 50% to 30%.

In Indonesia, the use of AR in education is still minimal; even in the pharmaceutical field, learning which uses AR media is still minimal (Gerup, Soerensen, & Dieckmann, 2020). Learning media using AR technology in the pharmaceutical field can help to explain several courses, especially the Pharmacology and Drug Specialist courses, especially the topic of diabetes mellitus (DM) drug information. This course has been taught relatively the same way for many years, namely using a theoretical memorisation system with very limited and minimal image media. By developing AR DM drug information media for use as a learning tool, it is hoped that it can help students in their learning process, help students to understand the material, and increase their learning motivation. Based on the above background, the authors aimed to research application design and the effectiveness of using digital applications for DM drug information with an augmented reality model to increase pharmacy education learning. Alternative media to help teach DM drug information have been developed to make it easier to understand and more attractive.

Methods

Design

This research design is based on the development of learning media for pharmaceutical education to produce innovative technology-based solutions. The research includes two stages, namely AR development and AR knowledge testing. This quasi-experimental study used pre-test and post-test to determine informational knowledge of DM.

Design and construction of AR codes and mobile app.

Application-based AR learning media is a development of pharmacology and drug specialist courses for pharmacy students. Android application-based AR learning provides an interactive, student-centred real-life experience with DM drug information. The final output of the learning media is the application of DMAR (Diabetes Mellitus Augmented Reality) and card markers. Each card has a printout of an organ impacted by DM; each card is embedded with QR codes which, when interacted with using AR applications will display three-dimensional representations. The three-dimensional model can be made with the help of a scan of the object and after completion the three-dimensional model (virtual object) can display in the real world in real-time. The cards contain educational material related to DM, such as signs and symptoms of DM, prevention of type 2 DM, and information on type 2 DM drugs such as glibenclamide, metformin, acarbose, and insulin.

The main menu display's interface design uses Adobe Photoshop (Figure 1). The front page of DMAR consists of a 'Start' button with an arrow symbol in the middle. Besides the start button, there are content, help, credit, and exit buttons. After clicking the 'Start' button on the main menu (Figure 2), it will enter the 'Select AR Object' menu, which then displays eight AR codes related to DM information materials, including DM, pancreas, signs and symptoms of DM, prevention, sulfonylureas, biguanides, alpha-glucosidase, and AR Quiz. The material's content is based on reference sources taken from Goodman and Gilmand with the book 'Basic Pharmacology' (2023), a series of AR images depicting pharmacology based on the mechanism of action and drug side effects with short explanatory text in Indonesian. The display menu is shown in Figure 2.

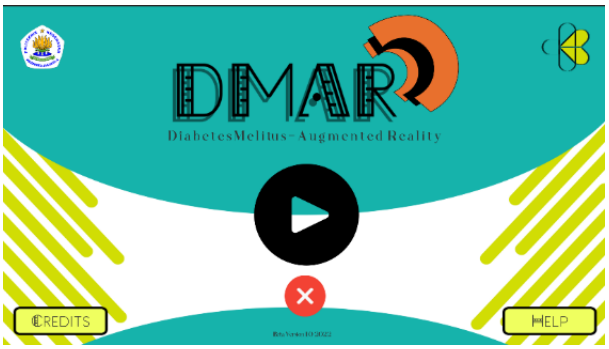

Figure 1: The front page of the DMAR learning platform

Figure 2: The nine menu display of the DMAR learning platform

Implementation of AR codes

The development of the AR system uses a model approach of analysis, design, implementation, and evaluation. The application used in this study is DMAR which is made with its copyright and can be downloaded via the Google Play Store and installed on an Android-based smartphone by pharmacy students and two material and information technology experts three days before learning activities using the AR model were established to explain how to install the application on their device and how to use it.

Evaluation of instructional tools

The DMAR application can evaluate its effectiveness as a learning medium in pre- and post-tests. The sampling technique was carried out by purposive sampling. The sampling was done by observing pharmacy diploma and bachelor study programmes. The sample had inclusion criteria which included: students in term four who had received Pharmacology and specialisation courses on DM among other factors. The sample consisted of 60 pharmacy students. They were divided into two groups, the control group and test group, with 30 students in each group. The function test questionnaire asked about the useful-ness and benefits of the tool, the level of satisfaction, and suggestions. Functional suitability testing was carried out using the User Acceptance Test (UAT) with a black box test technique based on the appearance and menus in the application. There were yes/no answers, a five-point Likert scale, and open-ended suggested questions in this test. The type of DM knowledge test with the DMAR tool was an objective test of true and false choices with ten queries. After completing the treatment for approximately three weeks, pre- and post-test knowledge questionnaires were taken.

Ethics

This research has an ethical clearance from the Research Ethics Committee on Poltekkes Kemenkes Jakarta II (KEPK-PKJ II) with license number LB.02.01/I/KE/39/292/2022.

Assessment

Knowledge scores were divided into good (between 75 and 100) and fair (below 75). In the usability testing, the instrument consisted of 20 questions with four criteria: benefits, design and operational ease, ease of learning, and satisfaction value. Each participant in the questionnaire was allowed to try out the DMAR application and were then asked to complete the questionnaire. The questionnaire-filled-in researcher calculated the results using a Likert scale, with an answer score of one to five (Very Good, Good, Fairly Good, Not Good, and Very Bad). The total usability score was calculated by summing the answers and dividing the total by 100 using the Minnesota Satisfaction Questionnaire (MSQ). This instrument uses a Likert scale format to generate satisfaction scores on various scales. The score criteria consist of low feasibility (20 - 40), fairly good tool function feasibility (41 - 69), good tool function feasibility (70 - 85) and excellent tool function feasibility (86 - 100). The level of feasibility of the average tool function was sought by dividing the total score by the number of respondents taken as samples.

Data analysis

The statistical analysis of the usability function test by calculating the average score was carried out using Microsoft Excel version 2016. Statistical analysis on the student knowledge test about DM drug information was tested for normality and homogeneity. The data analysis technique used an independent t-test to compare changes in knowledge in the intervention and control groups if the data were normally distributed and Mann-Whitney test if the data were not normally distributed. Then, paired sample t-test was used to see changes before and after treatment if the data were normally distributed and Wilcoxon signs rank test was used if the data were not normally distributed. The results of this study were based on Kolmogorov-Smirnov on the normality test in the pre-test knowledge of DM of 0.011 and post-test knowledge of 0.034, which showed that the data were not normally distributed.

Results

From the respondents, there was a higher proportion of female respondents (73.3%) than male. The age group of 20 - 22 years was the highest proportion participating in this study at 81.7%. The proportion of the questionnaire for the function test of the application system for students is 100%. In the aspects of the need for AR features to provide data information to students, there are statement points as follows:

1. The AR feature in the application provides complete and detailed information.
2. The existence of 3D objects on the type of drug in the AR feature makes the application more informative and detailed to students.

3. Be open and accept the latest technology, such as the presence of AR in student learning applications.

The results of the function test of the DMAR tool have an assessment of the utilisation aspect categorised as very good (4.35); The design and ease of operation are categorised as very good (4.23); ease of learning is categorised as very good (4.40); and satisfaction is classified as very good (4.39) (see Table I).

Based on the assessment results on the four tool functions that have been converted into the category of feasibility level, the usability, ease of learning, and satisfaction have an average feasibility value of above 85% with the 'very feasible' category. However, the category of design and appearance aspects and the operation of the DMAR tool are still in the 'appropriate' category of 84.7%.

Table I: Distribution of Diabetes Mellitus Augmented Reality (DMAR) application tool function assessment

No	Function Assessment on DMAR Application Tool	Very good	Good	Acceptable	Poor	Very poor	Total score	Mean score	Mean score (%)
Benefit		**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**			
1	This application helps me to be more active in learning diabetes mellitus drugs.	15 (50.0)	14 (46.7)	1 (3.3)	0	0	4.43	4.35	87.0
2	This application can save me time while studying and understanding diabetes mellitus drugs.	11 (36.7)	16 (53.3)	3 (10.0)	0	0	4.27		
Design and operational ease									
3	The steps for using this application are straightforward and practical how to operate the AR feature.	9 (30.0)	20 (66.7)	1 (3.3)	0	0	4.27	4.23	84.7
4	AR images do not distract from Diabetes Mellitus drug identifiers or information	11(36.7)	14 (46.7)	5 (16.7)	0	0	4.20		
Ease of learning									
5	AR images do not distract from Diabetes Mellitus drug identifiers or information.	10 (33.3)	20 (66.7)	0	0	0	4.33	4.44	88.0
6	AR tools are a helpful teaching resource compared to methods such as lectures and tutorial exercises.	14 (46.7)	16 (53.3)	0	0	0	4.46		
Satisfaction									
7	AR tools can be applied to various other pharmacy learning activities.	17 (56.7)	10 (43.3)	3(10.0)	0	0	4.46	4.45	89.0
8	I would recommend this app because it is easy, fun, and adds digital references.	13 (43.3)	17 (56.7)	0	0	0	4.43		

The knowledge questionnaire on the DMAR display shows two materials, including disease education, prevention of diabetes mellitus, and information on type 2 DM and insulin drugs. The intervention of DMAR application aims to determine the effect of knowledge after the pre-test and post-test as shown in Table II.

Table II: Distribution of diabetes mellitus drug information knowledge assessment comparison based on descriptive statistics

Knowledge Group	Pre-test				Post-test				z-test	*p*-value
	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum		
Experimental Group*	63.29	18.277	36	100	88.03	11.925	73	100	-4.069	<0.001
Control group+	57.58	15.247	29	85	64.25	15.822	29	100	-2.636	0.058

*Use of DMAR application

+ Without the use of DMAR application

Table II shows that the education group, through the DMAR application, can increase respondents' knowledge scores from 63.29 to 88.03 with a *p*-value < 0.001. Wilcoxon test results show a difference in respondents' average knowledge before and after the provision of DMAR application learning media.

Based on the observations and data processing results, this research compares the effectiveness of providing learning media through the DMAR application with not providing DMAR application learning media. The data obtained are listed in the presented tables.

In Table III, the mean post-test knowledge in the intervention group is 76.17, while in the control group is 60.43. The statistical test showed significant difference of mean change between the two groups (6.67 versus 12.88; $p < 0.001$). The intervention can increase the knowledge of pharmacy students using digital applications with AR models for DM 6.21 times compared to the control group, showing this application has effectiveness as a learning media in Pharmacy Education (3.76 to 8.64).

Table III: Comparison between average knowledge scores of diabetes mellitus drug information after intervention

Group	Change	Mean	Standard deviation	Minimum	Maximum	Mean difference (95% CI of the difference)	*p*-value
Knowledge							
– Experimental Group	12.88	76.17	18.367	36	100	6.21 (3.76 to 8.64)	< 0.001
– Control Group	6.67	60.43	16.93	14.20	100		

In Table III, the mean post-test knowledge in the intervention group is 76.17, while in the control group is 60.43. The statistical test showed significant difference of mean change between the two groups (6.67 versus 12.88; $p < 0.001$). The intervention can increase the knowledge of pharmacy students using digital applications with AR models for DM 6.21 times compared to the control group, showing this application has effectiveness as a learning media in Pharmacy Education (3.76 to 8.64).

Discussion

The Mann-Whitney test results showed a difference in respondents' knowledge about type 2 DM between the DMAR application group and the control group (non-DMAR application) during the pre-test and post-test. There was a difference in knowledge between the experimental and control groups ($p < 0.05$). The results showed that the DMAR application increased pharmacy students' knowledge by 6.21 (3.76 to 8.64) It is in line with research conducted by Coyn and colleagues (2019) on college students showing a significant difference between knowledge before and after being given virtual media and augmented reality with a *p*-value of 0.001. A second study conducted by Schneider and colleagues (2020) showed that AR technology was able to support student learning on the chosen topic, showing a 42% increase in quiz scores with $p < 0.0001$, and students found that AR use was stimulating, interactive, exciting, and easy to follow. Thus, AR technology can be an effective way to improve student learning about medicine (Schneider *et al.*, 2020).

Similar learning outcomes were reported in a study by Albrecht and colleagues, with a small group of ten medical students in Germany who studied forensic medicine. However, in this study, the students were divided into an experimental group (n = 6) using AR for learning, as well as a control group (n = 4), with the experimental group showing a statistically significant increase in knowledge compared to the control group ($p = 0.03$) (Albrecht *et al.*, 2013).

Another study conducted by Salem (2020) used mobile-based AR technology to develop interactive learning modules about contraceptives and drugs and to measure their acceptability and usefulness for undergraduate pharmacy students with the results that most of the students agreed or strongly agreed that the learning module AR motivated them to learn about drugs (84.8%, n = 28) and that AR was successful in presenting drug-related information for learning (81.8%, n = 27) (Salem *et al.*, 2020). Much evidence supports AR observations that produce good learning outcomes because students who are actively involved in the learning process are better able to retain knowledge, resulting in higher achievement levels (Albrecht *et al.,* 2013). Knowledge can be increased through communication, information, and education that can be conveyed through the media (Wen & Looi, 2019). Media is one factor influencing a

person's knowledge and attitudes. The media can make it easier for people to understand information that is considered complex. Increased knowledge shows the success of using Android-based digital AR media to provide education (Kurniawan, Adin Hakim. Fajri, 2020).

More knowledge can be learnt through engaging all of the senses in the learning process; studies have shown that learning is as much as 13% through hearing and as much as 35-55% through hearing and sight (Anmarkrud, Andresen, & Bråten, 2019). Students learn more deeply from words and pictures than words alone, a format that uses auditory and visual stimulation (Schneider et al., 2020). Roberts (2017) suggested that adding cues to multi-media material reduced learners' perceived cognitive load and significantly facilitated retention and transfer of learning (Roberts, 2017), and it could be successfully used as a technique to enhance learning (Xie *et al.*, 2017). Augmented reality media is a technology that combines two-dimensional or three-dimensional virtual objects into a natural three-dimensional environment and then projects these virtual objects in real-time (Küçük, Kapakin, & Göktaş, 2016; Moro *et al.*, 2017). Digital AR combines an Android application system and a marker card. Teaching aids that use the AR system are easier to understand than traditional teaching aids. Through these teaching aids, students gain learning experiences similar to the real world, so the learning process is more engaging for them. Teaching aids with AR systems help students easily understand Android digital tools and card simulations (Cheng & Tsai, 2016). According to research conducted by Shah & Khan (2015) using AR books, there was a significant difference between the intervention group and the control group. The limitation of this research includes using Android-based applications and cards to read available scanners, while teaching and learning media at the school already use barcode scans on learning books, so that it is necessary to make a learning book prototype with an AR code QR scan model.

Conclusion

AR technology is an effective way to improve student learning about diabetes mellitus drug information. Instructional information can be presented in various attractive formats, making it easier for pharmacy students to study independently anywhere and anytime (before, during, and after lectures) by improving performance and learning outcomes.

This study suggests additional three-dimensional features and barcodes through digital AR applications on QR scan models and other types of platforms besides Android such as IOS. Students expect to generate interest in understanding DM drug information. Pharmacology education and drug specialists need to do it repeatedly, not just one time, to maintain long-term memory.

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