Keywords: m-learning, augmented reality, scorm, mluat, geography

Abstract. The perceived difficulties and challenges in teaching geography compels the use of innovative instructional approach. Hence, this study developed an augmented reality (AR) application for m-learning, ‘ARGeo Philippines’, to provide undergraduate-level students an interactive learning experience of Philippine geography. We applied the waterfall model in software development, and subjected the AR application to software quality test, usability test, and pedagogical effectiveness test. Using the SCORM standard, software quality requirements for the AR application was met generally. For usability as mobile application, the AR application was rated overall as ‘highly’ acceptable (Mean=4.15, SD= 0.29) using the MLUAT instrument. Pedagogical potential still requires further verification due to the statistically insignificant result; however, using the AR application resulted to higher learning gains than those from the traditional learning approach. Thus, it might be beneficial to further explore the use of the AR application as an alternative learning material for the academe.

1. Introduction

Geography is considered one of the most vital subjects in school. This subject enables students to learn the diversity of landscapes, people, societies and cultures. According to [1], geography demands the use of innovative instructional resources to help address the difficulties and challenges in teaching the subject. Hence, the study recommended the improvisation of instructional devices and materials in teaching the subject.

M-learning as cited by [2] can substitute traditional methods for learning given its accessibility, flexibility, ease of assessment and feedback [3]. Mobile devices, as platform for m-learning, are tools for stimulating motivation, strengthening engagement, and delivering content [4]. A key feature of e-learning and m-learning alike is how it allows the users to interact with the learning tool, in which this intuitive interaction can be facilitated through AR [5].

AR is a new and evolving technology that brings together the real and digital worlds, where the learner-user sees a real-world environment that is superimposed with computer-generated objects and texts. The literature already shows several successful applications of AR in educational setting. For instance, in [6] AR was utilized by the students for learning human anatomy. The results revealed that students were satisfied with the AR application in terms of its usability and features which the students believed have positive impact in their learning experience. Another study in [7], where a mobile AR system for chemistry laboratory experiment simulations was developed, aimed to improve student learning experience and student performance in conducting laboratory experiments. The study showed that the AR system satisfactorily met the standards of its respondents relative to the conduct of laboratory experiments. Furthermore, the AR system also demonstrated versatility and portability which offers convenience for the students.

Thus, in this present work, we aim to develop a mobile AR application for teaching and learning the Philippine geography targeted among the undergraduate-level students. Specifically, we envision
2. Review of Related Literature

2.1 Characteristics of AR

AR is a developing area of interactive design in which virtual content is integrated with real-world scenes or environments. For technology to be considered as AR, it has to 1) combine real and virtual elements, 2) be interactive in real time, and 3) be registered in 3D. AR-driven opportunities are continuously being studied and explored due to the rise of mobile devices that support AR experiences [8].

AR has attracted the interest of investors and the general public over the past 5 years along with virtual reality. Notable companies with the likes of Sony, Samsung, HTC, and Google are big investors of AR technology. According to [9], AR is considered as one of the most interesting technologies companies should invest in due to the Industry 4.0 or the 4th Industrial Revolution initiative. In the Industry 4.0, AR is stated to facilitate representation of relevant information to technicians and workers, enabling them to watch real-time information from the work they are performing [10].

On the other hand, user experience is an important consideration in interactive mediums such as in AR systems. The emotions created are a crucial part in using AR as they initiate behavior, trigger decisions, and move the attention to what is perceived as interesting, discarding the unsatisfying; which emotions felt by users while using the AR application greatly affects the general experience [11]. In addition, AR is still considered to be an emerging technology given a considerable number of mobile phone models that still do not support AR technology which reinforces the novelty of the AR experience. To quote [12]: “novelty has a strong impact on the user experience particularly for first time users, as it generates fascination, positive amazement and interest”. Consequently, as AR is still considered to be novel, it is thought as more entertaining that enhances the consumer experience in terms of hedonic value, which helps in generating higher user satisfaction and a higher purchasing intention [13] as cited in [11].

2.2 AR in Education

According to [14], AR's application in education has increased steadily over the past 6 years. College or its equivalent, high school, and primary school levels are the most common target groups for AR applications. Studies have shown that integrating AR systems into educational settings hold benefits including improvements in academic performance, learning attitude, and cost reduction.

For students using AR technology for learning, they tend to feel more motivated in their acquisition for knowledge which in effect can facilitate the improvement of academic performance. Consequently, improvement in students' academic performance can reduce the risk of grade repetition and dropout from school or college [14].

The benefits of applying AR in educational environments are enumerated and discussed in [15]. First in the list of perceived benefits is increased motivation, where users get more eager, interested, engaged in dealing, teaching, and learning information using AR compared with non-AR (NAR) approaches. Furthermore, users develop willingness to continue learning using AR technology after class hours strengthening proof of how AR motivates learning. Second, it increases attention. This advantage is due to the attention that users give toward the technology and in effect, to the content of teaching and learning. Third, it increases concentration that is similar to the detailed description for increased motivation through AR application in [16], where “physical interaction induced deeper
concentration”. Lastly, it increases satisfaction. Increased satisfaction refers to positive evaluation of the learning process facilitated with the help of AR technology.

One of the most important pedagogical features of AR is that it provides a student-oriented and flexible space to provide opportunities for learning. However, only the most open-minded teachers and innovative educational institutions are willing to apply AR apps in education. In addition, providing the same quality of AR content on any device is still virtually impossible. Yet, the potential of AR in education is enormous and still remains to be uncovered.

2.3 AR for Teaching Geography

As a next-generation interface, AR provides a different way to interact with information, which can be used to create better experiences of learning. According to [17], AR has the potential to transform teaching and learning of complex concepts and content in geography such as space. Their research explores AR's potential for advancing visualization tools in education and learning technology design and development.

Likewise, the introduction of AR in teaching and learning Geography and similar subjects involving complex 3D spatial phenomena and concepts can greatly contribute to the improvement of the teaching methods used. In another study that developed an application called GeoAR [18], they helped high school students learn Europe's geography - countries, capitals, flags, and neighbors. GeoAR allows its users to simultaneously play and learn. With a full game of various questions, GeoAR offers the opportunity to test and deepen one’s memory. The proponents of GeoAR concluded that the idea of teaching new information to students through an AR game is beneficial given its results, which shows how students memorized information without exerting much effort.

On the other hand, AR can also fundamentally change the way content is understood. Through the AR interface, instructional content delivery mechanisms are improved, and powerful cognitive learning experiences are made through a unique combination of visual and sensory information.

Recently, AR is becoming more accessible and widely used with the current adoption of mobile technologies and the recent advances in hardware. Hence, it is along these lines that this present work intends to explore further the application of AR in a mobile platform to teach geography in Philippine setting among undergraduate-level students. Thus, this research endeavor is an opportune time to make the first steps towards the AR direction [19] in effecting and improving the pedagogical experience via an alternative approach.

3. Methodology

3.1 Data Gathering

The data used for this study, e.g. information on each province, were gathered online from reliable sources such as the Philippine Statistics Authority (https://psa.gov.ph/), official provincial sites (https://www.cebup.gov.ph/, http://www.palawan.gov.ph/, among others.), and other popular sites like Trip Advisor (https://www.tripadvisor.com.ph/) and Choose Philippines (https://www.choosephilippines.com/). The “reliability” of the online sources was determined based on whether it is owned by a government agency or it is confirmed to be an official website.
3.2 Software Development and Tools

In developing the application, the software development model used was the waterfall model (see Fig. 1) since the requirements are already clear, documented, and fixed. Each phase of the software development process was completed before the next phase began and there was no overlapping in between phases.

![The Waterfall Model](image)

**Fig. 1. The Waterfall Model.**

The study used Unity3D, an integrated tool for developing interactive contents such as three-dimensional animations. This tool was integrated with ARCore, a Google platform for building AR experiences. Google’s ARCore tool enables the smartphone to sense its environment, understand the world and interact with information. The three-dimensional models were created using a free software, i.e. Blender [20]. In testing the AR application, the mobile device that we used is a Huawei Mate 20 Pro with Android version 9.0 (Pie). The device has a screen resolution of 1080 x 2240 pixels and there are three cameras arranged across its back with 40MP + 20MP + 8MP resolutions.

A copy of ‘ARGeo Philippines’ (ARGeo3.apk) application is made freely available for download in Google Drive for interested individuals who want to install and try with their mobile devices (https://drive.google.com/drive/folders/1_08jIb5PgjpwL2a5zGushn8sErw8fG9?usp=sharing).

3.3 Software Evaluation

3.3.1 Software Quality Test

In evaluating for software quality and overall integrity of the application, the Shareable Content Object Reference Model (SCORM) standard was used as it is considered as a well-known standard model in designing for e-learning materials. This evaluation was done for both self-administered (by the proponents) and invited external evaluator (i.e., software developer), who is a faculty teaching Software Engineering and related courses of the Department of Computer Science (DCS) of University of the Philippines Cebu (UP Cebu).

3.3.2 Pedagogical Potential Test

In determining for the pedagogical potential of the application in learning or teaching Philippine geography among undergraduate students, two experimental groups were formed with 20 respondents for each group. The respondents were randomly selected and assigned to each group. The first experimental group studied the Philippine geography for 10 minutes using the AR application while
the second group also studied for 10 minutes using a printed module of similar contents. Specifically, the first experimental group was oriented first (prior to the learning session) on how to use ‘ARGeo Philippines’, at the same time, they were briefed on the purpose of the mobile application and were introduced to its functionalities. After the learning sessions, both experimental groups were given a 10-question assessment (i.e. paper-based) to test their learnings. To determine whether the assessment results of the two experimental groups are statistically significant, the T-test for Independent Samples was calculated using SPSS statistics software (ver. 26).

3.3.3 Usability Test

On the other hand, only those student-respondents who were assigned to try the AR application was surveyed using the Mobile Learning Usability Attribute Testing (MLUAT) evaluation instrument [21] to evaluate the usability of the mobile application - ‘ARGeo Philippines’. The MLUAT evaluation forms were given to the respondents immediately after 10-question assessment or quiz. The evaluation was done in the DCSes research laboratories at UP Cebu.

4. Results and Discussion

4.1 ‘ARGeo’ Application Interface and Features

4.1.1 Detecting Ground Surfaces

Before the user can add a virtual object in the real-world environment, a ground surface that is big enough should be detected. Looking for ground surface feature as shown in Fig. 2a starts automatically after pressing the start button in the mobile application’s menu. The user should point the phone’s camera to the ground to be able to detect ground surfaces. The detected ground surface is then highlighted with a violet sheet as shown in Fig. 2b.

![Fig. 2. Before (a) and after (b) ground surfaces are detected.](image-url)
4.1.2 Add ‘Map’ Button

After successfully detecting ground surfaces, the user could now add a virtual object in the real-world environment. This can be done by pressing the add button located at the bottom right of the application. When the button is pressed, a window appears as shown in Fig. 3 that gives the user options on what to augment. The options are the 81 provinces of the Philippines, the 17 regions, three (3) major island groups, and the Philippines as a whole.

![Fig. 3. Button to add a map overlay to the ground surface.](image)

4.1.3 Displaying the Maps

Furthermore, multiple virtual objects can also be placed into the real-world environment as shown in Fig. 4 (i.e. overlaying the virtual map of the three (3) Philippine major island groups) and Fig. 5 (i.e. overlaying the virtual map of one of the major Philippine island groups). The virtual objects can be moved by clicking the object once and can also be resized by pinching.

![Fig. 4. Augmenting the ground surface with the three-island group of the Philippines.](image)
4.1.4 Hiding/Unhiding Labels

The labels displayed in Fig. 6a are the names of each province in the Philippine map. The user could hide the labels as shown in Fig. 6b of the virtual objects in the application by pressing the ‘i’ button located at the lower left corner of the screen display. This feature serves to give an option for the user when studying to remember and to test whether the information is mentally retained.

4.1.5 View Province Information

Fig. 7 shows information of a province that is augmented to the ground surface. The information can be shown when the user clicks the virtual object. It contains information such as region, area, capital, and population (Fig. 7a); number of cities, municipalities, barangays, and districts (Fig. 7b); the governing officials of the province such as the governor and vice governor including their terms of
office (Fig. 7c); popular delicacies produced from the province (Fig. 8d); and, at most four (4) popular tourist spots of the province (Fig. 7e).

Fig. 7. Displayed information for a province when selected: region, area, capital, and population (a); number of cities, municipalities, barangays, and districts (b); governing officials with their corresponding terms of office (c); popular delicacies produced (d); and, four (4) popular tourist spots (e).

4.2 ARGeo Software Quality Test Results

The evaluation of the software using the SCORM standard was done by our group (i.e. self-assessment mode) and in tandem with an invited external evaluator (i.e. software developer cum faculty of DCS). The consensus results revealed that the application passed the ‘Accessibility’ requirement considering that the application can be shared online and offline. Moreover, the ‘Durability’ requirement was met since the application was developed using the latest versions of the software tools used to create the AR application. The AR application also passed the ‘Reusability’ requirement due to the fact that the application can be used many times. For the AR application’s relatively easy to install and freely available for download satisfied the ‘Affordability’ requirement of the SCORM standard. However, among the criteria of SCORM, only the ‘Interoperability’ requirement could not be fully met partly because the AR application can only run smoothly in smartphones with Android OS and in some limited number of mobile phones. This finding can be well-justified by [19] which reported that it is virtually impossible up to this time for AR content on any device to be provided the same quality due to its portability issues. In addition, considering that the use of AR for m-learning application is still an emerging technology, and hence, could still be not available in all devices.

4.3 ARGeo’s Pedagogical Potential

Table 1. Descriptive measures of the assessment ratings (n=40).

<table>
<thead>
<tr>
<th>Learning Method</th>
<th>n</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>20</td>
<td>6.15</td>
<td>2.30</td>
</tr>
<tr>
<td>M-learning (ARGeo)</td>
<td>20</td>
<td>7.00</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Note: P-value > 0.05ns
Table 1 shows the mean assessment scores for the two experimental (learning) groups. M-learning with the ‘ARGeo’ application, on the average, has resulted consistently (i.e. lower standard deviation) to higher assessment scores than traditional learning method. To determine if the observed numerical difference in the mean assessment scores is statistically different, the t-test for independent samples was employed. Unfortunately, the statistical result revealed that the mean assessment scores from the two experimental (learning) groups have no significant difference (i.e. \( p\)-value > 0.05). This means that, statistically speaking, the student-respondents in the traditional learning group did just as well as the respondents in the M-learning (‘ARGeo’) group. Hence, at this point in time, we cannot conclusively say regarding the effectiveness of the ‘ARGeo Philippines’ application with respect to its pedagogical potential (over the traditional learning method) even if it tends to effect “positive” learning outcome as shown by a reliably higher mean assessment scores.

One of the plausible reasons of the seemingly similar learning outcome between the m-learning (‘ARGeo Philippines’) and the traditional learning methods studied here is the fact that the informational content or information covered spans wide (17 regions and 81 provinces of the Philippines for that matter) for a coverage to study within a short period of time (i.e. 10-minute learning session).

By examining closely also the raw assessment scores of the two (2) experimental (learning) groups, we have noticed that only 3 student-respondents out of 20 (15%) got scores below 6 (out of 10 items) for the M-learning group while twice that number (30%) was observed in the traditional learning group. Furthermore, the remaining 85% of the student-respondents from the former group have obtained scores proximate to each other.

4.3 ‘ARGeo’ Software Usability Test Results

The AR application, ‘ARGeo Philippines’, was evaluated for the usability as a mobile application using the MLUAT evaluation instrument. The level of acceptance was measured using a 5-point rating scale with 5 being the highest and 1 being the lowest.

![Fig. 8. Results of the usability test using the MLUAT evaluation instrument (n=20).](image-url)
Fig. 8 shows the usability attribute test results using the MLUAT evaluation instrument. The ‘visibility of system status’ category got the lowest mean rating among the criteria (M= 3.80; SD=0.60), but above the average. This implies that the student-respondents find the system’s visibility as determined by the clarity with easy interpretable labels of the application and the consistency during navigation as fairly acceptable. The next lowest rated category is the ‘flexibility and efficiency on screen’ criterion (M= 3.90; SD= 0.91), in which the student-respondents have rated variably, i.e. with the highest standard deviation. Nevertheless, only these two (2) MLUAT criteria categories were rated below 4, but still well above the average.

For the other criteria, the student-respondents have rated the AR application quite satisfactorily or acceptable: ‘learner control and freedom’ (M= 4.00; SD= 0.63), ‘consistency and loyalty to standard’ (M= 4.13; SD= 0.69), ‘match between the system and the real-world’ (M= 4.18; SD= 0.56), and ‘minimize information on screen’ (M=4.50; SD= 0.57).

The best rated category, so far, is the ‘recommendation’ criteria (M=4.58; SD= 0.43), which means that the student-respondents find the AR application, ‘ARGeo Philippines’, helpful for studying the Philippine geography and that they would recommend this to other students if given the chance. It is also noteworthy that this criteria have the most consistent or reliable ratings obtained through the MLUAT evaluation. This simply means that the student-respondents are consistent in their desire to recommend the AR application to other students.

Overall, the mean rating for the AR application is highly acceptable (M= 4.15; SD= 0.29) or rated ‘Very Good’ reliably, which implies that ‘ARGeo Philippines’ has met the criteria for usability as a mobile application. In addition, most student-respondents also have shared their thoughts that the AR application is user-friendly with useful features that satisfies the user experience.

5. Conclusion and Future Works

An interactive AR mobile application for teaching Philippine geography was developed successfully wherein its pedagogical effectiveness, usability, and software quality characteristics were tested. Based on the results from the usability test (i.e. MLUAT), we can confidently say that the AR application developed for teaching Philippine geography is highly acceptable (M= 4.15; SD= 0.29) as a mobile application with useful features that satisfies the user experience. Although, the existing evidence of its pedagogical effectiveness is weak, using the AR application (‘ARGeo Philippines’) tends to have higher learning gains (as evidenced by the numerically higher assessment scores) than those subjected to the traditional learning approach. In effect, this can be considered as an alternative aid for teachers in teaching Philippine geography in the classroom setting as well as for students who are studying at home. Thus, it might be beneficial to further explore the use of the AR application as an alternative learning material for the academe.

For future works, it is desirable to have more functionalities and shortcuts in the AR application, e.g. when a province is clicked in the augmented Philippine map, related information should be shown also. A better control for model rotation and zoom capability are looked forward to in the next iteration of the AR m-learning application. Likewise, the addition of animations can be pursued judiciously to add more entertainment value to the AR application.

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