Jurnal Pendidikan Teknologi dan Kejuruan
Vol. 19, No. 2, Juli 2022
P-ISSN : 0216-3241 E-ISSN : 2541-0652

EVALUATION AND REDESIGN OF AUGMENTED REALITY APPLICATION BASED ON USABILITY TESTING

G.R. Dantes

Information System Department, Universitas Pendidikan Ganesha
rasben.dantes@undiksha.ac.id

ABSTRAK

Aplikasi apa pun yang dirancang untuk tujuan promosi harus dievaluasi dalam hal kegunaannya bagi penggunanya. Oleh karena itu, penelitian ini difokuskan untuk mengevaluasi kegunaan Aplikasi Augmented Reality e-Bahari yang dikembangkan untuk mempromosikan objek wisata bawah laut di Bali dalam bentuk 3D augmented reality. Evaluasi Heuristik (HE) diterapkan untuk mengevaluasi aplikasi dengan melibatkan tiga pengguna sebagai evaluator untuk berkomentar dan memberikan saran tentang kegunaan aplikasi di tiga level spesifikasi masing-masing dan cara meningkatkannya. Komentar dan saran ini kemudian dikategorikan menggunakan prinsip heuristik berdasarkan ISO 9241-11 dan kriteria Nielsen Heuristik yang disesuaikan. Evaluasi tersebut mengungkapkan bahwa E-Bahari AR telah berhasil merepresentasikan objek wisata bawah laut secara 3D, seperti efek pencahayaan bawah air, anemon, ikan, dan penyu. Namun, augmented reality 3D untuk objek virtual kehidupan nyata masih perlu ditingkatkan karena belum mencapai naturalitas dan kurangnya interaksi antara pengguna dan aplikasi. Selain itu, evaluasi juga mengungkapkan bahwa semakin rendah spesifikasi aplikasi, semakin rendah kualitas yang dihasilkan oleh augmented reality. Dengan demikian, aplikasi dengan spesifikasi tertinggi bekerja tanpa masalah yang jelas.

Kata kunci: evaluasi; usability; heuristic; augmented reality; e-Bahari

ABSTRACT

Any application designed for promotional purposes should be evaluated in terms of its usability for its users. Thus, the present study focused on assessing the usability of the e-Bahari Augmented Reality Application developed to promote underwater tourism objects in Bali in 3D augmented reality. Heuristic Evaluation (HE) was applied to evaluate the application by involving three users as evaluators to comment and give suggestions on its usability in three respective levels of specifications and how to improve it. These comments and suggestions were then categorized using heuristic principles based on ISO 9241-11 and adjusted Nielsen Heuristics criteria. The evaluation revealed that the E-Bahari AR had successfully represented underwater tourism objects in 3D, such as underwater lighting effects, anemones, fish, and turtles. However, the 3D augmented reality for virtual things of real life still needed improvement as it had not reached naturality and lacked interaction between users and applications. Moreover, the evaluation also revealed that the lower the application specifications, the lower the quality of the augmented reality. Thus, the application with the highest specification worked without apparent problems.

Keywords : *evaluation; usability; heuristic; augmented reality; e-Bahari*

1. INTRODUCTION

Augmented Reality (AR) is a technology that combines two- or three-dimensional virtual images into a natural three-dimensional environment which allows users to easily access the richness of the multimedia content contextually [1]–[6]. An application built on AR technology can control markers and the video loaded through the URL, where animation can be created using Blender in the Qualcomm Augmented Reality (QCAR) to be displayed in Android smartphones [2], [3], [7].

AR has been widely applied in entertainment, military training, medicine, design engineering, robotics and telerobotics, manufacturing, education, and other fields. Researchers employ AR as one of the novel ways to boost productivity, efficacy, and efficacy, as well as entertainment media [8]–[14].

AR can be utilized for extending information from print media to visual media, which has become one of the trends in advertising and promotional media.

E-Bahari AR is an application designed to simulate underwater tourism objects into 3D images aimed at ease of access for tourists, researchers, and the community in general to virtually find information about underwater tourism objects in Bali. This application employs library vuforia to represent 3-dimensional underwater tourism objects in a natural environment by using an e-Bahari Booklet and Android Smartphone. The pictures provided in the e-Bahari Booklet function as markers for displaying the underwater tourism object, along with the narration and animation.

As promotional media, an application that applies AR has to provide high-quality images [15]–[18]. This is quite a different application from conventional mouse-and-keyboard applications. Thus its usability for its users needs to be evaluated to verify whether or not the application has satisfied its intended users. Therefore, evaluation of such media is required in order to improve the quality of the advertisement. Such evaluation can be conducted through, among other ways, the usability method, which is one of the most widely used evaluation methods for measuring the success of a product [19]. In this evaluation, usability becomes the key to determining whether a system is beneficial and usable from the users' perspective [8], [20]–[22].

Usability Evaluation is widely employed for qualitatively assessing the ease of use of an application interface [23]–[25]. An application is considered usable if all the designed features can run effectively, efficiently, and, thus, satisfactorily [26]–[28]. There are several methods for conducting Usability Evaluation. One of the simplest ways is Heuristic Evaluation (HE), a user-based evaluation system that involves users as evaluators whose comments and suggestions are then heuristically categorized [29].

This article elaborates on the usability evaluation of the E-Bahari AR application using the AR Heuristic method following ISO 9241-11 and Nielsen Heuristics, as developed by Guimaraes and Martins [30]. This evaluation was expected to provide recommendations for the improvement of the application based on the evaluation result.

2. RESEARCH METHOD

The present study was conducted as a case study for evaluating the usability of the E-Bahari AR application in line with ISO 9241-11 and adjusted Nielsen Heuristics criteria for the reality contexts. The first step of the research was a literature study related to the Heuristic Usability method and AR application. The second step was a usability evaluation of the E-Bahari AR application using the heuristic method. Finally, based on the evaluation result, a recommendation is proposed for the application's improvement. Figure 1 below describes the research procedure of this evaluation.

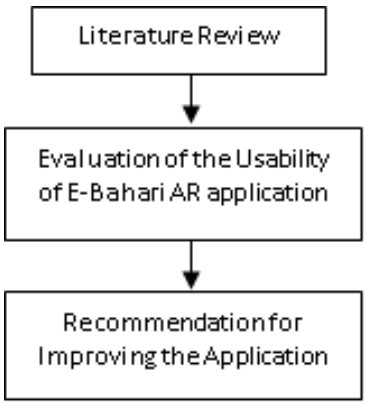

Figure 1. The procedure of Usability Evaluation of E-Bahari AR Application

A. Usability

Usability is the benchmark for evaluating and using a system, which includes the aspects of effectiveness, efficiency, and behavior for achieving the goal of the system [20], [22], [31]. Usability is often applied in qualitative analysis to assess the accessibility of an application interface. An application is considered usable when all the intended functions work effectively, efficiently, and satisfactorily [32]. Usability Evaluation is one of the most used techniques for assessing an application's usability, which in turn is a key to its users' reception of the application [19].

B. Augmented Reality

The line separating the real world from the virtual world is extremely thin because of computer applications that combine both worlds. Augmented Reality (AR) allows real-time exploration of the environment through the integration of various displays and contents as designed by computers [33]. AR can produce precise perception by combining spaces in real life and virtual objects to create a real-like experience.

However, unlike virtual reality, which entirely replaces reality, AR works by adding virtual data to fact in the sense that virtual reality completes reality. The process of combining virtual data and data from real life can provide ease of access to the richness of the multimedia content in a more contextual way, hence, more meaningfully [1].

As defined by Azuma (1997, 356) in [33], an AR application has to cover three requirements:

1. The combination of natural and virtual perception
2. Real-time interaction
3. Object has to be accurately adjusted into three-dimensional objects.

C. E-Bahari AR Application

Through AR technology, underwater tourism objects are simulated into 3D images for more accessible information access. In this study, the tourism objects covered are the underwater tourism objects around Bali. This application employs library vuforia, which represents three-dimensional underwater tourism objects in real-life environments with the help of the markers in the e-Bahari booklet and Android Smartphone. The booklet's pictures act as markers that will trigger the displays of the tourism objects, along with the animation and the voice-over narration. Figure 2 below describes the use of the e-Bahari AR application.

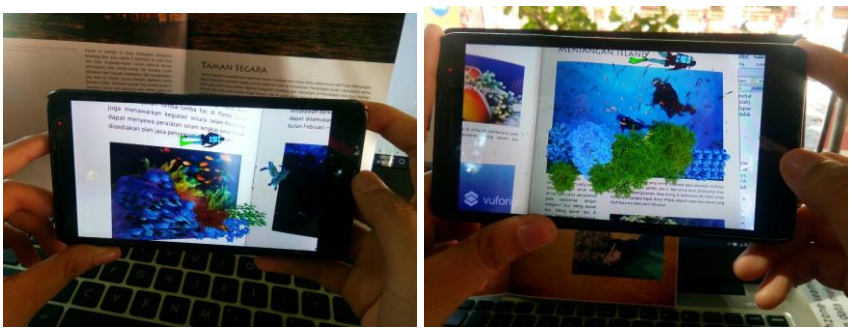

Figure 2. The use of the E-Bahari AR Application

D. Heuristic Evaluation

Heuristic evaluation is a systematic inspection of the usability of the users' interface design. Proponents of heuristic evaluation believe that through the user's interface in line with the heuristic usability, heuristic evaluation detects problems with the heuristic applied and the severity of the problem. This method is considered efficient, easy to learn and use, and affordable as it needs to involve a few users/evaluators to evaluate the application. Heuristic evaluation is usually conducted during the application development stage and is focused on the prototype. The heuristic evaluation aims to detect the most obvious usability problems before the application is further developed [33].

In the present study, the heuristic evaluation employed is adapted from the model developed by Guimaraes dan Martins [30] with adjusted criteria as follows.

1. Visibility of the system status evaluates how the application is perceived by the user. Because the AR application uses a detecting system to determine the position of the virtual content in the actual scene, users should receive feedback about the application. It must be quick and dependable;
2. Tracking system utilization to position virtual content in a real scene, which is fast and reliable if the user is spared while interacting with the app;
3. Match between the system and the natural world
   In order to present information in a manner that is both logical and natural, application design must adhere to real-world conventions.Virtual content must be accessed by users in the same way they would in the real world.The scale of the animations and objects must match that of the virtual environment;

4. User control and freedom
   Applications should provide freedom so that users can perform and undo wrong actions. If the user serves an incorrect marker to the camera, the application should support simple marker replacement, if possible, providing the user with information about the error;
5. Consistency and standards
   The layout of the application interface and user interaction must be consistent. Users should interact in the same way with all virtual objects. To prevent errors, each marker needs to be linked to a specific virtual object or action;
6. Error prevention
   Applications should be designed to avoid errors and prevent unwanted actions. Suppose it pops up the message "3D Loader is not working properly" appears;
7. Recognition rather than recall
   This determines whether the user can run the application intuitively. The function and position of the marker must be easy to understand;
8. Flexibility and efficiency of use
   Users must be able to interact with the application quickly and flexibly. Interaction conducted by novice users and expert user should not be much different. It is preferable that expert user can quickly interact without requirement to watching instruction. In addition, users and markers must be positioned easily in the environment;
9. Aesthetic and minimalist design
   Provided information for the dialogue with the user should be relevant. Irrelevant information may distract user's attention. Moreover, the presence of multiple virtual objects in the same application can lead to information overload;
10. Help users recognize, diagnose, and recover from errors
    The application must pinpoint the problem and provide constructive suggestions. For example, if a marker is not detected, the application must guide to resolve the error;
11. Help and documentation
    It is better if the application can be used without documentation, but providing reasonable procedures and documentation is beneficial. Information should be easy to find and focus on the user's task concisely. For example, the app should explain how each marker works. An explanatory video for AR users is an exciting solution.

The Nielsen heuristics defined for evaluating AR applications are extended to include effectiveness, efficiency, and satisfaction, following ISO 9241-11. This makes it possible to overcome the drawbacks of this heuristic method, whose initial focus was on desktop applications. These heuristics include the following [30].

1. Accuracy
   How accurate the system is during the interaction. The position of the virtual content on the image is determined by the tracking system and cannot be different;
2. Environment setup
   AR applications require special devices such as sensors and/or cameras. Environmental setup should be as simple as possible;
3. Satisfaction
   It measures the extent to which AR applications exceed user expectations. Interaction is an essential aspect of AR applications, and users must have a positive attitude toward the application.

Furthermore, each heuristic principle is assessed for its problem rating to determine the priority of the subsequent system development. Three factors affect the ranking of usability problems, namely how often the problem occurs (frequency), how difficult the problem can be overcome (problem impact), and how resistant users are to the problem (problem persistence). The rating scale for measuring the rating of usability problems is as follows [34]:

0 = no usability problem
1 = Cosmetics (issue does not need to be fixed unless additional time is available)
2 = Minor (problem needs to be fixed but low priority)
3 = Major (problem needs to be fixed with high priority)
4 = Disaster (Must be repaired before the product is released to the market)

The evaluator mapped the issue using a heuristic approach, ranked the issues according to each heuristic principle, and recorded all of the difficulties or issues that they encountered after performing a series of user tasks.The final step is to determine the design feature that caused the issue and give it a severity rating.. The list of problem parameters for grouping design features is as follows [35]:

1. Graphic Display, perspective distortion or 3D depth, low image resolution. The indicator is the problem of perception.
2. Movement and manipulation of the user's presence, divided into several devices (such as glove, joystick, 3D mouse, pointer, and so on), represent the user in a virtual environment. The indicators are navigation and manipulation problems; for example, the pointer object represents the user's focus of vision.
3. Interaction between objects in the virtual environment. Indicators are failed interactions or inappropriate feedback.
4. Environmental Features. Some environmental conditions do not have the proper effect.
5. Interaction with other controls. An example of a menu button problem.
6. Other hardware issues. Examples of smartphone and head-mounted display (HMD) problems

The severity rating value for the classification of design features is based on the following four categories [35]:

1. Severe = The problem encountered will make it impossible for the user's task to be completed successfully.
2. Annoying = The problem encountered will interfere with the user's task. Still, most users can solve the problem if there is a sufficient explanation of the solution; sometimes, it takes a lot of time to solve it.
3. Distracting = The problem at hand will interfere with the user's task, but most users are relatively quick to solve the problem with a few hints of a solution.
4. Inconvenient = The problem encountered will interfere with the user's task but most users are able to solve the problem without assistance. Peringkat diolah berdasarkan evaluasi sumatif dari AR dan evaluasi formatif untuk fokus area yang harus didisain ulang pada versi berikutnya. The ranking is processed based on the summative evaluation of AR and formative evaluation for focus areas that should be redesigned in the next version.

3. RESULT

This study evaluated the E-Bahari AR application, which aims to introduce underwater tourism objects in Bali. The heuristic evaluation method requires more than one evaluator to be reliable because it is impossible for one evaluator to find all design problems. In this case, the evaluation was carried out by three expert appraisers who studied Augmented Reality and Usability, where the experts had never used this E-Bahari AR application. This evaluation is based on the heuristic developed by Guimaraes and Martins [30]. The evaluators have analyzed the application of AR heuristics separately. After individual evaluation, the results were compared in one group session. Each evaluator has used this app individually and with different devices. Evaluator 1, Evaluator 2, and Evaluator 3 use mobile phones with other specifications in testing the E-Bahari AR application. The specifications of the equipment used by each evaluator can be seen in Table 1 below.

Table 1. Specifications of the E-Bahari AR Usability Evaluation Tool

Evaluator	Device	Specification
I	HP: Xiaomi Note 3	Size: 5.5 inches, OS: Android 5.1.1 (Lollipop), CPU: Hexa-core, 16 GB ROM, 2 GB RAM, Camera: 16 MP
II	HP: Vivo Y31	Size: 4.7 inches, OS: Android 5.1.1 (Lollipop), CPU: Quad-core, 8 GB ROM, 1 GB RAM, Camera: 8 MP
III	HP: Samsung S5	Size: 5.1 inches, OS: Android 4.4.2 (KitKat), CPU: Quad-core, 32 GB ROM, 2 GB RAM, Camera: 16 MP

The E-Bahari AR application has appropriately represented the underwater environment and the required 3D objects, including the effects of light on seawater, coral reefs, fish objects, turtles, and other objects. However, virtual things with the real world are still not suitable, the interaction of objects

displayed is still less natural, and the lack of interaction between users and applications can be seen in Table 2 and Table 3.

Table 2. Interpretation of Heuristic Evaluation and Ranking of Problems Found

No	Criteria	Rank	Problem Identified
1	*Visibility of system status*	0	Inconsistent marker sizes, significantly larger markers, cause applications to be slower in detecting and displaying AR objects
2	*Match between the system and the real world*	2	Sometimes only a few fish are seen, and the position of the fish object needs to be adjusted Suitability of fish objects based on habitat/area (dolphin not seen in Lovina virtual environment) The diver's object does not seem to move (adjustment of the diver's leg and body movements), so it looks less realistic
3	*User control and freedom*	1	The app can only detect one marker if the camera or sensor detects two markers
4	*Consistency and standards*	0	No problem, the size of the environment and virtual objects are consistent
5	*Error prevention*	1	The application does not show status or messages when it has not detected a marker
6	*Recognition rather than recall*	0	Images that become markers in one environment in a booklet do not have descriptions, so if there are several images, it is sometimes difficult to remember the markers.
7	*Flexibility and efficiency of use*	0	There is no problem. Users can easily change the position of the marker and the correct orientation so that it can be detected by the camera/sensor
8	*Aesthetic and minimalist design*	1	The number of virtual objects in the E-Barine AR environment is not appropriate, and the lack of variety of fish objects
9	*Help users recognize, diagnose, and recover from errors*	4	There are no user instructions on what to do during the interaction (For example, point the camera at the marker to see an object)
10	*Help and documentation*	3	There is no menu of instructions for using the application in the form of text, audio, or video
11	*Accuracy*	0	No problem, the app still works fine if the tracking system detects more than one object in the scene (stable tracker)
12	*Environment configuration*	0	Phone specifications affect the speed of the application and in detecting markers
13	*Satisfaction*	0	There is no problem, the user can move freely during the interaction with the virtual environment, and the application can achieve the goal of providing underwater tourism information on each area through virtual objects.

Table 3. Classification of Problems with Severity Rating and Proposed Design Development Based on Design Features

Feature	Problem Description	Degree	Proposed Design Development
Chart	3D object design	Minor	Improved the design of 3D objects, in particular the texture details of some fish, to make them more realistic
Presence	User vision focus representation	Minor	Using the appropriate marker size so that the application is fast in detecting and displaying objects
Interaction	Fish object interaction with other objects	Moderate	Make interactions between objects more natural, especially fish objects with other fish (eg fish move away when near divers)

Feature	Problem Description	Degree	Proposed Design Development
Environment	Variation and movement of objects	Moderate	Added several other types of fish objects to make them more varied, adjusting fish objects in each habitat/area
Control	Menu and Navigation	Severe	Fixed the position and animation of the movement of fish and divers objects (adjustment of the diver's leg and body movements)
Hardware	Camera and Lighting	Minor	Added instructions for novice users when first using the app

4. DISCUSSION

The usability evaluation results show that in the virtual AR environment, sometimes only a few fish are seen, and the diver's object looks like it's not moving. Figure 3 visualizes the application's lack of position adjustment and variation of virtual objects. It is necessary to improve the position and animation of the movement of fish and divers objects (adjustment of the diver's foot and body movements). The addition of several other fish objects and adjustment of fish objects in each habitat/area was also recommended.

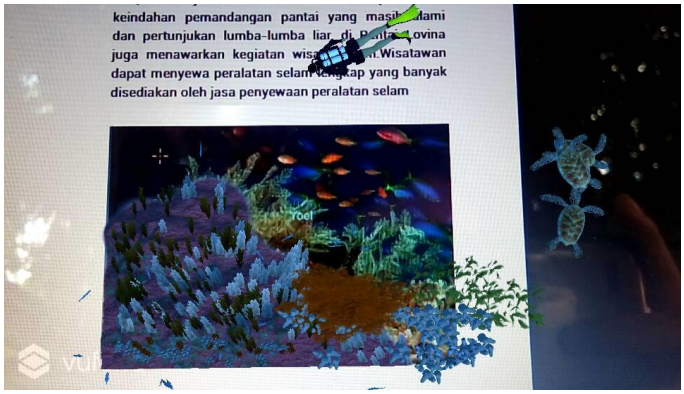

Figure 3. The position of the fish object and the movement of the diver are not appropriate

Furthermore, the evaluation results show a lack of interaction between fish objects and other objects (some fish appear to gather and move slowly, and there is no interaction when the diver approaches the fish), as shown in Figure 4. Therefore, it is necessary to make interactions between objects more natural, especially interactions between fish objects with other fish as well as divers (Suppose a fish moves away when near a diver).

Figure 4. The interaction of fish objects with other objects (fish and divers) is less natural

The evaluation results also show that the E-Bahari AR application does not yet have a manual user feature on what to do during the interaction, as shown in Figure 5. So it is necessary to add instructions for novice users when they first use the application (for example, point the camera at

the marker to view objects) and add a menu of application guides/tutorials in the form of text/video/audio to make it more interesting.

Figure 5. There is no application guide/instruction feature for users

Based on the usability evaluation results, application improvements are needed to overcome usability problems in the E-Bahari AR application so that this application has a better usability level.

In addition, the trial of the three devices with different specifications showed that particular problems were found when using a low-specification device (affecting application speed and detecting markers). In contrast, other devices with higher specifications did not experience problems. So to be able to run the application to remain stable it is recommended to use a device with a higher specification. This research does not contribute novel scientific progress but focuses on fulfilling aspects of effectiveness, efficiency, and satisfaction through heuristic evaluation of the developed application. Evaluation of this application is in line with research from [27] on heuristic evaluation of Virtual Reality applications that is aimed at gaining insights into the application being developed and the necessary improvement.

5. CONCLUSION

Based on the results of the analysis and discussion above, the conclusions of this study are as follows: (1) Evaluation of AR Heuristics that conforms to ISO 9241-11 and Nielsen Heuristics can diagnose problems that may occur in the E-Bahari AR application by taking into account usability aspects; (2) In general, the E-Bahari AR application has properly represented natural underwater conditions with the required 3D objects, including the effects of light in the sea, coral reefs, fish objects, turtles, and other biotas. But the app still has minor glitches with graphics, presence, interaction, and hardware features. An important part that needs attention when improving the application design is the rearrangement of the position and movement path of the fish object and the animation of the diver's body movements so that the movement of 3D objects looks more natural. In addition, it is necessary to add a feature of instructions for users on what to do during the interaction; (3) Based on trials of 3 devices with different specifications, particular problems are found when using low device specifications (affecting application speed and detecting markers). In contrast, other devices with higher specifications do not experience problems.

For further research, it is necessary to add other methods to measure other essential usability aspects so that the results of the study are more detailed about what indicators need attention. The current usability method still needs to be developed to see the effect of AR technology on interest and motivation to learn in the world of education.

REFERENCES

[1] J. Martín-Gutiérrez, P. Fabiani, W. Benesova, M. D. Meneses, and C. E. Mora, “Augmented reality to promote collaborative and autonomous learning in higher education,” *Comput. Human Behav.*, vol. 51, pp. 752–761, 2015, doi: 10.1016/j.chb.2014.11.093.

[2] M. A. Andújar, J. M.; Mejías, A.; Márquez, “Augmented Reality for the Improvement of Remote Laboratories: An Augmented Remote Laboratory IEEE Transactions on Education,” *IEEE Trans. Educ.*, vol. 54, no. 3, pp. 492–500, 2011, [Online]. Available: https://ieeexplore.ieee.org/document/5607327.

[3] N. Navab, T. Blum, L. Wang, A. Okur, and T. Wendler, “First deployments of augmented reality in operating rooms,” *Computer (Long. Beach. Calif).*, vol. 45, no. 7, pp. 48–55, 2012, doi:

10.1109/MC.2012.75.
[4] R. Y. Endra and D. R. Agustina, “Media Pembelajaran Pengenalan Perangkat Keras Komputer Menggunakan Augmented Reality,” *Expert J. Manaj. Sist. Inf. dan Teknol.*, vol. 9, no. 2, pp. 63–69, 2019, doi: 10.36448/jmsit.v9i2.1311.
[5] R. Y. Endra, D. R. Agustina, and S. C. Hadi, “Positioning Manipulate Real Property Object On Tourist Attraction Utilize Augmented Reality,” *4th Int. Conf. Eng. Technol. Dev.*, no. 89, p. 758, 2017.
[6] J. Carmigniani and B. Furht, *Handbook of Augmented Reality*, no. July 2011. 2011.
[7] C. Lio, “Perancangan Aplikasi Berbasis Teknologi Augmented Reality pada Sampul Media Promosi Cetak,” STMIK AMIKOM Yogyakarta, 2012.
[8] L. Hermawan and M. Hariadi, “Pemanfaatan Augmented Reality Sebagai Media Pembelajaran,” in *Seminar Nasional Teknologi Informasi dan Komunikasi*, 2015, vol. 13, no. 2, doi: 10.23887/jptk.v13i2.8525.
[9] M. Funk, A. Bachler, L. Bachler, T. Kosch, T. Heidenreich, and A. Schmidt, “Working with augmented reality? A long-term analysis of in-situ instructions at the assembly workplace,” *ACM Int. Conf. Proceeding Ser.*, vol. Part F1285, no. June, pp. 222–229, 2017, doi: 10.1145/3056540.3056548.
[10] M. Davidekova, M. Mjartan, and M. Gregus, “Utilization of Augmented Reality in Education of Employees in Slovakia,” *ICERI2017 Proc.*, vol. 1, no. September 2018, pp. 6151–6158, 2017, doi: 10.21125/iceri.2017.1600.
[11] C. Steel, “The potential of Augmented Reality to amplify learning and achieve high performance in the flow of work,” *ASCILITE 2019 - Conf. Proc. - 36th Int. Conf. Innov. Pract. Res. Use Educ. Technol. Tert. Educ. Pers. Learn. Divers. Goals. One Hear.*, pp. 563–568, 2019.
[12] D. McMahon, D. F. Cihak, and R. Wright, “Augmented reality as a navigation tool to employment opportunities for postsecondary education students with intellectual disabilities and Autism,” *J. Res. Technol. Educ.*, vol. 47, no. 3, pp. 157–172, 2015, doi: 10.1080/15391523.2015.1047698.
[13] M. Torres *et al.*, “Virtual reality and augmented reality in Onboarding of new employees,” *Proc. - Res. Interv. Hum. Resour.*, p. n.-9 (2019): IX Conferência Internacional de Inves, 2019, [Online]. Available: https://parc.ipp.pt/index.php/iirh/article/view/2850.
[14] S. R. Sorko and M. Brunnhofer, “Potentials of Augmented Reality in Training,” *Procedia Manuf.*, vol. 31, pp. 85–90, 2019, doi: 10.1016/j.promfg.2019.03.014.
[15] P. Clini, E. Frontoni, R. Quattrini, and R. Pierdicca, “Augmented reality experience: From high-resolution acquisition to real time augmented contents,” *Adv. Multimed.*, vol. 2014, no. Dl, 2014, doi: 10.1155/2014/597476.
[16] N. Magnenat-thalmann, G. Papagiannakis, and P. Chaudhuri, “Applications of Interactive Virtual Humans in Mobile Augmented Reality,” *Encyclopedia of Multimedia*. .
[17] G. J. Klinker *et al.*, “Confluence of computer vision and interactive graphics for augmented reality,” *Presence Teleoperators Virtual Environ.*, vol. 6, no. 4, pp. 433–451, 1997, doi: 10.1162/pres.1997.6.4.433.
[18] E. R. Elbasiouny, T. Medhat, A. Sarhan, and T. E. Eltobely, “Computer and Control Department , Faculty of Engineering , Computer and Control Department , Faculty of Engineering ,” vol. 1, pp. 9–47.
[19] F. Paz, F. A. Paz, D. Villanueva, and J. A. Pow-Sang, “Heuristic Evaluation as a Complement to Usability Testing: A Case Study in WEB Domain,” *Proc. - 12th Int. Conf. Inf. Technol. New Gener. ITNG 2015*, pp. 546–551, 2015, doi: 10.1109/ITNG.2015.92.
[20] H. Pranoto, C. Tho, H. L. H. S. Warnars, E. Abdurachman, F. L. Gaol, and B. Soewito, “Usability testing method in augmented reality application,” *Proc. 2017 Int. Conf. Inf. Manag. Technol. ICIMTech 2017*, vol. 2018-Janua, no. November 2020, pp. 181–186, 2018, doi: 10.1109/ICIMTech.2017.8273534.
[21] S. E. Schaeffer, “Usability Evaluation for Augmented Reality,” 2014.
[22] I. M. Ronyastra, I. Hapsari, and F. P. Pani, “Development and usability evaluation of virtual guide using augmented reality for Candi Gunung Gangsir in East Java,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 703, no. 1, 2019, doi: 10.1088/1757-899X/703/1/012033.
[23] J. Nielsen, “Usability 101: Introduction to Usability,” *World Leaders in Research-Based User Experience*, 2012. https://www.nngroup.com/articles/usability-101-introduction-to-usability/.
[24] T. Granollers, “Usability Evaluation with Heuristics, Beyond Nielsen’s List,” *ACHI 2018 Elev. Int. Conf. Adv. Comput. Interact.*, no. c, pp. 60–65, 2012.

[25] S. Federici and S. Borsci, “Usability evaluation: models, methods, and applications,” no. January 2010, 2014.
[26] N. L. P. R. Indriyani, G. R. Dantes, and K. Y. Ernanda, “Analisis Kebermanfaatan Website Sekolah Tinggi Pariwisata (Stipar) Triatma Jaya Menggunakan Metode Usability Testing,” *Int. J. Nat. Sci. Eng.*, vol. 1, no. 2, pp. 55–64, 2017.
[27] G. R. Dantes, P. H. Suputra, I. Komang Sudarma, N. K. A. Suwastini, and K. R. Dantes, “Evaluating and redesigning virtual reality ‘underwater tourism’ application based on heuristic method,” *Int. J. Bus. Inf. Syst.*, vol. 35, no. 2, pp. 225–238, 2020, doi: 10.1504/IJBIS.2020.110170.
[28] G. R. Dantes, K. Sudarma, and H. Suputra, “Virtual Reality Dan Augmented Reality : Pemberdayaan Wisata Bawah Laut Dalam Rangka Meningkatkan Daya Dukung Pariwisata,” *Semin. Nas. Vokasi dan Teknol.*, pp. 457–464, 2016.
[29] M. Sulistiyono, “Evaluasi Heuristic Sistem Informasi Pelaporan Kerusakan Laboratorium Universitas AMIKOM Yogyakarta,” *J. Ilm. Data Manaj. Dan Teknol. Inf.*, vol. 18, no. 1, pp. 37–43, 2017, [Online]. Available: https://ojs.amikom.ac.id/index.php/dasi/article/view/1832/1554.
[30] M. De Paiva Guimarães and V. F. Martins, “A checklist to evaluate augmented reality applications,” *Proc. - 2014 16th Symp. Virtual Augment. Reality, SVR 2014*, pp. 45–52, 2014, doi: 10.1109/SVR.2014.17.
[31] H. Sharp, Y. Rogers, and J. Preece, *Interaction Design. Beyond Human-Computer Interaction*, 2nd ed. John Wiley & Sons, Inc., 2007.
[32] Y. Y. O. Ola, Suyoto, and S. Purnomo, “Pengujian Usability Antarmuka Aplikasi Mangente,” in *Seminar Nasional Teknologi Informasi dan Komunikasi*, 2016, vol. 2016, no. Sentika, pp. 334–342, [Online]. Available: https://adoc.pub/pengujian-usability-antarmuka-aplikasi-mangente.html.
[33] J. Kalalahti, “Developing Usability Evaluation Heuristics for Augmented Reality Applications,” Lappeenranta University of Technology, 2015.
[34] A. Dix, J. Finlay, G. D. Abowd, and R. Beale, *Human-Computer Interaction Ch. 9 Evaluation Techniques*. 2004.
[35] A. Sutcliffe and B. Gault, “Heuristic evaluation of virtual reality applications,” *Interact. Comput.*, vol. 16, no. 4, pp. 831–849, 2004, doi: 10.1016/j.intcom.2004.05.001.