NIGERIAN ONLINE JOURNAL OF EDUCATIONAL SCIENCES AND TECHNOLOGY
nojest.unilag.edu.ng
nojest@unilag.edu.ng

USABILITY ASSESSMENT FOR DEVELOPMENT OF AUGMENTED REALITY FOR GEOGRAPHICAL INFORMATION SYSTEM

SULEIMAN ZUBAIRU, SOETAN, ADERONKE, K, & ABUBAKAR UMAR, M.

Gombe State University, Nigeria.
University of Ilorin, Nigeria.
Kwara State College of Education, Nigeria
zubairusulain@gsu.edu.ng

To cite this article:
Suleiman Z, Soetan, A. k, & Abubakar, U, M. (2023). Usability assessment for development of augmented reality for geographical information system. *Nigerian Online Journal of Educational Sciences and Technology (NOJEST)*, 5 (2), 276-287

Nigerian Online Journal of Educational Sciences and Technology (NOJEST)

Volume 5, Number 2,2023

USABILITY ASSESSMENT FOR DEVELOPMENT OF AUGMENTED REALITY FOR GEOGRAPHICAL INFORMATION SYSTEM

SULEIMAN ZUBAIRU, SOETAN, ADERONKE, K, & ABUBAKAR UMAR, M.

Article Infor

Article History

Received:
20 June 2023

Accepted:
November 28, 2023

Keywords
Usability Assessment, Mobile Package Development, Augmented Reality, Geographical Information System, Undergraduate Students

Abstract

The development of Augmented Reality (AR) for learning Geographical Information System (GIS) involves several challenges pertaining usability. Thus, this study conducted usability assessment during development of AR package for learning GIS (ArGIS) for undergraduate students in Gombe State, Nigeria. The study was based on design and development using pre-test and post-test. The population for the study comprised 194 undergraduate students from two universities in the state. The participants were purposively sampled using two intact classes of 84 in experimental group and 110 in control group. A sample of 15 experts from Instructional Design, GIS and Computer Science were involved in the study. A 3rd version Post-Study System Usability Questionnaire (PSSUQ) widely used in Human Computer Interaction (HCI) was adopted for the study. The PSSUQ was a standardized tool with 0.90, 0.91 and 0.83 reliability coefficients for system usefulness, information and interface quality respectively. The PSSUQ was administered both during and after development of the package. The findings revealed that the ArGIS was rated 94.875% and 97.35% usable by experts and students respectively. The study concluded that usability assessment of mobile package depends on the users, their characteristics and skills, the task they want to perform as well as the context of use. It was therefore recommended that usability assessment should be carried out throughout AR package development process for satisfying the desired learning needs in GIS and remote sensing tasks.

Introduction

Electronic or mobile learning comes with emerging technologies that align with learning needs and styles of digital natives. Augmented Reality (AR) emerged as one such technology that has the potentials to respond to the learning needs and styles of digital natives. AR is an immersive interactive experience of a real-world environment where features of the real world are enhanced

by computer-generated perceptual information (Marto, Goncalves, Melo, Bessa, & Silva, 2023). There are numerous benefits in integrating AR in education such as getting prompt feedback through synchronous interaction and simplifying complex concepts as well as students' ability to learn about the concepts and environment around them without being removed from the classroom (Cafino, 2021). AR based instruction can enable flexibility of time, space and audience depending on several associated factors.

AR has been widely applied not only in education but in many fields such as engineering, medicine, commerce, entertainment and so forth. An AR-based support system was used for training of skeching and orthographic projection drawing as an engineering course in Malaysia. The research has shown that an AR instructional package can give full demonstration of 3D virtual objects, and can effectively improve learners' attention and learning outcomes better than the traditional mechanical drawing (Horii & Miyajima, 2013). In this study, AR package was developed and integrated in students' handheld devices for instruction in Geographical Information System (GIS) course.

The term GIS is a convergence of traditional and technological disciplines such as geography, cartography, mathematics, statistics, computer science, surveying and photogrammetry. Research has shown that GIS systems are used in cartography, remote sensing, land surveying, public utility management, natural resources management, population distribution, photogrammetry, geography, urban and regional planning, emergency management, risk management, navigation and localized search engine (Musa & Abubakar, 2010). This means that many related disciplines provide techniques which make up the scope of GIS. These disciplines especially in Earth Sciences deal with spatial data, and GIS brings them together by emphasizing integration, modelling and analysis. Thus, GIS often claims to be the science of spatial information. GIS is a technology for collection, storage, analysis and dissemination of spatial data, and the outcome is usually displayed as spatial information in form of maps (Atubi & Dania, 2022).

Among the uses of GIS is that it allows planners to easily calculate emergency for evacuation in case of natural disaster such as earth's quake, earth's tremor, landslide and tsunami (Bajjali, 2018). GIS may be used to also locate wetlands that need protection strategies regarding water pollution or animal grazing, or it can be used by a firm to site a new business location in response to a

previously under-served markets (Goodchild, 2010). The interaction between AR and GIS creates even more opportunities both in the fields of education and geography. Students can use AR application in GIS for mapping, navigation, data collection and analysis, or for the purpose of learning GIS as a course.

As a best practice of mobile package development and implementation, usability trial testing is crucial. The process of rating the package by experts or exposing the users to the package for assessment of ease of use, interactivity and satisfaction is termed usability assessment (Lewis, 2002; Lewis, 2012; Lewis, 2014). This standard helps in developing a usable product desired by users. Usability test is a common standard used especially in projects related to HCI. It is a formal assessment of the extent to which user interaction with a system was effective and efficient. The development of effective AR package for GIS course (ArGIS) is therefore significantly dependent on usability assessment using standardized scale.

In elaborative sense, usability assessment also refers to the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (Aiyegbusi, 2020). This involves determining an interaction among several factors in iterative design such as users, product, task and environment. The main variables associated with usability of a mobile learning package are effectiveness, efficiency and user subjective satisfaction. The participants in a usability test consists of target users of the product or package to objectively measure its usability metrics (Lewis, 2014). The term mobile package in this study was the design and development of AR package for learning GIS (ArGIS) and determining the extent to which the package is usable by its users.

Research Questions

1. What is the experts' usability rating of AR instructional package for GIS course?
2. What is the usability rating index of AR instructional package for GIS course as perceived by undergraduate students in Gombe State?

Review of Related Literature

This research reviewed relevant literature on the concept, types and importance of usability assessment within the context of mobile technology development and implementation with

reference to AR package development for teaching and learning GIS course. The literature review is particularly imperative in understanding the essence of usability assessment and to identify gaps in mobile package development process with a view to guide the current and future research.

Concept and Context of Usability Assessment

As traced by Lewis (2012), the term usability came into literature in the early 1980s in an attempt to replace some concepts that determine acceptance of an emerging technology such as user friendliness and ease of use. Other researchers also noted that usability testing originated from experimental methods used in Cognitive and Applied Psychology with strong ties to HCI and iterative design (Dumas & Salzman, 2006). Several computer companies, practitioners and researchers usually employ usability testing during development and implementation of materials or products.

Usability basically involves two conceptions or types in terms of formative and summative tests. Each of these conceptions of usability is different in purpose and scope. Formative usability test aims to detect problems of usability and design of interventions, which makes it a diagnostic usability evaluation. Formative usability is tied to iterative design usually with the application of design test redesign-retest (Lewis, 2012). It is in formative usability that problems and errors can be identified, classified, counted and measured for improvement in the development process of a mobile learning package. This implies that formative usability aims to measure ease of use of material or product. As postulated by Lewis (2014), ease of use is inversely proportional to the number and severity of difficulties people face in using software. However, summative usability is directly a measurement-based usability as it deals with meeting global task and product goals.

Usability has several extensions including user-centred design (UCD) and user experience (UX). The extensions of UCD were primarily in the specification of product development practices and included usability engineering, human factors engineering, and ergonomics all within framework intended to incorporate these activities into the product development life cycle. For UX, the extensions have been more in the direction of design and measurement beyond the traditional goals of effectiveness, efficiency and satisfaction to experiences that have a more compelling emotional effect. Lewis (2014) predicted that UX will become part of a larger customer experience effort

especially given recent emphasis on service design and the emergence of the discipline of service science.

Most experts have acknowledged the fact that no mobile instructional package could be successfully developed and implemented without due consideration to usability metrics. The goal of usability assessment is basically to help developers produce more usable products. It also aims to identify and rectify usability deficiencies existing in computer-based and electronic materials prior to their official release. Usability metrics have been grouped into three as self-reported, observer-reported and implicit metrics (Romano-Bergstrom & Strohl, 2013; Aiyegbusi, 2020). Self-reported metrics come directly from participants and include satisfaction and difficulty ratings. Observer-reported relates to assessments of participants' actions by the evaluator. Observer-reported metrics include time to complete tasks.

The self- and observer-reported metrics may suffer from bias as participants often consider their responses and are conscious of their actions and may not act as they would in real life (Natesan, Walker, & Clark, 2016). Implicit metrics which are less commonly used may provide the most unbiased data as they measure participants' unconscious behaviours and physiology (Geisen & Romano-Bergstrom, 2017). These include eye tracking and pupillary dilation (Romano-Bergstrom & Schall, 2014). Some quantitative metrics of usability assessment include error and completion rates, time required for completing tasks, numbers of clicks to complete tasks, cost effectiveness, overall satisfaction rates and proportion of users reporting complaints (Aiyegbusi, 2020).

Although effectiveness, efficiency and subjective user satisfaction are often assessed quantitatively, but it could be assessed qualitatively. For instance, effectiveness could be assessed by discussing errors and successful tasks completion with the participants, and the participants could also express their satisfaction with the package in their own words (Geisen & Romano-Bergstrom, 2017). The choice and number of metrics to measure may be influenced by the type of usability testing being conducted. For instance, formative testing may involve the measurement of fewer quantitative metrics; relying more on qualitative feedback from participants, while summative testing, which often involves more statistical analyses, tends to require the measurement of more quantitative metrics.

Many usability scales have been developed and used by other researchers especially within the purview of HCI such as System or Software Usability Scale (SUS), which is usually used across broad spectrum of mobile package; the Website Analysis Measurement and Inventory, which is used for usability metrics of websites as well as Patient-Reported Outcome (PRO) questionnaire for validating ePRO system (Aiyegbusi, 2020). Lewis (2014) also reported that other usability scales include Questionnaire of User Interface Satisfaction (QUIS) and Post-Study System Usability Questionnaire (PSSUQ). The usability assessment for this study was based on the PSSUQ.

In a study on usability of Learning Management System (LMS) based on USE questionnaire (measuring 3 metrics of usefulness, ease of use, ease of learn and satisfaction) and with the use of eye-tracking device in which the study revealed that the LMS gained usability metrics of 81.29%, 79.87% and 85.16% for the 3 aspects of USE questionnaire. The study aimed at experimenting usability test in which 35 students were used. The outcome of the study showed that user interface displays affected web-based application's usability since the user interface becomes an essential component of all computer applications (Sidhawara, 2022). From the Sidhawara's study, it was also established that eye-tracking technology just like AR can be used to support the usability evaluation as a source of real-time information on the user's behaviour when interacting with interface.

To offer guidelines for conducting a worthwhile usability study, Lewis (2012) provided in his chapter contribution some tips on managing chances of error in estimating sample size for usability tests. These essential tips include using highly skilled observers; focus evaluation on new products with newly designed interface rather than older or a more refined interface; using examiners with usability and application-domain expertise during heuristic evaluation, and to ensure that the chosen sample is heterogeneous within the boundary of the population to which the results or findings will be generalized.

METHODOLOGY

The research design used for this study was quasi-experimental research and a design and development model using pre-test and post-test. The choice of quasi-experimental design was based on the need to compare experimental and control groups through pre-test and post-test on

their perceptions about the usability metrics of the ArGIS. The study also considered design and development model in which Cordova programming framework was used through the development of the package. Design and development of a mobile package must be guided by an appropriate framework and evaluating its effectiveness must be in quasi-experimental settings even though there are several types of such settings (Creswell & Guetterman, 2019). Specifically, the study also considered none-equivalent groups (intact classes) and administration of pre-test and post-test to the two groups as illustrated in Figure 1.

R O_1	X	O_2	Experimental Group (84)
R O_3		O_4	Control Group (110)

Figure 1: Symbolic Representation of the None-Equivalent Groups with Pre-test and Post-test

As depicted in the above figure, the population for the study comprised 194 undergraduate students from two universities in Gombe state of Nigeria in which the participants were purposively sampled into two intact classes. The consideration of the whole population as sample in a single study is termed Total Population Sample (TPS), which is the best representative sample size selection (Creswell & Guetterman, 2019). To ensure experts' rating of the package, a total of 15 experts were purposively sampled as shown in Table 1.

TABLE 1: **NUMBER OF EXPERTS FOR RATING THE AR PACKAGE**

University	Area of Expertise	Experts
University of Ilorin, Ilorin	Educational Technology	5
GSU and FUK	Geographical Information System	5
GSU and FUK	Computer Science	5
	Total	**15**

Note: GSU means Gombe State University, while FUK means Federal University, Kashere. These two universities were all in Gombe state, which is located in north-eastern Nigeria.

A 3rd version of PSSUQ was adopted from Lewis (2002) and used during the treatment package development to determine its usability metrics. The PSSUQ was a standardized tool with 0.90,

0.91 and 0.83 reliability coefficients for its three components of system usefulness, information and interface quality respectively (Lewis, 2012). The instrument was administered to experts and students at different times when the package was developed. This activity lasted for a period of 6 weeks. The data collected was analysed using descriptive statistics of mean and percentage for answering the research questions posed.

Results

Research Question 1: What is the experts' usability rating of AR instructional package for GIS course?

Table 2: mean rating of Usability of the Package by Experts

S/N	Statements	Mean
1	Overall, I am satisfied with how easy it is to use this package.	2.12
2	It was simple to use this mobile package.	2.34
3	I was able to complete the tasks and scenarios quickly using this package.	2.23
4	I felt comfortable using this package.	2.25
5	It was easy to learn to use this package.	2.32
6	I believe I could become productive quickly using this package.	2.38
7	The package gave error messages that clearly told me how to fix problems.	2.02
8	Whenever I made a mistake using the package, I could recover easily and quickly.	2.13
9	The information (such as online help, on-screen messages and other documentation) provided with this package was clear.	2.60
10	It was easy to find the information I needed.	2.52
11	The information was effective in helping me complete the tasks and scenarios.	2.13
12	The organization of information on the system screen was clear.	2.33
13	The interface of the package was pleasant.	2.50
14	I liked using the interface of the package.	2.47
15	This package has all the functions and capabilities I expect it to have.	2.50
16	Overall, I am satisfied with the package.	3.11
	Weighted Mean	**37.95**

EQUATION 1: EQUATION TO SHOW THE EXPERTS RATING OF THE USABILITY INDEX OF THE ARGIS PACKAGE

∴From Table 2, the weighted mean score of the package was calculated at 37.95. The score was then normalized by multiplying the weighted mean score by a coefficient of 2.5 (benchmark) as depicted in Equation 1. The experts' usability index rating of the package was therefore about 95 out of a maximum possible score of 100%. This implies that the package is usable and satisfactory for the purpose of teaching and learning GIS course.

Research Question 2: What is the usability rating index of AR instructional package for GIS course as perceived by undergraduate students in Gombe State?

TABLE 3: MEAN RATING OF USABILITY OF THE PACKAGE BY UNDERGRADUATE STUDENTS

S/N	Statements	Mean
1	Overall, I am satisfied with how easy it is to use this package.	2.50
2	It was simple to use this mobile package.	2.44
3	I was able to complete the tasks and scenarios quickly using this package.	2.23
4	I felt comfortable using this package.	2.25
5	It was easy to learn to use this package.	2.32
6	I believe I could become productive quickly using this package.	2.38
7	The package gave error messages that clearly told me how to fix problems.	2.50
8	Whenever I made a mistake using the package, I could recover easily and quickly.	2.13
9	The information (such as online help, on-screen messages and other documentation) provided with this package was clear.	2.60
10	It was easy to find the information I needed.	2.52
11	The information was effective in helping me complete the tasks and scenarios.	2.13
12	The organization of information on the system screen was clear.	2.33
13	The interface of the package was pleasant.	2.50
14	I liked using the interface of the package.	2.50
15	This package has all the functions and capabilities I expect it to have.	2.60
16	Overall, I am satisfied with the package.	3.00
	Weighted Mean	**38.94**

EQUATION 2: EQUATION TO SHOW RATING OF THE USABILITY INDEX OF THE ARGIS PACKAGE BY UNDERGRADUATES

Table 3 presents the mean of usability test of the package as rated by undergraduate students. As shown in the table, the weighted mean score of 38.94 when multiplied by the benchmark of 2.50 = 97.35 at the maximum obtainable score of 100. This means the package was rated about 97% by the respondents as usable and learnable for GIS course.

Discussion of Findings

The study further revealed that the package was found to be highly usable for effective learning of GIS course after formative and summative trial testing. This finding is in line with the assertion of Aiyegbusi (2020) and Lewis (2014) that usability trial testing is a formal assessment of the extent to which user interaction with a system was effective and efficient. To establish a more usable learning package, effectiveness, efficiency and perceived satisfaction should be measured in a usability assessment. Aiyegbusi (2020) also explained that effectiveness in usability assessment is the ability of the participants to perform tasks accurately to achieve pre-determined objectives, while efficiency relates to the number of resources required by the participants to achieve the set

objectives. This research finding is also consistent with Lewis (2012) that usability index of a learning package shall be determined by formative and summative tests using the same research participants in a given interval. Although the package and context were different, the findings of this study are also consistent with those of Sidhawara (2022) on the significance of usability assessment in developing effective learning package based on established usability metrics.

Conclusion and Recommendations

The best practice for mobile technology design, development, implementation, and evaluation is to incorporate usability assessment intermittently through the process. The usability assessment depends on the users, their characteristics and skills, the task that they want to perform as well as the context of use. Both relevant experts and the actual users of a product are significant in providing the product's usability data required in usability assessment. Hence, it is therefore recommended that both formative and summative usability assessment should be carried out throughout AR package development process for satisfying the desired learning needs.

References

Aiyegbusi, O. L. (2020). Key methodological considerations for usability testing of electronic patient-reported outcome (ePRO) systems. *Quality of Life Research*, 325-333. doi:https://doi.org/10.1007/s11136-019-02329-z

Atubi, O. F., & Dania, P. O. (2022). Geographical information systems as learning resources for Social Studies: A literature review. *Journal of Digital Learning and Education, 2*(1), 42-50. doi:10.52562/jdle.v2i1.325

Bajjali, W. (2018). *ArGIS for environmental and water issues.* USA: Springer International Publishing. doi:https://doi.org/10.1007/978-3-319-61158-7_2

Cafino, G. (2021). Frequency and satisfaction to the flexible mode of learning utilized by higher education institutions in National Capital Region. *Academia Letters, 2169*. doi:https://doi.org/10.20935/AL2169

Dumas, J. S., & Salzman, M. C. (2006). Usability assessment methods. *Reviews of Human Factors and Ergonomics, 2*, 109-140.

Geisen, E., & Romano-Bergstrom, J. (2017). Developing the usability testing protocol. In E. Geisen, & B. J. Romano, *Usability testing for survey research* (pp. 111-129.). Bonston: Morgan Kaufmann.

Goodchild, M. F. (2010). Twenty years of progress: GIS science in 2010. *Journal of Spatial Information Science*, 3-20.

Horii, H., & Miyajima, Y. (2013). AR-based support system for teaching hand-drawn mechanical drawing. *13th International Educational Technology Conference.* Kuala Lumpur, Malaysia: IETC.

Irhebhude, M. E., Abdullahi, F., Celestine, A. U., Kolawole, A. O., & Mohammed, L. (2019). Augmented Reality: User perception on effectiveness in educational delvery assessment in Kaduna. *Pacific Journal of Science and Technology, 20*(2), 102-111.

Lewis, J. R. (2002). Psychometric evaluation of the PSSUQ using data from five years of usability studies. *International Journal of Human Computer Interaction, 14*, 463-488.

Lewis, J. R. (2012). Usability testing. In G. Salvendy, *Handbook of human factors and ergonomics (4th ed.).* (pp. 1267-1312.). New York: John Wiley and Sons, Inc.

Lewis, J. R. (2014). Usability: Lessons learned and yet to be learned. *International Journal of Human-Computer Interaction, 30*(9), 663-684. Retrieved from http://dx.doi.org/10.1080/10447318.2014.930311

Marto, A., Goncalves, A., Melo, M., Bessa, M., & Silva, R. (2023). ARAM: A technology acceptance model to ascertain the behavioural intention to use augmented reality. *Journal of Imaging, 9*(73). Retrieved from https://doi.org/10.3390/jimaging9030073

Musa, H., & Abubakar, P. (2010). Availability and accessibility of geographical information systems in Nigerian federal universities of technology libraries. *Samaru Journal of Information Studies, 10*(1 & 2), 60-72.

Natesan, D., Walker, M., & Clark, S. (2016). Cognitive bias in usability testing. *Proceedings of the International Symposium on Human Factors and Ergonomics in Healthcare, 5*(1), 86-88.

Romano-Bergstrom, J. R., & Schall, A. (2014). *Eye tracking in user experience design.* San Francisco: Morgan Kaufmann.

Sidhawara, A. G. (2022). An evaluation of UAJY Leaning Management System's usability using USE Questionnaire and eye-tracking. *Indonesian Journal of Information Systems, 4*(2), 174-189.