Evaluation and Design Recommendation of Interactive Mobile Learning Application for Individuals with Intellectual Disabilities

Margareta Hardiyanti[1,*], Taufik Kemal Thaha[1], Nanang Arifudin[1], Muhardi Saputra[2]
[1]Department of Electrical Engineering and Informatics, Vocational College, Universitas Gadjah Mada;
taufik.k.t@mail.ugm.ac.id
nanangarifudin@mail.ugm.ac.id
[2]Information System, School of Industrial and System Engineering, Telkom University;
msaputra@telkomuniversity.ac.id
[*]Correspondence: margareta.hardiyanti@ugm.ac.id;

Abstract – This study evaluates the usability of an app designed to improve literacy skills in individuals with intellectual disabilities named "Baca Yuk". The qualitative field usability studies engaged teachers specializing in working with individuals with disabilities, totaling twelve participants from two special needs schools. Usability issues were categorized into two groups: accessing learning materials and learning practice. These issues included challenges in recognizing speaker button status, forming syllables, pairing letters, dealing with multiple-choice questions, managing small text and touch areas, and comprehending complex image illustrations. From these issues, design recommendations were formulated to enhance the user interface and user experience for individuals with intellectual disabilities. Recommendations emphasized providing clear visual feedback, introducing tutorial screens for unfamiliar actions, simplifying complex processes, enlarging clickable areas and text, prioritizing simplicity in image illustrations, and reducing the number of answer options in multiple-choice questions. Additionally, valuable participant suggestions were considered, such as incorporating audio instructions, avoiding scrolling interfaces, and integrating audio feedback for quizzes. These suggestions aim to enhance accessibility and user-friendliness for individuals with intellectual disabilities which hold practical value for developers and designers striving to create inclusive and effective learning experiences for this unique user group.

Keywords – Usability Evaluation, Intellectual Disabilities, Mobile Application, Learning, Design Recommendation

Intisari – Penelitian ini mengevaluasi antarmuka aplikasi "Baca Yuk, yang dirancang untuk meningkatkan keterampilan membaca pada individu dengan disabilitas intelektual. Studi kualitatif yang dilakukan melibatkan dua belas guru yang mengajar individu dengan kebutuhan khusus, yang berasal dari dua sekolah yang berbeda. Permasalahan antarmuka dikategorikan menjadi dua kelompok: akses ke materi pembelajaran dan latihan pembelajaran. Permasalahan yang ditemukan mencakup kesulitan dalam mengenali status tombol audio, membentuk suku kata, menggabungkan huruf, menjawab pertanyaan pilihan ganda, mengenali area sentuhan yang berukuran kecil, serta memahami ilustrasi gambar yang kompleks. Dari permasalahan tersebut, terdapat beberapa rekomendasi desain yang dirumuskan untuk meningkatkan antarmuka bagi pengguna dengan disabilitas intelektual. Rekomendasi yang dihasilkan berupa pemberian feedback visual yang jelas, menampilkan tutorial, menyederhanakan proses yang kompleks, memperbesar area yang dapat diklik, menampilkan ilustrasi gambar yang sederhana, dan mengurangi jumlah pilihan jawaban pada pertanyaan pilihan ganda. Selain itu, saran dari peserta juga dipertimbangkan, seperti menggabungkan instruksi pada audio, menghindari scroll pada layar, dan mengintegrasikan audio feedback pada kuis. Rekomendasi ini bertujuan untuk meningkatkan aksesibilitas dan kemudahan penggunaan bagi individu dengan disabilitas intelektual yang dapat berguna bagi developer dan desainer yang ingin berusaha menciptakan pengalaman belajar yang inklusif dan efektif untuk kelompok pengguna yang khusus ini.

Kata Kunci – Evaluasi Kegunaan, Disabilitas Intelektual, Aplikasi Seluler, Pembelajaran, Rekomendasi Desain

I. INTRODUCTION

In recent years, the use of mobile smart devices has significantly increased in the sector of education. Various mobile applications have been employed as instructional media by teachers from primary schools to higher education institutions [1]–[3]. Moreover, mobile apps were also widely adopted in schools for special needs students [4], [5]. These apps are capable of assisting teachers in delivering personalized learning interventions for the students [6]. However, individuals with disabilities may experience difficulties in the use of technologies, particularly when facing complex design [7]. In particular, this demographic experiences challenges in managing cognitive processes due to limitations in adaptive and cognition functioning [8]. Cognitive load is also associated with the effort needed for users to complete tasks on a mobile device [9]. Therefore, it is crucial to develop a user interface which easy to use and provide a high level of usability when designing a system for the individual with disabilities.

In order to comply with poor usability design damage in a system, multiple evaluation techniques can be carried out. Questionnaires, user testing, heuristic evaluation, interviews, and thinking out loud were discovered to be the most used usability techniques in the software development process [10]. In some studies, third-party tools such as eye-tracking and log interaction features were also used to perform the evaluation [9]. Additionally, in terms of environmental settings, the evaluation can be carried out in both controlled laboratory settings and practical field surveys [11]. Both can be performed in a qualitative approach to obtain the users'

opinion or perceptions regarding the usability issues of the evaluated applications.

In an educational context, several usability studies have been conducted in the past years. The studies that assess usability in mobile learning applications for various users by various methodologies were presented [12]–[16]. The usability studies that particularly focus on mobile applications for children were also conducted to find usability dimensions that designers and developers must consider to ensure that children are able to access the applications in a more convenient way [17], [18]. Another study targeting preschool children was also conducted by evaluating "BenKids", a vocabulary-learning mobile application [19]. While these studies have been conducted for typical users, there were some other usability evaluation studies for people with disabilities. In the context of users with hearing loss, a focus group research study was conducted to evaluate user perceptions of an application specifically designed to improve literacy skills for individuals with hearing impairment [20]. This study involved both caregivers and children. Furthermore, in a usability study focused on users with autism syndromes, the research was conducted by collecting users' perceptions of an Arabic language learning application through a questionnaire [21]. While a study that specifically investigated individuals with intellectual disabilities focused on assessing the effectiveness of these applications in teaching essential living skills [22].

However, there remains a significant gap in the literature concerning the evaluation of interface design for applications specifically tailored to individuals with intellectual disabilities, which could yield valuable design recommendations for literacy learning applications based on usability issues. In response to this gap, our study aims to perform a usability evaluation on an application developed by the authors named "Baca Yuk". This application is designed to enhance reading comprehension abilities and combines user testing and interviews in a real-world educational setting. Therefore, the evaluation of usability was carried out after the successful development of the application, allowing for a comprehensive understanding of user interactions and experiences.

II. LITERATURE REVIEW

Usability studies were primarily carried out to identify usability issues that designers and developers should address in order to enhance the effectiveness of the design for users. A higher education application, namely UniKL Link, was tested by 64 participants, which ranging from undergraduate to graduate students, by performing 30 tasks [14]. While the completion rates indicated that the application is highly effective, some issues related to user notifications were identified, which led to user confusion [23]. A similar study was also undertaken at Fiji University, where a mobile learning application was evaluated by both experienced and inexperienced users. Following independent task completion in the lab, a group interview was carried out to obtain the users' opinions. The research findings suggested improving the navigation experience and including brief documentation on some particular features. Usability studies were not limited to adults, they were also conducted to evaluate applications for children. For instance, the evaluation of "BenKids" application applied usability testing and observed the actions performed by users based on heuristic usability principles leading to the conclusion that the application is intuitive [19]. In addition, usability evaluation was also used to observe a group of children, from 4 to 5 years old, who were given specific tasks and procedures to perform within the evaluated English application [18]. Then, the children's behaviors were compared to Nielsen's usability principles to identify the application's efficiency. The results analysis revealed that most children had encountered difficulties in understanding and identifying the applications menu, suggesting the need for visual aids to assist them in recognizing it. Notably, the application implemented a picture-based in the main menu and provided appropriate feedback to display the correctness or incorrectness of users' answers in the quiz features, making it user-friendly and straightforward for users to interact with. While in the context of users with disabilities, some studies demonstrate various results. In a usability study of the mobile application "Hear Me Read" for users with hearing impairments, several issues were identified related to the unintuitive nature of flipping page gestures and the recording button [20]. Apart from this, an application designed for autistic children in developing speech, "I Can Talk", was evaluated and demonstrated a questionable result of cognitive load when Cronbach's alpha value is observed [21]. Consequently, it was suggested to improve the interactivity of the applications, such as by providing avatars or adding gamification elements. Another usability investigation incorporating individuals with disabilities was carried out by testing a table application developed to learn how to use a vacuum cleaner [22]. The participants in this study had intellectual disabilities, and it was found that the application, which integrates audio and images within its features, successfully attracted the users' attention.

Additionally, usability evaluations also determine whether the user interface designs are acceptable for the users. A study conducted by [15] established usability assessment instruments which contain several criteria indicating requirements that must be incorporated by the tested mobile learning systems to be considered usable for users. The result shows that the system's usability was perceived as acceptable by 82.4% of users, including professors and high school students. Arain et al. [16] conducted usability testing to evaluate "DARSGAH", an m-learning mobile application, involving ten university students as participants. Based on the task completion rate and System Usability Scale (SUS) results, the application was found to be user-friendly and highly effective.

III. METHODOLOGY

We conducted the initial usability testing of the application named "Baca Yuk" , which was designed to assist students with intellectual disabilities in improving their literacy skills. These features encompass a wide range of capabilities, including learning the alphabet, pronouncing syllables, acquiring new words, and constructing sentences from the available words. The study utilized a qualitative approach through the implementation of field testing method, which involved immersing participants in real-world scenarios to assess the usability of the product or system [24] . As individuals with disabilities may face challenges in expressing their thoughts, or communicating effectively [8], we decided to conduct a participatory design interview with teachers who specialize in working with individuals with disabilities to gather more valuable insights. Furthermore, teachers are also expected to guide the students in using the application during the study process. A research study conducted in an inclusive school revealed a finding that although technology was designed to support student's development, its effectiveness was compromised due to the teacher's limited proficiency in using the application [25]. Thus, teachers from two distinguished schools for special needs students were invited to participate in the study through focus groups. Focus groups have the potential to offer unique insight into the context of product use and foster representative opinions compared to individual interviews [26]. Consequently, small groups, each comprising two to seven people were formed to test the application, resulting in a total of 12 participants. In this study, the research evaluation was conducted in two parts. The first part involves participants undertaking a series of pre-designed tasks within the application. Table 1 shows the details of the tasks which must be performed by participants by using a tablet. In the subsequent second part, they were invited to share their feedback based on their experience with the application, which also reflects the potential issues that intellectual disabilities students might encounter. Following that, we organized the feedback based on the characteristics of the issues to determine the design recommendations, which will be detailed in the next section.

IV. RESULT AND DISCUSSION

A. Usability Issues

The analysis of focus group has identified several issues which have been categorized into two groups: accessing learning materials, and learning practice. Table 2 shows the summary of the issues which were analyzed based on the observations and feedback from the participants. The subsequent paragraphs present the details of each issue:

1) Lack of awareness in recognizing the speaker button status: When learning alphabets, syllables, and words, the users were provided with the ability to hear how words or sounds are spoken or articulated. To listen to the sound, they had to click the "sound" button. However, the participants experienced challenges due to delays in playing the sound caused by network connection issues. Thus, this led to confusion about whether they had already clicked the button or not. Hence, some users clicked the button multiple times, resulting in the audio playing repeatedly:
"Students will tend to click the button more than once if they cannot see any changes or responses on the screen." [group 2].

Table 1. Task List for Usability Testing

Category	Task
Account	Account Registration
	Login
	Forgot password
	Logout
Student data	Add student data
	Update student data
	Remove student data
Alphabets reading	Learn capital letters
	Learn small letters
	Distinguish between capital and small letters
	Match capital letters
	Match small letters
Words reading	Learn syllables
	Learn words
	Compose syllables
	Guest a word from a picture
Sentences reading	Compose words
	Guest a sentence from a picture
History	Alphabets reading history
	Words reading history
	Sentences reading history

1) Difficulty in forming a syllable: To learn a syllable, users need to combine two alphabets before playing its audio or sound. Figure 1 illustrates the interface that was perceived by users to access this feature. Some users were observed to take a little longer to think before performing the required action:

"*It is not clear how to perform the required action, and the steps needed to play the syllable audio are too long."* [group 3].

Table 2. Usability issues

Category	Issue
Accessing learning material	Unaware to recognize the active status of the speaker button
	Unable to construct a syllable
Taking learning practice	Unable to identify the action to match letters
	Difficulty in using four options answers in multiple-choice questions
	Too small text size and touch area
	Complex image illustration

When the feedback was collected, the dash symbol shown on the screen likely caused misunderstanding among the participants.

2) Struggling to recognize the procedures for pairing letters: In the alphabet learning practice, users are required to match one main letter with another letter from a list of letter options. Figure 2 shows the illustration of the exercise interface design. The users are expected to match identical letters by dragging the main letter to another identical one. However, most participants had trouble identifying the gesture action which must be carried out because there were no instructions or tutorials provided:

"I thought we should draw a line between two identical alphabets" [group 1]

Figure 1. Learning syllables issue

3) Dealing with multiple-choice questions that offer four answer options: Practicing words and sentences involve the features of quiz in multiple-choice format questions. The users must select one answer out of four options to get the correct answer. Despite that, the teachers believed that four options were excessive for students with intellectual disability:

"*In multiple choice questions, students usually only understand the answers in top-middle-bottom position* " [group 3]

"The number of options should be reduced from four to three options" [group 4]

4) Small size of text and touch area: It was noted that both the size of radio button selections and the answers' font in the multiple-choice questions are too small, making it difficult for users when trying to select the intended correct answer.

5) Image illustrations were difficult to comprehend: Image illustrations were utilized in the features of learning words and sentences to provide visual support and enhance comprehension for users. Nonetheless, some images were considered to be complex due to the presence of numerous objects within the image:

"*Displaying too many objects in a single image could lead to ambiguity for the students."* [group 2]

For example, a picture that includes both a sun and a cloud can cause confusion, as students may be uncertain whether to identify it as the word "sun" or "cloud"

Figure 2. Matching syllables practice

B. Design Recommendations

The usability challenges observed in this study underscore the nature requirements of designing applications that cater to the diverse needs of individuals with intellectual disabilities. There were two main issues discovered

specifically for user interaction and cognitive load issues. The interaction issues encompass the actions that users need to perform: play the alphabet sound, compose a syllable, match the letters, and answer multiple-choice questions. While the cognitive load concerns encompass the content design such as image illustration and the number of answers in multiple-choice questions. Therefore, based on qualitative observational studies, we have compiled design recommendations for developing interactive learning mobile applications for individuals with intellectual disabilities, which are presented in Table 3.

First, appropriate visual feedback is necessary for users to understand their status while performing tasks within the applications. In this case, apart from the auditory feedback, users were not informed when the audio button successfully clicked, leading to confusion when the audio experienced delays. Moreover, the lack of feedback in education apps could leave users feeling disoriented [27]. In another case, this study reported similar results which are in line with the findings in [15], highlighting challenges in recognizing gestures to perform tasks. It was examined that individuals with intellectual disabilities may encounter difficulties when presented with unfamiliar gestures, as seen in the task of matching the letters, which requires users to drag and drop them into the intended position. Figure 3 shows an example of visual instruction or tutorial. Therefore, it is advisable to present a brief tutorial screen before users attempt any task, especially the first time they engage in the activity. This tutorial screen can provide step-by-step instructions and visual cues to guide users through the task, ensuring a smoother and more accessible experience. This approach can also be extended to other functionalities that involve actions users may not be familiar with.

Table 3. Design Recommendation

Category	Recommendation
User Interaction	Provide visual feedback
	Minimize the required steps taken to perform a task
	Display bigger text size
	Enlarge button/touch area
	Prevent users from scrolling
Reduce cognitive load	Provide a maximum 3 choices
	Promote the use of minimalistic image illustrations
	Add audio instructions for each activity
	Add sound effects indicating correct and incorrect answers

Apart from this, an issue was also found in the activity of composing a syllable. When a user wishes to compose a syllable to learn, they must select the letter combinations that form a syllable before being able to play the audio pronunciation of that syllable. This process has to be repeated each time they want to learn other syllables, leading to an inefficient and cumbersome step. As students with intellectual disabilities tend to lose focus easily before successfully completing a task, the process of learning syllables should be simplified and shortened. One potential solution is to provide a comprehensive list of the syllable combinations, as illustrated in Figure 4. Therefore, users no longer need to manually compose the syllables since all combinations have already been listed.

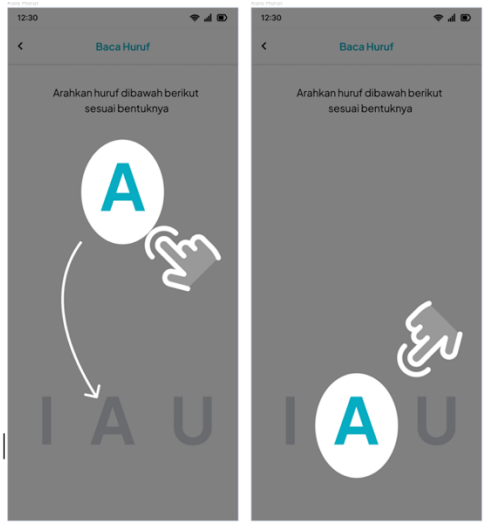

Figure 3. Visual instruction to match letters

Figure 4. List all syllables in group 'A'

Third, to address the issue concerning the clickable area and small text used for answer choices in multiple-choice questions. It is essential to increase the size of the radio

buttons and the answer font. By enlarging these elements, users with intellectual disabilities will have an easier time selecting their intended answer. This adjustment should be substantial enough to enhance visibility and interaction without compromising the overall layout of the application. Notably, large buttons and text were also suggested by a similar study which developed an application for intellectual disabilities to engage in physical activities [28].

Last, the images used within the application's features, including illustrations for learning or practicing words or sentences, should prioritize simplicity and clarity. They should avoid unnecessary complexity or details to ensure that students with intellectual disabilities can easily understand them. We believe that considering both the visual elements and cognitive demands of the application is essential in designing an interface for individuals with disabilities, especially for children. In line with our emphasis on reducing cognitive load for users, we also recognize the significance of minimizing the number of answer options provided in multiple-choice questions. Despite a study carried out by [29] recommending the limitation of presented options to 3 to 4 in learning application layout, the teachers advised us to offer only 3 choices. When there are fewer answer choices, the cognitive load typically decreases. Test-takers have fewer options to evaluate, making it simpler to identify the correct answer. This can be particularly beneficial for individuals with intellectual disabilities as it reduces the mental effort required.

In addition to the issues identified in this study, we have also taken into account additional suggestions provided by participants. The implemented system offered a wide range of activities for users to learn materials and do practices, providing diverse interaction methods. As a result, it was suggested to incorporate audio instructions each time users initiate a new activity within the application. Furthermore, the teachers also recommended to design the interface without any scrolling. Individuals with intellectual disabilities may experience other co-occurring impairments such as motor or sensory difficulties [8]. As a result, they may find it difficult to use scrolling gestures effectively. Then, in the context of learning practice, it was recommended to incorporate audio responses as feedback to indicate both correct and incorrect answers. Thus, the application would not solely rely on visual feedback. Notably, a study that implemented gamification techniques in a design framework for students experiencing difficulties in learning also utilized audio feedback for both correct and incorrect responses in quizzes [29].

C. Limitations and Future Work

The study underwent the exploratory study based on pre-defined tasks which have been identified as the main tasks within the applications. Consequently, issues may arise when users perform tasks other than those covered by the pre-defined set. Additionally, the design recommendations generated in this study must be implemented in the upcoming development phase to observe their effectiveness. This implementation will involve iterative usability testing over time. For more comprehensive evaluation, future iterations of the study should incorporate quantitative measures, such as surveys, usage analytics, and task success rates, to quantifiably assess the impact of design recommendations on usability aspects. Integrating these quantitative metrics will enrich the study's insights and contribute to a more robust understanding of the usability enhancements for individuals with intellectual disabilities.

V. CONCLUSION

This study has identified several usability issues in the design of a mobile learning application for individuals with intellectual disabilities. These issues encompassed difficulties in recognizing speaker button status, forming syllables, pairing letters, handling multiple-choice questions, dealing with small text and touch areas, and comprehending complex image illustrations.

To address these challenges and create a more user-friendly and inclusive learning experience, we have compiled a set of design recommendations. These recommendations include the need for clear and appropriate visual feedback to help users understand their progress, the implementation of brief tutorial screens to guide users through tasks, and simplifying the process of composing syllables by providing a comprehensive list of combinations. Furthermore, we emphasized the importance of increasing the size of clickable areas and text in multiple-choice questions to enhance accessibility. Additionally, we highlighted the significance of using simple and clear images to reduce cognitive load and minimize the number of answer options in quizzes to make tasks more manageable. We also considered additional suggestions from participants, such as incorporating audio instructions for new activities, avoiding scrolling in the interface, and providing audio feedback for both correct and incorrect answers.

In conclusion, these design recommendations aim to create a more accessible and user-friendly mobile learning application that meets the diverse needs of individuals with intellectual disabilities, ultimately enhancing their learning experience.

REFERENCE

[1] A. Noorhidawati, S. G. Ghalebandi, and R. Siti Hajar, “How do young children engage with mobile apps? Cognitive, psychomotor, and affective perspective,” *Comput Educ*, vol. 87, pp. 385–395, Sep. 2015, doi: 10.1016/j.compedu.2015.07.005.

[2] E. M. De La Cruz, M. A. Trujillo Meza, and L. Andrade-Arenas, “Mobile application to improve the learning of secondary school students,” *Advances in Mobile Learning Educational Research*, vol. 3, no. 1, pp. 586–595, Jan. 2023, doi: 10.25082/AMLER.2023.01.007.

[3] M. S. Goundar and B. A. Kumar, “The use of mobile learning applications in higher education institutes,” *Educ Inf Technol (Dordr)*, vol. 27, no. 1, pp. 1213–1236, Jan. 2022, doi: 10.1007/s10639-021-10611-2.

[4] J. Ismaili and E. H. O. Ibrahimi, “Mobile learning as alternative to assistive technology devices for special needs students,” *Educ Inf Technol (Dordr)*, vol. 22, no. 3, pp. 883–899, May 2017, doi: 10.1007/s10639-015-9462-9.

[5] A. Stathopoulou, Z. Karabatzaki, D. Tsiros, S. Katsantoni, and A. Drigas, "Mobile Apps the Educational Solution for Autistic Students in Secondary Education," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 13, no. 02, p. 89, Feb. 2019, doi: 10.3991/ijim.v13i02.9896.

[6] A. I. M. Qahmash, "The Potentials of Using Mobile Technology in Teaching Individuals with Learning Disabilities: A Review of Special Education Technology Literature," *TechTrends*, vol. 62, no. 6, pp. 647–653, Nov. 2018, doi: 10.1007/s11528-018-0298-1.

[7] H. Spencer González, V. Vega Córdova, K. Exss Cid, M. Jarpa Azagra, and I. Álvarez-Aguado, "Including intellectual disability in participatory design processes: Methodological adaptations and supports," in *Proceedings of the 16th Participatory Design Conference 2020 - Participation(s) Otherwise - Volume 1*, New York, NY, USA: ACM, Jun. 2020, pp. 55–63. doi: 10.1145/3385010.3385023.

[8] A. A. Bayor *et al*., "Toward a Competency-based Approach to Co-designing Technologies with People with Intellectual Disability," *ACM Trans Access Comput*, vol. 14, no. 2, pp. 1–33, Jun. 2021, doi: 10.1145/3450355.

[9] P. Weichbroth, "Usability of mobile applications: A systematic literature study," *IEEE Access*, vol. 8, pp. 55563–55577, 2020, doi: 10.1109/ACCESS.2020.2981892.

[10] F. Paz and J. A. Pow-Sang, "A systematic mapping review of usability evaluation methods for software development process," *International Journal of Software Engineering and Its Applications*, vol. 10, no. 1, pp. 165–178, 2016.

[11] Z. Huang and M. Benyoucef, "A systematic literature review of mobile application usability: addressing the design perspective," *Universal Access in the Information Society*, vol. 22, no. 3. Springer Science and Business Media Deutschland GmbH, pp. 715–735, Aug. 01, 2023. doi: 10.1007/s10209-022-00903-w.

[12] B. A. Kumar and P. Mohite, "Usability of mobile learning applications: a systematic literature review," *Journal of Computers in Education*, vol. 5, no. 1, pp. 1–17, Mar. 2018, doi: 10.1007/s40692-017-0093-6.

[13] B. A. Kumar and M. S. Goundar, "Usability heuristics for mobile learning applications," *Educ Inf Technol (Dordr)*, vol. 24, no. 2, pp. 1819–1833, Mar. 2019, doi: 10.1007/s10639-019-09860-z.

[14] N. A. Nik Ahmad and M. Hussaini, "A Usability Testing of a Higher Education Mobile Application Among Postgraduate and Undergraduate Students," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 15, no. 09, p. 88, May 2021, doi: 10.3991/ijim.v15i09.19943.

[15] A. Pensabe-Rodriguez, E. Lopez-Dominguez, Y. Hernandez-Velazquez, S. Dominguez-Isidro, and J. De-la-Calleja, "Context-aware mobile learning system: Usability assessment based on a field study," *Telematics and Informatics*, vol. 48, p. 101346, May 2020, doi: 10.1016/j.tele.2020.101346.

[16] A. A. Arain, Z. Hussain, W. H. Rizvi, and M. S. Vighio, "Evaluating Usability of M-Learning Application in the Context of Higher Education Institute," 2016, pp. 259–268. doi: 10.1007/978-3-319-39483-1_24.

[17] E. O. C. Mkpojiogu, A. Hussain, and F. Hassan, "A systematic review of usability quality attributes for the evaluation of mobile learning applications for children," in *AIP Conference Proceedings*, American Institute of Physics Inc., Sep. 2018. doi: 10.1063/1.5055494.

[18] M. Masood and M. Thigambaram, "The Usability of Mobile Applications for Pre-schoolers," *Procedia Soc Behav Sci*, vol. 197, pp. 1818–1826, Jul. 2015, doi: 10.1016/j.sbspro.2015.07.241.

[19] S. Eltalhi, H. Kutrani, R. Imsallim, and M. Elrefady, "The Usability of BenKids Mobile Learning App in Vocabulary Teaching for Preschool," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 15, no. 24, pp. 4–18, Dec. 2021, doi: 10.3991/ijim.v15i24.22237.

[20] S. DeForte *et al*., "Usability of a mobile app for improving literacy in children with hearing impairment: Focus group study," *JMIR Hum Factors*, vol. 7, no. 2, Jun. 2020, doi: 10.2196/16310.

[21] M. F. Hajjar, S. T. Alharbi, and F. M. Ghabban, "Usability Evaluation and User Acceptance of Mobile Applications for Saudi Autistic Children," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 7, pp. 30–46, 2021, doi: 10.3991/ijim.v15i07.19881.

[22] S. Yeni, K. Cagiltay, and N. Karasu, "Usability investigation of an educational mobile application for individuals with intellectual disabilities," *Univers Access Inf Soc*, vol. 19, no. 3, pp. 619–632, Aug. 2020, doi: 10.1007/s10209-019-00655-0.

[23] B. A. Kumar and P. Mohite, "Usability study of mobile learning application in higher education context: An example from Fiji national university," in *Education in the Asia-Pacific Region*, vol. 40, Springer Nature, 2017, pp. 607–622. doi: 10.1007/978-981-10-4944-6_29.

[24] C. M. Barnum, *Usability testing essentials: Ready, set... test!* Morgan Kaufmann, 2020.

[25] L. de Medeiros Braz, E. de Souza Ramos, M. L. P. Benedetti, and H. Hornung, "Participatory design of technology for inclusive education: A case study," in *Universal Access in Human–Computer Interaction. Human and Technological Environments: 11th International Conference, UAHCI 2017, Held as Part of HCI International 2017, Vancouver, BC, Canada, July 9–14, 2017, Proceedings, Part III 11*, 2017, pp. 168–187.

[26] K. Kuhn, "Problems and benefits of requirements gathering with focus groups: a case study," *Int J Hum Comput Interact*, vol. 12, no. 3–4, pp. 309–325, 2000.

[27] F. BENMARRAKCHI, O. ELHAMMOUMI, E. L. Jamal, and others, "Evaluation of an educational game for children with learning disabilities: FunLexia-A case study," *International Journal of Information Science and Technology*, vol. 3, no. 6, pp. 4–14, 2019.

[28] I. Wold, "Creating an App Motivating People with Intellectual Disabilities to Do Physical Activity," NTNU, 2019.

[29] A. Shaban and E. Pearson, "A learning design framework to support children with learning disabilities incorporating gamification techniques," in *Conference on Human Factors in Computing Systems - Proceedings*, Association for Computing Machinery, May 2019. doi: 10.1145/3290607.3312806.