

Effects of Mobile Augmented Reality and Self-Regulated Learning on Students' Concept Understanding

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Abstract—Several studies have shown an increase in students' interest towards implementing augmented reality. The majority of these studies focus on how this technology can affect student performance with various abilities and skills. Therefore, the purpose of this study is to examine differences in students understanding level after using mobile augmented reality and conventional learning based on their self-regulated learning levels in the solar system class. Data were obtained from 91 students, with 47 of them in the experimental group using mobile augmented reality, while the remaining 44 are in the control group using conventional learning. This study measured students' self-regulated learning ability using a four-point Likert scale and 2multiple-choice questions. This result showed higher levels of concept understanding among students in the experimental group compared to the control. Furthermore, the results indicate the effect of the self-regulated learning level towards students' concepts understanding. It showed that students with high self-regulated learning levels had a different conceptual understanding from those with low self-regulated learning levels.

Keywords—Mobile Learning, Augmented Reality, Self-Regulated Learning, Students' Concept Understanding

1 Introduction

Mobile computing devices such as smartphones are currently used to provide positive contributions in learning. The smartphone also known as a mobile device as an instrument used to achieve learning goals irrespective of place and time[1]. Therefore, there is a need to adopt cellular technology in learning due to its capacity to attract and motivate students[2], providing an understanding and visualization of complex scientific reasoning[3]. Various studies have shown that this instructional technology encourages students to be directly involved in learning, influences performance, and motivation[4][5]. In addition, mobile learning has changed the educational paradigm effectively and flexibly.

The presence of augmented reality provided numerous ways for students to comprehend scientific concepts. It can embrace digital information in a variety of media formats, thereby enabling students to learn summary concepts using 3D and geometric objects[6]. Augmented reality has a property to draw attention, which enables the association of virtual and reality, thereby ensuring adequate learning knowledge through experience, interest, and encouragement[7]. The offered learning proficiency comprises of many factors with augmented reality as a new development technology in education[8]. Therefore, augmented reality attends to promote the edutainment concept and increase students' participation substantially.

The concept of mobile augmented reality emerged since mid-1990 as an interface technology established by cellular settings, thereby, making it useable by the learning environment[9]. In this way, the learning procedure is easier, more efficient, and the concept is properly understood[10]. Liu et al.[11] and Abdallah et al.[12] reported that mobile augmented reality provides benefits used to motivate students' involvement in learning, and the ability to rectify learning outcomes and experiences and performed significantly better than those in achievements and visual thinking..

This proves that the education system is widely open to the online environment, although there are many factors to consider for further development of the learning process. Therefore, it is estimated that the involvement of students' self-regulated learning is needed. Some research stated that the self-regulated learning process is recognized as an important factor in student learning success. Barnard et al.[13] stated that students with high self-regulating abilities are skilled and academically better than those with low self-regulated learning. This is because they proactively find information and develop themselves to master it. Furthermore, they can overcome difficult situations by viewing learning acquisition as a systematic and controlled process, therefore, they accept responsibility for their own achievement[14].

Development of Mobile Augmented Reality Application

Augmented reality enables users to determine experiences in the real and virtual world environments simultaneously. Milgram and Kishino[15] stated that the continuums of augmented and virtual realities are shown in figure 1.

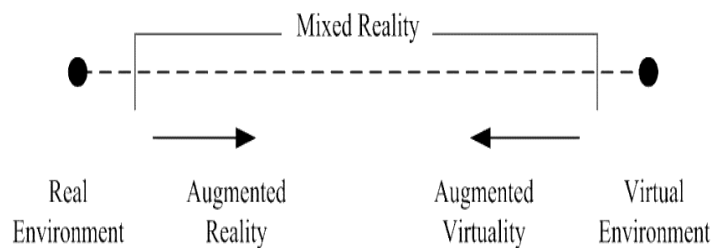


Fig. 1. Milgram Augmented Reality continuum

The situation in the two environments is called mixed reality, and it integrates digital information in a real environment. Augmented reality combines 2D and 3D object types with real-time interactions while reflecting mixed reality in the augmented

continuous[16]. Users experience natural and real human-computer interaction with virtual objects placed in a real view[17].

Preliminary observations have been made regarding the use of tools and learning technology. It was found that augmented reality was developed based on markers, with the use of computer equipment as teaching material. This study adopted sural[6] using the Vuforia SDK and Unity tools to achieve good support and documentation. Unity and Vuforia plugin are used to develop learning material because it is one of the best development platforms for building high-quality 3D and 2D games. The main components used in the development process are shown in figure 2.

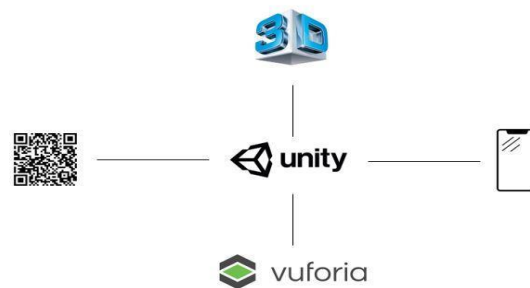


Fig. 2. Marker-based mobile Augmented Reality development process[6]

- **3D Models:** This is the most important part of an augmented reality application. The quality and functionality of virtual objects such as video, text, or 3D computer models, affect the application. The first step in marker-based augmented reality design is developing a 3D model or video, with a link used to show when the camera is scanning markers[6].
- **QR Code:** QR code is an evolution of the barcode. It is a type of matrix code or two-dimensional barcode with the main functionality readable by the scanner or smartphones and cellphones with cameras[18]. Initially, the QR code was used for tracking vehicle parts in manufacturing. QR codes are now used in a broader context, including commercial applications and the ease of tracking smartphone-oriented applications. The presence of this code allows the audience to interact through smartphones effectively and efficiently. QR codes have a smaller appearance than bar codes. QR code is able to accommodate data horizontally and vertically. Automatically, the size of the appearance of the QR code image can be only one-tenth of the size of a barcode.
- **Vuforia:** Vuforia is an augmented reality (SDK) software development device for mobile devices. It uses computer vision technology to recognize and track 3D objects, being able to position and orient virtual objects, such as 3D models and other media with real objects when viewed through a mobile device's camera. Vuforia SDK supports various types of targets, including image targets, 3D models, and fiducial marker shapes. It also allows developers to create augmented reality applications and games easily[19].

- **Unity:** Unity is an application for developing multi-platform games. Unity is fully integrated with professional applications. Unity graphics are high-level graphics for OpenGL and DirectX. Unity supports all file formats, especially common formats such as all formats of art applications. Unity is compatible with the 64-bit version and can operate on Mac OS X and Windows and can produce games for Mac, Windows, Wii, iPhone, iPad and Android.

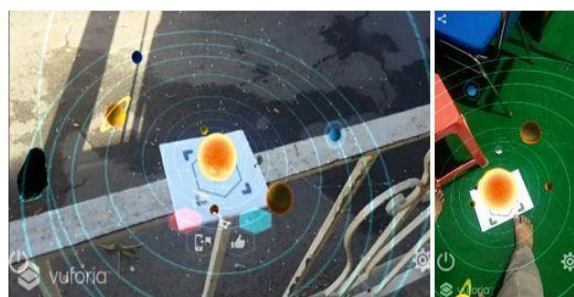


Fig. 3. Display augmented reality on mobile devices

2 Method

2.1 Research design

This study used a quasi-experimental design in the pretest and posttest non-equivalent control group. The study used an intact group to reduce the establishment of causal relationships due to the difficulty in randomly determining the subjects. There was no doubt on the equivalence groups before the experiment started[20]. The hypothesis tested in this study was the difference in students' mean scores of concept understanding. This was taught by using mobile-augmented reality based on self-regulated learning and those that learn without using mobile augmented reality.

2.2 Participant

Participants of this study involved the ninth-grade student of Pakuniran Probolinggo Public Middle School obtained through random cluster sampling. A total of 91 participants divided into the experimental group consisting of 47 students and the control group with 44 students.

2.3 Instruments

This research uses two types of research instruments:

Self-regulated learning: This instrument was developed by Onah & Sinclair[21] through the MOOC online self-regulated questionnaire (MOSLQ), used to measure the

dimensions of self-regulated learning. The study also used a 19 Likert scale items with a 4-point type, ranging from 4-always to 1-never to collect students' responses. Therefore, the research can be evaluated to answer the MOSLQ questions which were carried out using the following dimensions: Goal Settings (GS), the process where students set specific predetermined goals and plan, Task Strategies (TS), as students' ability to plan and strategize how to achieve set goals, Time Management (TM), as a dimension that involves the ability or skills of time management during learning, Environment Structuring (ES), as a learning dimension in an online or virtual environment, Help-Seeking (HS), as students ability to ask for help in their area of concern when studying online and Self-Evaluation (SE), as the process of reflecting student ability to understand the fields that have been achieved. One component in MOOC is the ability to collaborate and interact while learning, which are all aspects of discussion forums. Table 1 shows the 19 items of MOSLQ instrument questions.

Table 1. MOSLQ survey question

| | |
|------|---|
| GSQ1 | I know what to achieve in this study. |
| GSQ2 | I have prepared myself to study in this class. |
| GSQ3 | I have high standards in learning performance on this subject. |
| GSQ4 | I have set targets to achieve success in this lesson. |
| GSQ5 | I was not directly involved in this learning because it was carried out online. |
| GSQ6 | I have written down my predetermine goals after this lesson. |
| TSQ1 | I have a strategy to complete study assignments in order to achieve learning goals. |
| TSQ2 | I prepared myself by reading the available learning material before participating in this study. |
| TSQ3 | I set the study agenda before participating with online resources. |
| TSQ4 | I am prepared to face the challenges associated with learning. |
| TMQ1 | I have mapped out plans on how to spend a lot of time studying online. |
| TMQ2 | I found the right time to study, to avoid distractions. |
| ESQ1 | I chose a quite location (place) to avoid distractions while studying. |
| ESQ2 | I found a convenient learning location. |
| ESQ3 | I chose the right location to learn effectively. |
| HSQ1 | I plan to use the interactive communication channel in order to get support from peers and teachers (tutors). |
| HSQ2 | I intend to actively participate in the discussion forum in order to acquire maximal learning results. |
| SEQ1 | When following this lesson, I intend to reflect on my studies in each module |
| SEQ2 | I intend to be proactive in involving and reviewing progress in my chosen learning path |

Concept understanding: This instrument was developed to determine students' concepts understanding during the study. It starts by making a grid based on the concept understanding indicators and learning objectives for grade IX students in Junior High Schools to fulfill the content and items validity. The content validity in this study consists of conformity with learning objectives as reflected by indicators, tests arranged in a clear and simple form, and suitability tests to measure the conceptual understanding level on Physics. A trial was carried out for students group considered to have the same characteristics as those used as research subjects to analyze the test items' validity, differentiation, and difficulty level.

This study utilized a conceptual understanding test in the form of multiple choices consisting of 27 items. Furthermore, 20 items out of the 27 were found to fulfill the

empirical validity requirement. Subsequently, the test was carried out with content validity to ensure there were no unmeasured concepts. Based on the learning technology of experts and test result data, valid items to measure students' conceptual understanding are 20 from 27 compiled items.

2.4 Data analysis

This study analyzed the following data:

- The concept understanding between groups of students using conventional learning to examine mobile augmented reality.
- The concept understanding between groups of students with high and low levels of self-regulated learning.
- The interaction effect between mobile augmented reality learning and self-regulated learning towards students' concepts understanding, with data collected and analyzed using descriptive and variance analysis.

3 Result

3.1 Improvements on students’ concept understanding in experimental and control group

This study aims to determine the implementation effect of augmented reality mobile applications in improving students' concept understanding. Table 2 shows the differences between the mean scores of concepts understanding at the pre-test and post-test stages.

Table 2. The differences between mean scores of concept understanding pretest and posttest

| Paired Samples Statistics | | | | |
|---------------------------|-------|----|----------------|-----------------|
| | Mean | N | Std. Deviation | Std. Error Mean |
| Pretest | 69.89 | 91 | 5.238 | .549 |
| Posttest | 79.35 | 91 | 4.413 | .463 |

| Paired Samples Test | | | | | | | | |
|---------------------|--------------------|----------------|-----------------|---|--------|---------|----|-----------------|
| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| Pretest - Posttest | -9.462 | 5.214 | .547 | -10.547 | -8.376 | -17.311 | 90 | .000 |

The findings show a significant difference in students' concepts understanding after learning using the augmented reality mobile application. The paired sample tests showed a significant increase in understanding the pretest and posttest concepts (M = 9,462, SD = 5,214) with a significant increase in t (90) at -17,311 with a significant

below 0.05. These findings indicate that the augmented reality mobile application is an effective learning tool in improving students' concept understanding.

3.2 Differences in students' concept understanding based on self-regulated learning

This study also tested the differences in students' concepts understanding with low and high self-regulated levels, as shown in table 3.

Table 3. The differences students concept understanding based on self-regulated learning

| Concept Understanding | | | | | |
|-------------------------|----|-------|----------------|---------|---------|
| Self-regulated learning | N | Mean | Std. Deviation | Minimum | Maximum |
| High | 44 | 81.36 | 3.889 | 72 | 87 |
| Low | 47 | 77.47 | 4.059 | 70 | 86 |
| Total | 91 | 79.35 | 4.413 | 70 | 87 |

The findings show that the average score of students' concepts understanding with high and low self-regulated levels was 81.36 and 77.47, with a score difference of 3.89 at a significant p below 0.05. The rejection conclusion of the null hypothesis indicates that students 'self-regulated learning causes differences in students' concept understanding. This is supported by the results of the pairwise comparisons, which act as outputs of estimated marginal means, as shown in table 4.

Table 4. The differences between mean scores of concept understanding based on self-regulated learning, Pairwise Comparisons.

| Dependent Variable: Concept Understanding | | | | | |
|---|-----------------------|------------|------|---|-------------|
| (I) SRL (J) SRL | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Differencea | |
| | | | | Lower Bound | Upper Bound |
| High low | 3.791* | .661 | .000 | 2.476 | 5.105 |
| Low high | -3.791* | .661 | .000 | -5.105 | -2.476 |

3.3 The influence of interaction students' concept understanding between mobile augmented reality and self-regulated learning

Inter-subject effect test is interpreted as the interaction between learning with mobile augmented reality and self-regulated learning towards students' concepts understanding, as shown in table 5.

Table 5. Test of between subject effects

Dependent Variable: Concept Understanding

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|-----------------|-------------------------|----|-------------|---------|------|---------------------|
| Corrected Model | 889.560 ^a | 3 | 296.520 | 29.886 | .000 | .508 |
| Intercept | 571302.518 | 1 | 571302.518 | 5.758E4 | .000 | .998 |
| MAR | 508.014 | 1 | 508.014 | 51.202 | .000 | .370 |
| SRL | 326.117 | 1 | 326.117 | 32.869 | .000 | .274 |
| MAR * SRL | 46.436 | 1 | 46.436 | 4.680 | .033 | .051 |
| Error | 863.187 | 87 | 9.922 | | | |
| Total | 574751.000 | 91 | | | | |
| Corrected Total | 1752.747 | 90 | | | | |

a. R Squared = .508 (Adjusted R Squared = .491)

According to table 5, a statistical F-value of 46,436 is significant at $p < 0.05$ for interaction variables. This indicates that the null hypothesis is rejected without an interaction effect between mobile augmented reality and self-regulated learning assisted with concept understanding. In contrast, the hypothesis stated that there is an interaction effect between mobile augmented reality, and self-regulated learning assisted with concept understanding is accepted.

This research is strengthened by the F-value variables generated by partial eta squared for Mobile Augmented Reality (MAR) and Self-Regulated Learning (SRL) at $0.051 > 0.26$. Therefore it can be categorized as having strong interactions, which indicates that the research is in accordance with the actual situation[22]. Meanwhile, the adjusted R2 value generated by the model is 0.508, which means that MAR and SRL can be used to explain variations in the dependent variable of concept understanding. This means that 50.8% of the variation in concept understanding can be explained by the variables of mobile augmented reality and self-regulated learning.

4 Discussions and Conclusion

There is an adequate need to use technology contribution in education to shift the old paradigm in learning. The technological role is associated with replacing paper sheets in conventional learning with digitalized teaching materials[23]. The use of mobile augmented reality in learning has eliminated the limitations of space and time, thereby increasing students' motivation and concept understanding[24], [25]. This is evident from the analysis results associated with concepts understanding with significant differences obtained from the pretest and posttest scores. Therefore, mobile augmented reality learning has a considerable influence in improving students' understanding of concepts during the learning process. This is shown from the significant differences in the paired sample test results for concept understanding between students in the experimental and the control groups. Those in the experimental group showed higher concept understanding scores using mobile augmented reality than those in the control group that utilized the conventional learning technique. These results are in line with a Sural study[6], which stated that augmented reality needs to be

integrated into certain learning strategies, with further research carried out to determine the effectiveness of teaching and learning materials designed with augmented reality devices.

Teachers and students' responses in measuring the satisfaction level using mobile augmented reality are not included as the main objectives of this study. However, they performed a dynamic two-way interaction during the learning process and were motivated to achieve learning goals. This is in line with Ozdamli & Hursen [26] research, which stated that prospective teachers are very enthusiastic in managing to learn using mobile augmented reality. Meanwhile, Tugun [27] stated that the use of augmented reality applications on some material and other subjects influences students' positive roles.

Teachers and students find it challenging to change the learning environment from conventional to integrated technology[28]. This is because the use of technology and mobile devices requires them to possess different perspectives on learning and teaching[29]. This study shows that the aspects of technological mastery are essential for effective time management. This research is in line with Papadakis et al.[30] study, which stated that the use of software for the development of daily routines makes a substantial contribution in accelerating student learning time and understanding.

Other empirical results obtained in this study are that students with high self-regulated learning can manage to learn independently while mastering the online tools. This research is in line with the study carried out by Albelbisi and Yusuf [31], which measures six main factors that influence students' self-regulated learning in an online environment. In this study, MOOC online self-regulated questionnaire (MOSLQ) was developed and used as an instrument to measure the students' self-regulated learning level. This research is in accordance with Kizilcec et al.[32] and Littlejohn et al.[33] studies, which stated that the significant influence of self-regulated learning is in e-learning environments.

This research explained that concept understanding depends on students' level of self-regulated learning, which requires the online implementation of effective e-learning strategies[34]. The pairwise comparisons test results were used to determine the different levels of students' concepts understanding with variations between their high and low self-regulated learning. This study is in line with Cho and Shen[35] research, which stated that students with high self-regulated learning can learn independently. Therefore, their ability to successfully learn online is greater[36].

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