Usability Evaluation Methods of Mobile Applications: A Systematic Literature Review

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***Abstract*—At this time, mobile devices have an important role because it provides changes for users. Not only making calls, but many features and applications are used to make work easier. Mobile application development brings new challenges to mobile devices, such as usability context when users use mobile applications. Usability is an important factor in mobile applications' role in making them easy to use and efficient. User Interface (UI) and User Experience (UX) has a critical role in software development. It has a function that is one of the keys to the effectiveness of using the software. This study aims to find popular usability evaluation on mobile applications with the help of a Systematic Literature Review (SLR). The usability evaluation process of mobile applications is carried out with a systematic literature review of 22 papers. The results show that 73% of the methods used are usability testing, 23% heuristic evaluations, and 4% are user satisfaction usability evaluations. To conduct usability evaluation on mobile applications, usability testing is carried out in five stages, involves participants, and has the characteristics of Effectiveness, Efficiency, and User Satisfaction. Meanwhile, in heuristic evaluation, experts must be involved in evaluating the user interfaces. This study proposes a mixed method of usability testing and heuristic evaluation in conducting usability evaluation on mobile applications. This method is expected to provide effective and objective usability issues from the perspective of users and experts in improving User Interface (UI) and User Experience (UX).**

Keywords—usability, usability evaluation, heuristic evaluation, usability testing, mobile application.

I. INTRODUCTION

Mobile devices at this time are very widely used for the purpose of communicating and exchanging information. The existence of mobile devices has made extensive changes for users who previously could only make calls, and now there are many features that can be used, such as listening to music, opening visual media, transferring money quickly, purchasing through online platforms, and others [1]. These changes bring new challenges to mobile devices, such as mobile application development, including factors in the usability context when mobile applications are used by users [1]. User Interface (UI) has a critical role in software development. It has a function that is one of the keys to the effectiveness of using the software. Usability is a concept in achieving a key to ease and friendliness for users. Usability can be a reference in a software system where a product can be used efficiently, effectively, and satisfactorily for users [2].

In designing user interfaces, usability evaluation is the primary basis for obtaining user behavior data in interacting with an application. With the development of innovation and technology, human interaction with computers, especially in designing user interfaces, must always change continuously according to the times [2]. Evaluating using the usability method is very often used. In this case, usability testing is the method most frequently encountered. Usability testing is generally used to assess the usability of users of an application based on user experience using a prototype or finished application. Applications that are often found for evaluation of the website and mobile-based usability [3].

Evaluation of usability using usability testing can also provide an assessment of the impression and experience of users using an application to obtain information related to the justification of whether users will use the application continuously or not [3]. User Experience (UX) in software design also has an important role. However, a user interface that is not suitable or expected from the user's point of view will quickly be abandoned even though the application has benefits [4].

II. BACKGROUND

A. Usability

Usability has many components and has five usability attributes which include Learnability, Efficiency, Memorability, Errors, and Satisfaction [5].

- Learnability: the system must be able to be learned and used quickly by the user so that with the help of the system, the work will be completed much faster.
- Efficiency of Use: the system must be efficient when used, so when the user understands the use of the system, it will be possible to be more productive in completing work.
- Memorability: the system must be easy to remember so that when the user does not use it for a specific time, the user does not need to adapt it again.
- Few and Noncatastrophic Errors: the system should have a low error rate so that when users make mistakes in using the system, they will quickly recover.
- Subjective Satisfaction: the system must be pleasant when used so that users can feel satisfied.

In the development of technology and software, usability is an important factor without exception. Once the importance of quality attributes, several existing evaluation methods can be used for usability problems [6].

B. Usability Evaluation

Usability evaluation is increasingly being used to detect problems in user interaction with the system. Usability evaluation can be applied to any software development and

can be done by people with different skills and knowledge [9]. There are two groups that can be categorized in the usability evaluation method, namely the inspection method and the empirical method. These two engineering categories have a major difference in that the inspection method requires the participation of a usability expert [7].

A usability specialist can also be called a usability analyst to ensure the product meets the usability and reliability requirements. On the other hand, empirical methods involve user participation. Several inspection methods are action analysis, heuristic evaluation, and cognitive walkthrough. In comparison, some empirical methods are paper and pencil tests, user testing, and query techniques [8].

C. Heuristic Evaluation

As Nielsen proposed [10], heuristic evaluation is most likely to use the usability inspection method. This method involves three to five groups of usability evaluators who analyze the system using well-recognized design principles usability heuristics as a guide for finding usability problems in interactive software systems. A set of heuristics chosen can significantly affect the usability findings of the heuristic evaluation conducted [10].

It all depends on the evaluators' experience, and they may require more specific heuristics or at least detailed specifications than generic ones [9]. Since heuristic evaluation was proposed by Nielsen [11], a set of usability heuristics has been the most accepted and applied. However, heuristics are still too general to be used successfully in any software domain. Proposals from other heuristics are still being developed to cover specific features from different software domains.

D. Usability Testing

A popular method for user acceptance testing is usability testing, where the results indicate important qualities for the client to decide whether to continue or discontinue the software product [12]. System Usability Scale (SUS) is a technique to evaluate usability testing. With the most regulation, questionnaires were adopted for assessing usability perceptions. Hence this mechanism has become very popular [12]. No less critical part when testing software is the tester, the number must be adjusted before testing.

The sampling technique is used to take part of the entire population by determining the optimal number of testers [12]. The task of usability testing is to evaluate products or services by representative testing users to identify usability problems, collect qualitative and quantitative data, and determine user satisfaction with the product or service [13]. Usability testing is one of the methods to evaluate usability, evaluate perspectives, develop the environment more quickly, and increase user and system satisfaction [14] [15].

III. Research Method

A. Research Question

This paper is conducted to discuss and see the method in usability evaluation on mobile applications. At this stage will describe the research question. Three research questions will serve as guidelines in this SLR.

- RQ1: What are the techniques used in the usability evaluation of mobile applications?
- RQ2: How to do usability evaluation on mobile applications?
- RQ3: What are the characteristics of usability evaluation in mobile applications?

B. Search Process

In this systematic review, we use the main search using the following selected sources:

- Scopus
- Elsevier Science Direct
- Springer Link
- IEEE Xplore

While in the activity of looking for papers to get maximum results from sources that have been selected by using the following keywords:

TABLE 1. KEYWORDS USED

Search Topic	Keywords
Usability Evaluation	Usability Evaluation Usability Evaluation Mobile Application
Usability Testing (UT)	Usability Testing Usability Testing Mobile Application
Heuristic Evaluation (HE)	Heuristic Usability Heuristic Evaluation Mobile Heuristic Evaluation
Usability Mobile Application	Usability Mobile Application

C. Inclusion and Exclusion Criteria

During the inclusion criteria validation process, a collection of suitable papers for the research question in this systematic review are listed in the following:

TABLE 2. SEARCH PAPER ACTIVITIES

Source	Studies Found	Selected Studies
Scopus	198	16
Elsevier Science Direct	27	3
Springer Link	8	0
IEEE Xplore	68	3

As a further explanation, the study search has followed the inclusion criteria as follows:

- Papers are focused on mobile devices or mobile applications.
- Papers must be related to usability.
- Papers related to the evaluation of mobile applications.
- Papers must be published as full or short papers.

The following criteria were defined for the exclusion of a study:

- Papers must be published in English.
- Papers has been published between 2017-2022
- Papers presents usability evaluation of mobile applications instead of others platform.

D. Quality Assessment

Quality assessment is needed to select papers of appropriate quality. The Quality Assessment used for the paper selection process is

- QA1: Does the paper obtained indicate a problem with usability evaluation?

- QA2: Does the paper obtained discuss usability evaluation on mobile applications?

IV. Result

Overall, 22 papers were selected from digital databases related to the usability evaluation of mobile applications. The following are answers to three questions provided in this systematic review.

RQ1: What are the techniques used in the usability evaluation of mobile applications?

Based on a total of 22 final papers that have been selected and observed, it was found that the most widely used usability evaluations in mobile applications are Usability Testing and Heuristic Evaluation. Not only limited to those two techniques, but some papers also use more than one technique to carry out usability evaluation on mobile applications, such as Eye-Tracking, Think-Aloud Method, and User Satisfaction Usability Evaluation, whose techniques are almost the same as usability testing. Semiotic evaluation analyzes, understands, and interprets signs/icons on the user interface.

Then in usability testing, questionnaires are almost always used to obtain quantitative data from users. Guided by ISO 9241-11, a questionnaire is used to get results from three aspects of usability, namely Effectiveness, Efficiency, and User Satisfaction. The questionnaires used were System Usability Scale (SUS), User Interface of Satisfaction Questionnaire (QUIS), Usefulness, Satisfaction, and Ease of use Questionnaire (USE), and Post-Study System Usability Questionnaire (PSSUQ).

Table 3. Usability Evaluation Techniques On Mobile Applications

Method	Paper
Usability Testing	[3][17][18][19][20][21][23][24] [25][26][29][30]31][32][33][35]
Heuristic Evaluation	[22][27][28]34][36]
User Satisfaction Usability Evaluation	[16]
Eye Tracking	[20][33]
Retrospective Think Aloud / Concurrent Think Aloud	[20][30][33][35]
Questionnaire	[3][16][17][18][19][21][23][24] [25][26][29][31][32][33][35]
Semiotic Evaluation	[36]

RQ2: How to do usability evaluation on mobile applications?

Usability evaluation can be done in several stages. 16 out of 22 papers use the usability testing method, where there are five steps in conducting a usability evaluation. This step starts with planning, determining participants and their numbers, testing the user interface, conducting analysis, then the last is making recommendations that can be made for further research. In testing, usability testing can use post-tasks, namely by giving several questionnaires to users. Retrospective think-aloud and concurrent think-aloud methods can also be done by users conveying their feelings and thoughts when using mobile applications.

Eye-tracking is done to strengthen the research analysis and the think-aloud method [20][33]. Meanwhile, 5 of the 22 papers used the heuristic evaluation method. In heuristic evaluation, those who can play a role in conducting usability evaluation are evaluators or experts. 4 of the 5 papers obtained related to heuristic evaluation used 3 to 5 experts based on Nielsen.

In contrast, in the article [29], only two evaluators were used. Nielsen's 10 heuristics guide heuristic evaluation to evaluate the user interface, but article [27] uses 15 heuristics as needed. Semiotic evaluation on mobile applications can be used with the Sign Interface Sign Design and Evaluation (SIDE Framework) by scoring the elements and signs on the user interface [36].

RQ3: What are the characteristics of usability evaluation in mobile applications?

From a total of 22 papers selected for this systematic review, seven methods can be used to carry out usability evaluation on mobile applications. The first characteristic of usability evaluation is usability testing. The main characteristics or aspects are Effectiveness, Efficiency, and User Satisfaction, while in [29], there is an additional aspect, namely Ease of Use. The second method is a heuristic evaluation which has the main characteristic is that only experts or evaluators can conduct usability evaluations independently of the guidelines on Nielsen's heuristics.

Then in the questionnaire method, the characteristics have a form of a Likert Scale. Structure of questions with answer choices points on a scale of 1-5 to measure attitudes and opinions. In eye-tracking and think-aloud methods, eye tracking uses sensors to detect eye movements when using applications. In think-aloud, verbal context is needed in conveying feelings and thoughts. User satisfaction usability evaluation methods have almost the same characteristics as usability testing. There are only additions to Readability, Navigation, and Accessibility. Finally, semiotic evaluation is characterized by using signs/icon elements to assess a user interface.

V. Conclusion

[1] Usability evaluation on mobile applications is done to improve the quality of the application to make it easier for users to use. At this time, many mobile applications have been developed to help facilitate human work, especially in terms of effectiveness and efficiency. However, usability problems are still a problem that cannot be avoided in every application developed. In this study, the usability evaluation process of mobile applications is carried out with a systematic literature review of 22 papers. The results show that 73% of the methods used are usability testing, 23% heuristic evaluations, and 4% are user satisfaction usability evaluations.

[2] In the context of the method used, 18 of the 22 papers used more than one method. To conduct usability evaluation on mobile applications, usability testing is carried out in five stages, involves participants, and has the characteristics of Effectiveness, Efficiency, and User Satisfaction. Meanwhile, in heuristic evaluation, experts must be involved in evaluating the user interfaces. Experts evaluate independently based on 10 Nielsen heuristics and produce a report evaluation.

VI. Future Work

For future work, we propose a mixed method of usability testing and heuristic evaluation in conducting usability evaluations on mobile applications to get maximum and objective usability results. This is done because these two methods are the most widely used methods to find usability problems in the user interface.

REFERENCES

[3] R. Parente Da Costa, E. Canedo, R. De Sousa et al, "Set of Usability Heuristics for Quality Assessment of Mobile Applications on Smartphones," IEEE Access, pp. 116145-116161, 2019.

[4] M.N. Islam, H. Bouwman, A. K. M. N. Islam, "Evaluating Web and Mobile User Interfaces With Semiotics: An Empirical Study," IEEE Access, vol. 8, pp. 84396- 84414, 2020.

[5] K. M. P. E.Galera, C. M. V. Malabanan, "Evaluating on User Experience and User Interface (UX/UI) of EnerTrApp a Mobile Web Energy Monitoring System," The Fifth Information Systems International Conference, Elsevier, pp. 1225–1232, 2019.

[6] D. Dharmayanti, A. M. Bachtiar, A. P. Wibawa, "Analysis of User Interface and User Experience on Comrades Application," IOP Conf. Series: Materials Science and Engineering, 2018.

[7] J. Nielsen. "What is Usability" in Usability Engineering, An Imprint of Academic Press, pp. 26, 1993.

[8] F. Paz, D. Villanueva, C. Rusu, S. Roncagliolo, and J. A. Pow-Sang, "Experimental Evaluation of Usability Heuristics," Proc. Tenth International Conference on Information Technology: New Generations (ITNG 2013), IEEE Press, pp. 119-126, 2013.

[9] A. Holzinger, "Usability Engineering Methods for Software Developers," Commun. ACM, vol. 48, no. 1, pp. 71-74, 2005.

[10] R. Otaiza, C. Rusu, and S. Roncagliolo, "Evaluating the Usability of Transactional Web Sites," Proc. Third International Conference on Advances in Computer-Human Interactions (ACHI 2010), IEEE Press, pp. 32-37, 2010.

[11] C. Jimenez, P. Lozada, and P. Rosas, "Usability Heuristics: A Systematic Review," IEEE, pp. 1-8, 2016.

[12] J. Nielsen and R. Molich, "Heuristic evaluation of user interfaces," Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ser. CHI '90. New York, NY, USA: ACM, pp. 249–256, 1990.

[13] S. Hermawati and G. Lawson, "Establishing usability heuristics for heuristics evaluation in a specific domain: Is there a consensus?," Applied Ergonomics, vol. 56, pp. 34-51, 2016.

[14] A. Uddin and A. Anand, "Importance of Software Testing in the Process of Software Development," IJSRD-International J. Sci. Res. Dev., vol. 6, pp. 2321–0613, 2019.

[15] U. Kokil and S. Scott, "Usability testing of a school website using qualitative approach," VISIGRAPP 2017 - Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications, vol. 2, pp. 55-64, 2017.

[16] E. Folmer and J. Bosch, "Architecting for usability: a survey," The Journal of Systems and Software, vol. 70, no. 1-2, pp. 61-78, 2004.

[17] N. Bevan and I. Curson, "Methods for Measuring Usability," Human-Computer Interaction: INTERACT '97, pp. 672-673, 1997.

[18] M. Matraf and A. Hussain, "Usability evaluation model for mobile e-book applications," AIP Conference Proceedings, vol. 1891, October, 2017.

[19] A. Hussain, E. Mkpojiogu, H. Abubakar et al., "The usability evaluation of Mudah.my on mobile device," AIP Conference Proceedings, vol. 1891, October, 2017.

[20] A. Hussain, E. Mkpojiogu, N. Jamaludin et al., "A usability evaluation of Lazada mobile application," AIP Conference Proceedings, vol. 1891, October, 2017.

[21] A. Hussain, E. Mkpojiogu, J. Musa et al., "A user experience evaluation of Amazon Kindle mobile application," AIP Conference Proceedings, vol. 1891, October, 2017.

[22] H. Cho, P. Yen, D. Dowding et al., "A multi-level usability evaluation of mobile health applications: A case study," Journal of Biomedical Informatics, vol. 86, pp. 79-89, December-2017, 2018.

[23] P. Bokingkito and L. Caparida, "Usability evaluation of a real-time water quality monitoring mobile application," Procedia Computer Science, vol. 197, pp.642-649, 2021.

[24] A. Ridwan, I. Safrudin, M. Ramdhani et al., " Heuristic evaluation on mobile halal detection application," Indonesian Journal of Electrical Engineering and Computer Science, vol. 19, pp. 957-963, 2020.

[25] N. Asy'Ari and D. Murriyatmoko, "Usability Testing for Android Radio Streaming Apps of Songgolangit FM," Journal of Physics: Conference Series, vol. 1471, 2020.

[26] A. Balcita, R. Ventayen, and T. Palaoag, "Usability of KITIKIT: A mobile-based app for implementing customizable online product ordering," IOP Conference Series: Materials Science and Engineering, vol. 482, 2019.

[27] R. Banimahendra and H. Santoso, "Implementation and evaluation of LMS mobile application: Scele mobile based on user-centered design," Journal of Physics: Conference Series, vol. 978, 2018.

[28] Harwati and I. Widodo, "Usability Testing for Android Based Application "jogja Smart Tourism"," IOP Conference Series: Materials Science and Engineering, vol. 215, 2017.

[29] S. Humayoun, P. Chotala, M. Bashir et al., "Heuristics for evaluating multi-touch gestures in mobile applications," HCI 2017: Digital Make Believe - Proceedings of the 31st International BCS Human Computer Interaction Conference, HCI 2017, pp. 2-7, 2017.

[30] R.Aldekhyyel, J. Almulhem, and S. Binkheder, "Usability of telemedicine mobile applications during COVID-19 in Saudi Arabia: A heuristic evaluation of patient user interfaces," Healthcare (Switzerland), vol. 9, 2021.

[31] N. Lynn, A. Sourav, and D. Setyohadi, "Increasing user satisfaction of mobile commerce using usability," International Journal of Advanced Computer Science and Applications, vol. 11, pp. 300-308, 2020.

[32] M. Storm, H. Fjellså, J. Skjærpe et al., "Usability testing of a mobile health application for self-management of serious mental illness in a norwegian community mental health setting," International Journal of Environmental Research and Public Health, vol. 18, 2021.

[33] N. Muhamat, R. Hasan, N. Saddki et al., "Development and usability testing of mobile application on diet and oral health," PLoS ONE, vol. 16, pp. 1-21, 2021.

[34] A. Kresna, M. Achmad, Iqbal et al., "Usability testing of an android application of tractor distribution information system (GIS Tractor)," IOP Conference Series: Earth and Environmental Science, vol. 807, 2021.

[35] A. Nugraha, Rolando, M. Puspitasari et al., "Usability Evaluation for User Interface Redesign of Financial Technology Application," IOP Conference Series: Materials Science and Engineering, vol. 505, 2019.

[36] H. Saeidnia, A. Ghorbi, M. Kozak et al., "Smartphone-Based Healthcare Apps for Older Adults in the COVID-19 Era: Heuristic Evaluation," Studies in Health Technology and Informatics, vol. 289, pp. 128-131, 2022.

[37] Z. Andriawan, R. Pratama, and Khadijah, "Usability Testing of Multifinance Mobile Application for End-Customer (Case Study: PT.XYZ), " ICICoS 2020 - Proceeding: 4th International Conference on Informatics and Computational Sciences, pp. 13-18, 2020.

[38] S. Kundu, A. Kabir, and M . Islam, "Evaluating Usability of Pregnancy Tracker Applications in Bangladesh: A Heuristic and Semiotic Evaluation," IEEE Region 10 Humanitarian Technology Conference, R10-HTC, 2020.