

## ORIGINAL ARTICLE

# AR MammoFun: Medical Imaging Students' Perception in Learning Mammography

Juliana Mohd Radzi<sup>1</sup>, Shuhada Jan Mohamed<sup>1</sup>, Nurul Syazwina Mohamed<sup>1</sup>, Wan Mohd Rizhan Wan Idris<sup>2</sup>, Arif Faddilah Mohd Noor<sup>1</sup>

<sup>1</sup> School of Medical Imaging, Faculty of Health Sciences, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia

<sup>2</sup> School of Multimedia, Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, 22200 Besut, Terengganu, Malaysia

## ABSTRACT

**Introduction:** Augmented reality (AR) emerges as a reliable tool for medical imaging students to overcome the difficulty of engagement during learning and practical experience of mammography. Thus, this study aims to investigate students' perceptions regarding the application of AR in learning mammography. **Materials and methods:** AR MammoFun was developed and introduced during the lecture sessions. A questionnaire was then distributed to the Medical Imaging students of the Faculty of Health Sciences at Universiti Sultan Zainal Abidin (UniSZA) to assess their perception of the learning experience of the AR MammoFun. Descriptive statistics were employed to evaluate the data. **Results:** A total of 45 students (7 males, 38 females) with an average age of  $21.31 \pm 0.67$  years old participated in this study. Most students did not know AR was used for educational purposes ( $n=26$ ) and did not have experience in AR-based learning ( $n=37$ ). Most students also strongly agree that AR MammoFun enhances their learning motivation and improves their knowledge of mammograms. Most students strongly agree that learning mammograms with AR MammoFun was better than traditional ones. **Conclusion:** This AR MammoFun has been shown to have good potential in making the learning process more effective and meaningful. It brings a breakthrough to the traditional education system by transforming the complete learning experience.

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## Corresponding Author:

Juliana Mohd Radzi, PhD

Email: julianamradzi@unisza.edu.my

Tel : +609-6687979

## INTRODUCTION

In the present era, modern technologies can serve as educational tools to enrich the teaching and learning experience using mobile technology. Within higher education institutions, mobile devices have gained growing significance as integral elements of the educational journey for both educators and students. The outbreak of Covid-19 has led to the closure of schools and universities, affecting approximately 1.54 billion children and youth across 185 countries in Asia, Europe, the Middle East, North America, and South America [1]. As a result, there is a need to shift from traditional face-to-face teaching to an e-learning approach.

E-learning proves advantageous as it allows swift delivery of learning materials to students, ensuring standardisation and prompt updates when necessary

[2]., The respondents generally agreed that online learning offers the flexibility to choose study times and locations with easily accessible learning materials [3]. Numerous innovations in e-learning aim to enhance students' learning and motivation, and one notable development is the integration of smartphones. Past research indicates that a significant proportion of school and vocational high school students use smartphones [4], enabling learning opportunities beyond the confines of a traditional classroom setting.

Smartphones provide a robust platform for augmented reality (AR), allowing the overlay of contextual digital information onto the real-world environment using the camera, built-in GPS, compass, gyroscope, and touchscreen functionalities [5]. The 2019 Horizon Report highlights mixed reality as high-impact learning technology, particularly in higher education, encompassing both AR and virtual reality (VR) to blend real-world and virtual elements generated by mobile devices [6-7]. The concept of AR has been in existence since the 1960s and has found applications across diverse fields such as medicine, education, tourism,

culture, military, gaming, and entertainment [8-10].

Augmented reality can be classified into image-based and location-based applications. Image-based AR includes marker-based applications, which require specific labels, and marker-less tracking, where the image is needed to initiate the playback of multimedia content. In the case of location-based AR, the application is triggered when the user reaches a specific location [11]. Notably, location-based AR was implemented in the popular game Pokemon Go [8]. The technology of AR enables users to perceive both real and virtual environments by incorporating three-dimensional virtual objects with animation, video, audio, and/or text [12]. Consequently, this enhances users' knowledge and comprehension of their surroundings.

Moreover, numerous studies have explored the impact of augmented reality (AR) applications across various educational levels, from childhood to university settings. These studies have consistently demonstrated that AR offers multiple learning opportunities and benefits for both teaching and learning purposes [11]. Additionally, AR holds significant potential to enhance students' learning experiences, particularly in higher education, where its implementation cost is lower compared to virtual reality (VR) due to the absence of additional equipment required for VR [13].

Furthermore, the integration of augmented reality (AR) has demonstrated positive outcomes in various educational aspects, from enhancing digital skills [14,15] to increasing motivation [16] and improving academic performance [17]. These benefits of AR extend beyond traditional educational settings and find valuable application in specialised fields such as medical education. In the context of mammography teaching and learning, AR has the potential to revolutionise the training process. By providing an immersive and interactive experience, AR can aid in the interpretation of mammograms, offering learners a realistic and dynamic environment for honing diagnostic skills and improving accuracy in breast cancer detection.

Likewise, AR applications also make teaching and learning more fun as they enable new learning experiences hence facilitating students to improve skills such as critical thinking, problem-solving, and communication [18]. Its also offered an opportunity to visualise different stages of a constructive process by AR on mobile devices, to improve the understanding of the process, and to investigate the relationship between the usability of the tool, students' participation, and academic performance after using AR [19]. The results pointed out that the use of mobile devices in the classroom and motivation and academic achievement are highly correlated. Therefore, this study aims to investigate the student's perception and satisfaction of AR in learning mammograms.

## MATERIALS AND METHODS

### Development of AR MammoFun

AR MammoFun is an engaging e-learning app developed using augmented reality (AR) on the Android platform, complemented by a simple handbook (Figure 1). This allows users to interact with educational content more engagingly and memorably. It covers eight subtopics related to mammography, providing an interactive and immersive educational experience.. It consists of an introduction to mammogram, breast anatomy, patient preparation, basic projections, and images. There was a 3-dimensional (3D) model of the mammographic unit and breast anatomy. Students can rotate, zoom in, and explore these models to better understand mammographic unit (components and its function) and breast anatomy. Besides, a video was embedded to give a realistic experience of performing a basic projection of a mammogram. A 'Perfect, good, moderate, inadequate (PGMI)' evaluation and radiograph for both projections were also included to make AR MammoFun a comprehensive mammography module for e-learning. This innovative AR technology will stimulate real-world scenarios and guide students' hands-on practice during the practical session. The AR MammoFun also incorporates gamified element such as quiz that test students' knowledge in a fun and interactive manner. AR MammoFun is accessible anytime, anywhere, making it convenient for users to integrate learning into their daily routines. Furthermore, AR MammoFun is designed specifically for educational purposes, aligning with curriculum standards and learning outcomes.



Figure 1: AR MammoFun E-Learning App and Handbook. © 2023 Universiti Sultan Zainal Abidin. All rights reserved. CRLY2023C03558

### Implementation

The learning content for each subtopic was initially covered through traditional PowerPoint lectures at the beginning of the semester. These classes took place in a classroom setting with adequately sized tables and flexible seating arrangements conducive to group discussions. AR MammoFun was introduced to the students in week twelve of the lecture to facilitate the same topics covered earlier, offering a dynamic and interactive learning experience. Instructions on the installation and utilisation of AR MammoFun were given to ensure that students could independently and

correctly use the software for their learning before the final exam. The questionnaire was distributed after the final exam ended.

**Participants**

The participants were Bachelor of Medical Imaging students, Year 2 at the Faculty of Health Sciences, UniSZA, who were enrolled in the Additional Radiographic Procedure courses for the current semester. Inclusion criteria required participants to have fundamental skills in using mobile apps, possess a smartphone operating on the Android system, and install the AR MammoFun mobile learning app. Students who do not possess an Android smartphone or tablet were excluded from the study. All participants were fully informed about the study's objectives, procedures, and rights and voluntarily chose to participate. Informed consent was obtained from all participants. The study protocol had been reviewed and granted ethical approval by the Universiti Sultan Zainal Abidin Human Research Ethics Committee (UHREC). This study had been assigned with study protocol code (UniSZA/UHREC/2023/567).

**Research Instrument**

The questionnaire used in this study was adapted from a previous study titled; Use of Augmented Reality to Optimize the Effectiveness of Biomedical Education [20]. The questionnaire was distributed online using Google Form. The questionnaire was divided into three sections. The first section was sociodemographic (age, gender, and race). The second section consists of seven multiple-choice answer questions that evaluate the students' knowledge regarding AR time spent on electronic devices for learning purposes. The third section consists of five Likert questions that were used to evaluate the perception of AR in learning mammography.

**Data Analysis and Statistical Application**

All data were analysed using Statistical Package for the Social Sciences (SPSS) version 27. Descriptive statistics such as frequency (%) for categorical data and mean (SD) for numerical data were applied for the analysis.

**RESULTS**

A total of 45 students have participated in this study. There were seven males and 38 females. As indicated in Table I, the predominant age among respondents was 21 years old, constituting 77.8% of the total. Most participants (84.4%, n=38) identified as Malay, with 8.9% (n=4) being Hindu. The remaining students were one Bugis (2.2%) and two Chinese (4.4%).

**Table I: Demographic Characteristics of Respondents**

| Demographic characteristics | Frequency (n) | %    |
|-----------------------------|---------------|------|
| Gender                      |               |      |
| Female                      | 38            | 84.4 |
| Male                        | 7             | 15.6 |
| Age (in years)              |               |      |
| 21                          | 35            | 77.8 |
| 22                          | 7             | 15.6 |
| 23                          | 2             | 4.4  |
| 24                          | 1             | 2.2  |
| Race                        |               |      |
| Bugis                       | 1             | 2.2  |
| Chinese                     | 2             | 4.4  |
| Hindu                       | 4             | 8.9  |
| Malay                       | 38            | 84.4 |

Based on Table II, most students (44.4%) had prior knowledge of what Augmented Reality (AR) entails before their involvement in this study. However, most of them did not know that AR was used for educational purposes (57.8%) and did not have experience in AR-based learning (82.2%) and playing AR games (62.2%), respectively. Surprisingly, 11.1% and 4.4% were unsure whether they had AR-based learning experiences and played AR games, respectively. Regarding experience in playing non-AR computer games (60%) and in computer programming (40%), most of them had experience with it. Most of them spend more than two hours (on average) using an electronic device(s) for learning purposes every day (84.4%), with 11.1% unsure about their usage patterns.

**Table II: Respondents' Background on Augmented Reality (AR).**

| Item | Question  | Frequency (n) | %    |
|------|---|---------------|------|
| 1    | Did you know what AR was before this study?                               |               |      |
|      | Yes   | 20            | 44.4 |
|      | Not sure  | 8             | 17.8 |
| 2    | Did you know that AR was used for educational purposes before this study? |               |      |
|      | Yes   | 14            | 31.1 |
|      | Not sure  | 5             | 11.1 |
| 3    | Do you have experience in AR-based learning?                              |               |      |
|      | Yes   | 6             | 13.3 |
|      | Not sure  | 2             | 4.4  |
|      | No  | 37            | 82.2 |

CONTINUE

**Table II: Respondents' Background on Augmented Reality (AR). (CONT.)**

| Item | Question  | Frequency (n) | %    |
|------|---|---------------|------|
| 4    | Do you have experience in playing AR games?   |               |      |
|      | Yes   | 12            | 26.7 |
|      | Not sure  | 5             | 11.1 |
|      | No  | 28            | 62.2 |
| 5    | Do you have experience in playing non-AR computer games?  |               |      |
|      | Yes   | 27            | 60.0 |
|      | Not sure  | 3             | 6.7  |
|      | No  | 15            | 33.3 |
| 6    | Do you have experience in computer programming?   |               |      |
|      | Yes   | 18            | 40.0 |
|      | Not sure  | 10            | 22.2 |
|      | No  | 17            | 37.8 |
| 7    | Do you spend more than two hours (on average) using electronic device(s) for learning purposes every day? |               |      |
|      | Yes   | 38            | 84.4 |
|      | Not sure  | 5             | 11.1 |
|      | No  | 2             | 4.4  |

Based on Table III, students have a positive perception of using AR MammoFun in their learning process. The mean scores for all 12 statements were above 4.0, which indicates that most students agree or strongly agree with the statements. Enhancing attention or concentration in the lesson and promoting enjoyment in the learning process was the statement with the highest mean score (4.67). The statement with the lowest mean score pertained to "increasing confidence in tests or examinations" (4.20), with most students indicating agreement or strong agreement.

**Table III: Students' Perception of AR MammoFun on Learning Mammography**

| Item.          | Statement   | Frequency (n) | %    | Mean (SD)   |
|----------------|---|---------------|------|-------------|
| 1.             | Enhancing your learning motivation                      |               |      |             |
|                | Strongly disagree                                       | 0             | 0    | 4.58(0.543) |
|                | Disagree  | 0             | 0    |             |
|                | Neutral   | 1             | 2.2  |             |
|                | Agree   | 17            | 37.8 |             |
| Strongly agree | 27  | 60.0          |      |             |
| 2.             | Enhancing your attention or concentration in the lesson |               |      |             |
|                | Strongly disagree                                       | 0             | 0    | 4.67(0.477) |
|                | Disagree  | 0             | 0    |             |
|                | Neutral   | 0             | 0    |             |
|                | Agree   | 15            | 33.3 |             |
| Strongly agree | 30  | 66.7          |      |             |

CONTINUE

**Table III: Students' Perception of AR MammoFun on Learning Mammography. (CONT.)**

| Item.          | Statement  | Frequency (n) | %    | Mean (SD)   |
|----------------|--|---------------|------|-------------|
| 3.             | Facilitating your engagement in the topic                |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.51(0.589) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 2             | 4.4  |             |
|                | Agree  | 18            | 40.0 |             |
| Strongly agree | 25   | 55.6          |      |             |
| 4.             | Facilitating your understanding of knowledge             |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.42(0.583) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 2             | 4.4  |             |
|                | Agree  | 22            | 48.9 |             |
| Strongly agree | 21   | 46.7          |      |             |
| 5.             | Consolidating your memory of the contents of the subject |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.38(0.535) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 1             | 2.2  |             |
|                | Agree  | 26            | 57.8 |             |
| Strongly agree | 18   | 40.0          |      |             |
| 6.             | Extending your awareness toward mammo concepts           |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.56(0.546) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 1             | 2.2  |             |
|                | Agree  | 18            | 40.0 |             |
| Strongly Agree | 26   | 57.8          |      |             |
| 7.             | Increasing your ability to apply what you have learned   |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.56(0.503) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 0             | 0    |             |
|                | Agree  | 20            | 44.4 |             |
| Strongly Agree | 25   | 55.6          |      |             |
| 8.             | Developing your ability in self-directed learning        |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.47(0.588) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 2             | 4.4  |             |
|                | Agree  | 20            | 44.4 |             |
| Strongly Agree | 23   | 51.1          |      |             |
| 9.             | Improving the efficiency of revision                     |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.47(0.661) |
|                | Disagree   | 0             | 0    |             |
|                | Neutral  | 2             | 4.4  |             |
|                | Agree  | 20            | 44.4 |             |
| Strongly Agree | 23   | 51.1          |      |             |
| 10             | Increasing your confidence in tests or examinations      |               |      |             |
|                | Strongly disagree  | 0             | 0    | 4.20(0.661) |

CONTINUE

**Table III: Students’ Perception of AR MammoFun on Learning Mammography. (CONT.)**

| Item. | Statement   | Frequency (n) | %    | Mean (SD)   |
|-------|---|---------------|------|-------------|
| 10    | Increasing your confidence in tests or examinations |               |      | 4.20(0.661) |
|       | Disagree  | 0             | 0    |             |
|       | Neutral   | 6             | 13.3 |             |
|       | Agree   | 24            | 53.3 |             |
|       | Strongly Agree                                      | 15            | 33.3 |             |
| 11    | Promoting enjoyment in your learning process        |               |      | 4.67(0.522) |
|       | Strongly disagree                                   | 0             | 0    |             |
|       | Disagree  | 0             | 0    |             |
|       | Neutral   | 6             | 13.3 |             |
|       | Agree   | 24            | 53.3 |             |
|       | Strongly Agree                                      | 15            | 33.3 |             |
| 12    | Stimulating your creativity                         |               |      | 4.62(0.535) |
|       | Strongly disagree                                   | 0             | 0    |             |
|       | Disagree  | 0             | 0    |             |
|       | Neutral   | 1             | 2.2  |             |
|       | Agree   | 15            | 33.3 |             |
|       | Strongly Agree                                      | 29            | 64.4 |             |

Only a small fraction, six students (13.3%), expressed neutrality on this aspect. Conversely, most students strongly agreed that AR MammoFun positively influences their learning motivation (60%), engages them in the topic of mammography (55.6%), enhances their understanding of mammography concepts (57.8%), and improves their ability to apply learned content (55.6%). Additionally, most participants strongly agreed that AR MammoFun enhances their efficiency in revision (51.1%) and stimulates creativity in learning mammography (64.4%). In summary, fewer than 10 students provided neutral responses for each statement posed in this study.

According to Table IV, items four and eight have the highest level of satisfaction, with a mean of 4.69. While item three has the lowest level with a mean value of 4.24. The overall mean for each attribute ranged from 4.16 to 4.69. This indicates that most of the students were satisfied or very satisfied with the features of AR MammoFun. The statement of item eight received the lowest mean score.

**Table IV: Student’s satisfaction with AR MammoFun features.**

| Item | Statement   | Mean | SD    |
|------|---|------|-------|
| 1.   | Tailor-made display layout (e.g., user-friendly menu)               | 4.31 | 0.763 |
| 2.   | Higher diversity of multimedia (e.g., videos and graphical content) | 4.53 | 0.661 |
| 3.   | Background music (with on/off selection)                            | 4.24 | 0.908 |
| 4.   | Interesting sound effects   | 4.16 | 0.878 |
| 5.   | Detailed annotations of figures                                     | 4.40 | 0.837 |
| 6.   | Detailed labels of 3D structures                                    | 4.58 | 0.690 |
| 7.   | Control of the speed of animations                                  | 4.40 | 0.688 |
| 8.   | Definitions of medical terms  | 4.69 | 0.596 |

CONTINUE

**Table IV: Student’s satisfaction with AR MammoFun features. (CONT.)**

| Item | Statement  | Mean | SD    |
|------|--|------|-------|
| 9.   | Pronunciations of medical terms  | 4.69 | 0.596 |
| 10.  | Supplementary notes or further readings  | 4.47 | 0.757 |
| 11.  | Instant self-assessment tools (e.g., built-in Q&A for revision)                    | 4.42 | 0.723 |
| 12.  | Good flexibility in the manipulation of objects (e.g., more smooth rotation)       | 4.29 | 0.869 |
| 13.  | Good flexibility to select which component(s) and/or projection(s) to show or hide | 4.29 | 0.815 |

**DISCUSSION**

A mammogram is a type of X-ray image of the breast that is commonly used for screening and diagnosing breast cancer [21]. It is a key tool in early detection, allowing healthcare providers to identify and address potential breast abnormalities before they cause symptoms. Mammography was chosen as an ideal modality for interactive learning as mammography suites are highly restricted, primarily owing to privacy concerns and the necessity for close contact with patients. Besides, male students are prohibited from entering the mammography suites. Therefore, learning mammography becomes quite challenging for male students. With the help of AR, male students can have a better understanding of this topic.

Before participating in this study, many students appeared to know what augmented reality (AR) is. However, it was surprising to note that they were unaware of AR's application in education, possibly due to limited exposure, particularly in medical imaging. AR has been utilised in various fields in education [22] but not in medical imaging, especially focusing on mammography. Learning mammography requires students to know the mammographic unit and understand the anatomy of the breast and its basic projections. AR emerges as a highly effective learning tool as it allows for presenting objects like the mammographic unit and the breast in three dimensions (3D). This enables students to manipulate images from various angles, enhancing visualisation. Educational tools that enable the display of different angles are particularly beneficial for studying anatomy [23]. Besides, integrating AR into medical imaging education can bring a new level of excitement and effectiveness to the learning process.

Furthermore, correct patient positioning techniques are crucial for Medical Imaging students. Patient positioning was taught during lecture and demo sessions. They need to apply their knowledge during clinical placement. However, students often find the transition from theory to clinical practice challenging, preventing the link between theory and practice during clinical placement [24,25]. In learning mammography, male students often find it difficult to imagine the patient's positioning as they cannot enter the mammography suite. But with the

help of AR MammoFun, they can get the real picture of how to position a patient during a mammography examination.

Another study finding was that most students spend more than two hours daily with electronic devices for their learning purposes. This is unsurprising as all students nowadays have smart devices such as smartphones, tablets, or iPads, which they use for studying and other activities [26]. These electronic devices have become more important since Covid-19 pandemic changed traditional lectures to online lectures. Electronic devices also play a vital role in digital learning, especially when using AR [27]. A similar finding was found in another study that the motivation to learn AR comes from using smart devices [28]. The finding was similar to our study, which found that AR MammoFun enhances students' motivation to learn mammography.

AR learning tools make lessons more interesting and enjoyable by boosting students' curiosity, aiding in grasping abstract concepts, and offering unique experiences not possible in real-life situations [27]. A positive perception of incorporating augmented reality (AR) into the learning of mammography was shown in this study, as indicated by the mean score exceeding 4.0 for each of the statements. AR MammoFun boosts learning motivation and enhances concentration, understanding of mammography concepts, and confidence in tests. Students find learning mammography enjoyable and believe it sparks creativity, aligning with similar findings in studies on AR in media and communication courses in Palestine and Egypt [28,29]. Besides, AR technology can enhance the educational experience by making the course material more engaging and immersive, helping students better understand and remember the information [30].

AR features play an important role when designing AR for learning tools. Most students participating in this study were also very satisfied with the features of AR MammoFun. Music stands out as an important feature of an enjoyable learning experience. To enhance students' understanding, ensuring high-quality visuals, seamless integration of content with the curriculum, and careful selection of materials in AR software is essential. Students are looking for exciting and new technology to use. Simplicity and visibility in the design attracted students. Animation in the video stream easily communicates university information with students. Using AR makes students enjoy what they are doing. Usability and learnability in the application helped students complete basic tasks and recall the app in the second experience [30]. Therefore, AR can enhance lectures by projecting real-time 3D models or medical images onto a screen, aiding students in comprehending complex concepts and encouraging active engagement. Similar findings suggest that AR technology can improve instructors' ability to assess students' understanding in

the classroom by incorporating virtual annotations and illustrations into physical devices [31].

## CONCLUSION

In summary, implementing AR in learning mammography has been shown to have good potential in making the learning process more effective and meaningful. It brings a breakthrough to the traditional education system by transforming the complete learning experience. The findings of this study show that most students were motivated and enjoyed learning mammography using AR MammoFun.

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