# The Effectiveness of Teaching Aid for a Mathematics Subject Via Mobile Augmented Reality (MAR) for Standard Six Students

**Hafizul Fahri Hanafi, Nur Azlan Zainuddin, Mohd Faizal Nizam Lee Abdullah, Mohd Hairy Ibrahim**

***Abstract: This main purpose of this study is to investigate the impact of a mobile augmented reality application on the understanding of mathematics subjects among primary school students. This study is constructed on a quasi-experimental procedure using the pre-test, post-test control group design. The study sample consisted of 78 primary school students that were selected from two intact classes, with a mean age of 13.5 years. Students were assigned to two groups, with a control group and an experimental group comprising 38 and 40 students, respectively. The research instrument utilized to measure students' understanding of Augmented Reality components before and after treatment was based on a set of 40 multiple-choice questions. Learning sessions took place for one hour per week, spanning over four consecutive weeks, in which the control group and the experimental group used a desktop-based application and a mobile augmented reality application, respectively. Data were analyzed using paired samples t-test and analysis of covariance (ANCOVA). The results of the t-test explicated that there was a significant gain in students' understanding after training for both groups. The results of ANCOVA depicted the main effects of learning method and gender were significant, explicating the experimental group outperformed the control group and males outperformed females, respectively. Interestingly, a notable interaction effect between the learning method and gender, with both male participants tended to perform better when learning using MAR application. Exerted together, the foregoing findings underscore the significance of expending appropriate learning applications, notably mobile applications, in the teaching and learning of technology in a classroom such as Mathematics subject. Nevertheless, the finding implied female student should have given more expanse to familiarize such practice.***

***Keywords: Mobile Augmented Reality; Ancova Analysis and Mathematics Subject.***

## I. INTRODUCTION

In this new century, many new changes, transformations, and reforms have been taking place in many nations across the globe encompassing a wide range of the human's facets, such as the economy, politics, culture, technology, and education. From the economic perspective, nations need to be competitive and resilient to face new and emerging economic challenges.

Clearly, to attain such economic posturing, these nations need to have a sound, robust educational system that is capable to produce a vast pool of talents to spearhead the nations' economic initiatives. In recent decades, a number of technologies, especially Information and Communications Technology (ICT), have emerged as important tools to help nations move forward with greater ease and efficiency. More importantly, every society has to be literate enough to use such technologies with greater ease and confidence. In this regard, from the learning perspective, teachers need to use ICT learning tools to help them deliver and explain important concepts to their pupils [1, 2]. Of late, many developing nations have begun quartering in every resource available to improve the ICT literacy of their populace. In particular, Malaysia has embarked on several initiatives to help improve its educational system by focusing on the improvement of learning and teaching of science, technology, engineering and mathematics (STEM) courses or subjects. Amongst such courses, information technology (IT) has been given definite emphasis to help produce the future workforce that is highly skilled and competent in IT. To date, IT subject or course has been taught in all primary and primary schools in Malaysia, the impact of which has been quite wanting at best.

In tandem, new teaching strategies using novel technologies have been implemented to further improve the delivery of such STEM contents at the primary, primary, and tertiary levels. Notably, multimedia technology has been used quite extensively in the delivery of learning materials, which would lead to better students' engagement, motivation, and performance. Lately, many efforts have been devoted to improving existing pedagogical approach by expending a host of computer-based learning applications. Of late, the use of mobile learning tools has become quite a commonplace given the proliferation of mobile devices, in particular, mobile headphones, which are continually becoming more affordable and powerful, which students can use to enlist in collaborative and engaging [3]. In keeping pace with the advancements in mobile hardware, more and more applications, tools, or software has been developed for training and learning purposes, encompassing a full spectrum of disciplines. One of such software is the mobile augmented reality (MAR) that has been widely used to develop learning applications for mathematics [4], sciences [5, 6], engineering [7, 8, 9] and Programming [10] courses or subjects.

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Several studies have established that some of these learning applications have made a vast impact on students' engagement, motivation, and learning performance across the globe is a novel type of software that has excogitate from a series of technologies as far back in late 1960, in which the first head-mounted virtual reality (VR) system was developed by [11]. Spurred by Sutherland's (1968) invention, other newer technologies, both in terms of hardware and software have been developed and used, principally in the research and military domains, such as Immersive Technology, Virtual Reality (VR), and Augmented Reality (AR). Particularly, AR technology, which was developed by Boeing, has made an influential demeanor initially in the military and now in education [12]. In the first place, AR technology is a combination of real-world elements such as text, pictures, video and three-dimensional (3D) models, and animation, when utilized accurately in the decorous learning context can be potentially beneficial [13].

Based on the hardware and software, an AR system can be divided into two main categories, namely Marker-based AR and Markerless AR [14]. The marker-based AR systems use visual markers that, when scanned by the user's camera will launch an AR application. Typically, these markers are based on a pattern of black and white squares, and the most commonly used markers are the QR codes. Normally, these codes when scanned will be concocted by the user's device to deliver the contents, encompassing a range of elements such as 2D images, 3D objects, audio, video, and animations to the user [15]. On the other hand, the markerless AR systems make use of any part of the real environment as a target that can be tracked in order to place virtual objects – thus, eliminating the need for visual markers [16]. In order to perform the object tracking, markerless augmented reality systems rely upon natural features instead of visual markers. Hence, here lies a significant advantage of such systems, as there are no ambient intrusive markers, which are not literally part of the environment. Furthermore, markerless augmented reality makes use of existing specialized and robust trackers already available [17]. Another advantage of the markerless systems is the ability to extract from the environmental characteristics and information that may later be used by them. However, a primary downside of markerless augmented reality systems is that tracking and registration techniques become more complex [28]. Within these two types, the former is more affordable and easy to implement.

As highlighted in the literature, several studies of the use of MAR learning applications have been found to be effective in assisting students to learn various concepts and facts regarding biology, mathematics, natural science, and physics, among others. Arguably, each study has its own merits, and downsides, depending on an array of interrelated factors, notably learning context, the methodological approach practiced, and implementation strategy. In particular, gender has been consistently found to be a significant factor in most studies in which male participants inclined outperform their opposite counterparts [18]. Hence, such findings have to be considered with uttermost attention as they were established on case studies, the results of which may not replicate in other learning contexts. Against such a backdrop, this study was carried out with the main aim to develop a learning MAR application and to test its effectiveness in the learning of a topic of the Mathematics subjects such as fractions, a volume of liquids and percentage, among a group of primary students. The following research hypotheses were expressedto oversee the research:

a) Students' understanding of a topic of the mathematics subject before and after the learning treatments would differ significantly.

b) Students' understanding of a topic of the mathematics subjectwould differ significantly based on the method of learning (MAR basedlearning vs. conventional learning).

c) Students' understanding of a topic of the mathematics subject would differ significantly based on their gender.

## II. RESEARCH METHOD

This study applied a quasi-experimental research in which the research design was based on the pretest-posttest control group research design. The Quasi-experiment was preferred because to render more evidence for the educational values of AR that incorporate a large sample and valid instrument that is demanded [29].Notwithstanding, the limitation Quasi-experimental is the intact class given by the coordinator remarkably the principle of the school [30]. Due to the students' fixed timetable and logistical captivity, true randomization of students was not possible, thus precluding the generalization of the findings. As such, the findings of the study were limited only to the sample of the target population the use of ANCOVA for data analysis helped minimize any imbalance, if any, between groups. In addition, The following are the details of the research method of the study:

### Participants

The study sample consisted of 78 primary school students that were picked from two intact classes. Students in the first class comprising 17 males and 21 females (n = 38) were assigned as the control group, while the second class consisting of 18 males and 22 females (n= 40) was assigned as the experimental group.

### Learning Materials

Both groups were given a set of instructions, detailing the purpose of expected learning outcomes. They were also furnished with learning materials associated with the topic of learning of mathematics subject, albeit in different formats. For the experimental group, the participants were allowed to use their mobiles on which the mobile augmented reality learning application (MAR) was installed. For this group, the participants would use a simple poster to show several topics such as fractions, a volume of liquids and percentage with each having a target object to which they would use the headphone camera to scan. Once the trigger images scanned, relevant 3D models would be downloaded to their smartphone, with which they could interact for further investigation.

Besides, such visual displays, they could access additional information in the form of video and audio clips to learn the details of each component. For the control group, they were obliged to regulate the traditional approach in a normal classroom in which a similar application was installed. Figure 1 demonstrates a snapshot of the MAR application utilized by students in the experimental group.Furthermore, the example of a Multiple Choice Question(MCQ) question that has been proposed during the intervention session similar to what is the value place of four digits 1234567 and the student will answer the question by clicking the appropriate MCQ answers in MAR.In addition, the students also being exhibited to the explanation that presented through a pre-recorded video that has been outfitted by the teacher as depicted in the figure 2.In the recent studies, represented that the implementation of practicing videos can captivate the concentration of the students and also their level of motivation via teaching and learning in the classroom [33].

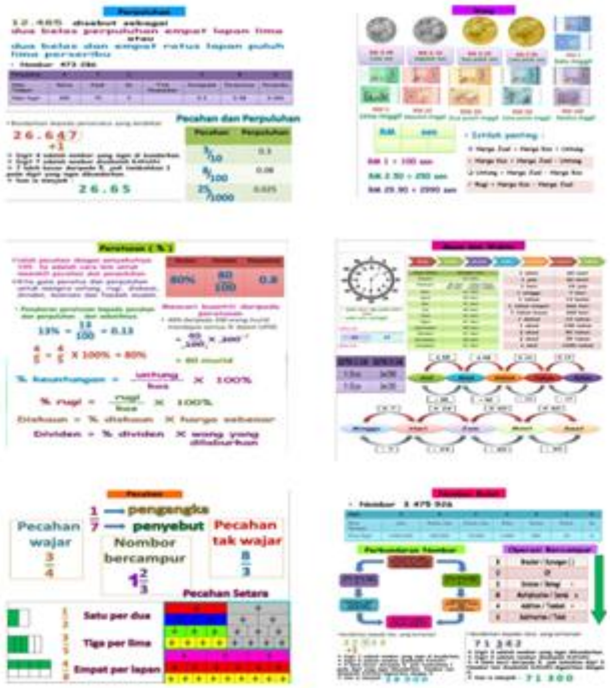

**Fig. 1** A snapshot of the MAR Mathematics application

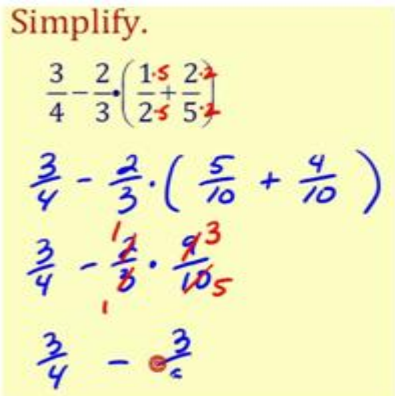


**Fig. 2** A snapshot of the video by teacher

**Procedure**

Participants' learning performances were measured before the learning session and after the last learning, fractions, a volume of liquids and percentage, comprising 40 multiple-choice questions that assessed their understanding of Mathematics subject. In fact, such questions were based on previous examination questions administered by a mathematics teacher of the selected school. As such, such questions were regarded both reliable and valid.Learning took place for one hour per week, spanning over four consecutive weeks. Through the learning sessions, the researchers played as facilitators in assisting the participants to utilize such learning materials.

## III. FINDINGS

For the control group, the results of the descriptive analysis showed that male and female students' understanding of mathematics subject before learning was 8.41 (SD= 1.17) and 9.05 (SD = 1.74), respectively. Subsequent learning, the male and female students' understanding progressed to 15.41 (SD =1.17) and 22.05 (SD = 1.74), respectively. For the experimental group, the results of the same analysis explicated that male and female students' understanding of mathematics subject before learning was 8.50 (SD= 1.09) and 9.09 (SD = 1.68), respectively. After learning, the male and female students' understanding rose to 29.50 (SD =1.09) and 22.18 (SD = 1.79), respectively. Table 1 compiles the mean scores of comprehension of mathematics subject of both groups before and after learning.

**Table. 1 Mean score and standard deviation of students' understanding**

| Group | Pre-test | | Post-test | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Control: | | | | |
| Male (n = 17) | 8.41 | 1.17 | 15.41 | 1.17 |
| Female (n = 21 ) | 9.05 | 1.74 | 22.05 | 1.74 |
| All (N = 38) | 8.76 | 1.53 | 19.08 | 3.66 |
| Experimental: | | | | |
| Male (n = 18) | 8.50 | 1.09 | 29.50 | 1.09 |
| Female (n = 22) | 9.09 | 1.68 | 22.18 | 1.79 |
| All (N = 40) | 8.83 | 1.46 | 25.48 | 3.98 |

The results of the t-test attested that there was a significant accretion in students' understanding after training for the control group, $t(37) = 21.03$, $p < .001$. Likewise, the same results indicated that the experimental group also attained a significant gain after learning, $t(39) = 26.35$, $p < .001$. Table 2 summarizes the results of the t-test for both groups.


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**Table. 2** T-test for control and experimental groups

| Group | Mean difference | SD | Std. Error | t | df | Sig |
|---|---|---|---|---|---|---|
| Control | 10.31 | 3.02 | .49 | 21.03 | 37 | .000** |
| Experimental | 16.65 | 3.99 | .63 | 26.35 | 39 | .000** |

The results of ANCOVA bestowed the main effect of the learning method was significant, attesting the experimental group outperformed the control group, F (1, 78) = 18,383.19, p < .001. Moreover, the same results indicated that the main effect of gender was also significant, which favored male participants, F (1, 78) = 327.96, p <. 001. Interestingly, the learning was a significant interaction effect between learning method and gender, with both male participants tended to perform better when learning using MAR the Mathematics application, F(1,78) = 17,922.35, p < .001. Table 3 compiles the results of ANCOVA.

**Table. 3 Result of Ancova**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 1908.15 | 4 | 477.03 | 9169.09 | .00 |
| Intercept | 373.23 | 1 | 373.23 | 7173.87 | .00 |
| Pre-test | 167.04 | 1 | 167.04 | 3210.75 | .00 |
| LM | 956.41 | 1 | 956.41 | 18383.1 | .00* |
| Gender | 17.06 | 1 | 17.06 | 327.96 | .00* |
| LM * Gender | 932.44 | 1 | 932.44 | 17922.3 | .00* |
| Error | 3.79 | 73 | .05 | | |
| Total | 40906.00 | 78 | | | |
| Corrected Total | 1911.94 | 77 | | | |

## IV. DISCUSSION

The paired samples t-test carried out showed that the students' understanding of Mathematics subject after the learning sessions was significantly greater than that prior to learning. Distinctly, this result provides ammunition to support the first research hypothesis stating that there will be a significant difference in the understanding of Mathematics subject before and after learning. This finding resembles consistent with other previous other findings indicating that learning or training sessions will have appreciable impacts on students' understanding of concepts or facts of what has been acquired [19, 20]. The analysis of ANCOVA attested that the experimental group significantly outperformed the control group, thus accommodating support to not reject the second research hypothesis which states that there will be a significant difference in the understanding of Mathematics subject between student groups based on the types of learning method used. Likewise, the same analysis explicated that male participants significantly outperformed their opposite counterparts, thus presenting strong evidence to support the third research hypothesis that states that there will be a significant difference in the understanding of mathematics subject between male and female students after the learning sessions. Ditto such findings are in line with other previous findings of studies of using mobile applications for the learning of mathematics, science, engineering, and technology [18, 21, 22].

Extra finding that should fascinate the teaching fraternity is that male students tended to perform significantly well when using the mobile application compared to when they were using the computer-based application [32]. Such differential performances were not replicated for the female participants. This finding is also consistent with other findings of studies of a similar nature[23, 24]. Obviously, such a finding warrants some explanations as to why a particular gender, namely male students, tends to exhibit superior performance in learning or training involving novel applications. In this regard, Rafi [24] propound that male students are arguably more receptive and eager to utilizing novel learning tools compared to female students given the former's rich experiences in using computer-based games or activities, thus making them more adept and familiar with computer-mediated environments. Such a finding is hardly surprising as male users are more able to solve spatial tasks in mobile augmented reality environments [25, 26, 27].
Taken together, the above findings underscore the significance of using appropriate learning applications, notably mobile applications, in the teaching and learning of technology courses such as Mathematics subject [31]. As demonstrated, such novel learning tools can be adopted by students to set forththeir understanding of technical concepts and facts more effectively and efficiently. Nevertheless, incomparably regard must be adhered to as gender factor conduces to moderate the learning impact, with male students having a greater ability to use such tools more effectively than female students. To alleviate such differential impacts, teachers and instructors should ordain more time and energies to inspire female students in familiarizing the utilization of mobile technology.

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