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Design and Evaluation of an Augmented Reality Application for Learning Workshop Tool Recognition

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ABSTRACT

This study aims to design and evaluate an Augmented Reality (AR) application for workshop tool recognition, with a focus on enhancing interactivity and student engagement in technical education. Developed using the ADDIE methodology—Analysis, Design, Development, Implementation, and Evaluation—the application integrates Blender for 3D modelling, Unity for development, and Vuforia for AR tracking. Usability was assessed through the System Usability Scale (SUS), involving 48 students from workshop practicum and Occupational Health and Safety (OHS) courses. The application achieved a SUS score of 50.5, classified as Fair according to the classification by Bangor et al. (2009). Key usability aspects were rated positively, including comfort (4.2), ease of use (4.0), functional integration (3.9), stability (4.1), and ease of learning (4.3). While the study highlights the application's potential as an effective learning tool, limitations include a small, institution-specific sample size. Future research should examine its adaptability in broader educational contexts and assess its impact on student learning outcomes. This study supports the integration of AR in technical education, fostering more interactive, efficient, and Industry 4.0-aligned learning environments.

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1. INTRODUCTION

Augmented Reality (AR) integrates real-world and virtual elements to transform user experiences across various sectors, including education, healthcare, and industrial applications (Ayodeji, 2021) (Hind, 2020). This technology facilitates complex data interaction and enhances visualization, making it a pivotal tool in advancing the Fourth Industrial Revolution (Zhihan, 2021) (Zuev, 2020). In educational settings, AR provides interactive virtual laboratories, simplifying and enriching the learning process. This adaptability shows AR's potential to extend beyond conventional classroom applications into more dynamic, technical training environments (Zagoranski, 2003) (Ilana, 2019).

Technical education, especially in workshops and bench work practices, involves practical skills essential for engineering students. These include the operation and maintenance of machinery and the use of various hand tools, where understanding and safety are paramount (Hincapié, 2021) (Criollo-C, 2021). Traditional training methods, however, often face challenges such as limited access to tools and maintaining student engagement. By integrating AR, this study aims to address these challenges by providing a safer, interactive learning environment that enhances students' understanding and engagement through detailed 3D tool visualizations and operations (Ali, 2021) (Fernandez, 2021).

The focus of this research is to develop and evaluate an AR application specifically designed for the introduction of workshop tools in technical education settings. The application uses the ADDIE model for development and incorporates interactive features like quizzes and tool explanations to engage users effectively. This approach not only aims to improve learning outcomes but also ensures that students can apply their skills safely and efficiently in real-world settings (Gloria, 2021) (Alyafei, 2021).

To determine the effectiveness of the AR application, this study utilizes the System Usability Scale (SUS) to measure user satisfaction and usability across several criteria, including comfort, ease of use, and functional integration. This evaluation will help refine the application to better meet educational needs while setting a precedent for the broader application of AR technology in technical and vocational education beyond the pandemic context (Thiciany, 2021).

2. METHODS

This study follows the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to develop and evaluate an Augmented Reality (AR) application for workshop tool recognition. The ADDIE model is widely used in educational development for its structured and systematic approach shown in Figure 1. Each phase is described below, highlighting key activities, tools, and evaluation methods.

Figure 1. Research Flow of the ADDIE Model.

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2.1. Analysis

The analysis phase focused on identifying learning needs and user requirements. Observations were conducted during workshop practicum and Occupational Health and Safety (OHS) courses at an Indonesian university. The findings revealed that students needed an interactive tool to enhance their engagement and understanding of workshop tools prior to hands-on sessions. Augmented Reality (AR) was selected due to its ability to present 3D visualizations of workshop tools, enabling students to explore and interact with the tools safely. To support this, a pretest feature was designed to assess students' prior knowledge, ensuring they were better prepared for the practicum sessions.

2.2. Design

The design phase focused on the structure, interface, and key features of the AR application. The interface was designed to be simple, interactive, and user-friendly to ensure smooth navigation. The main features of the AR application are outlined in Table 1. Each feature is tailored to support student learning and enhance user engagement. The main menu includes options for Play, Quiz, Information, and Exit, making it easy for students to navigate.

Table 1. Features and Specifications of the AR Program.

Feature	Description
Pretest	A feature that allows students to test their prior knowledge before starting learning with the app.
3D Workshop Tool AR Visualization	This feature allows students to view 3D models of workshop tools, enabling them to understand tools from different angles and in greater detail.
Text Explanation	Each workshop tool displayed in the app is accompanied by detailed text explanations, providing information on the function and usage of the tool.
Easy Navigation	The user interface is designed for easy navigation, with clear menus and simple instructions.
Visual Aesthetics	The app's design is engaging and colorful to enhance user interest and involvement.
AR Book	This feature transforms traditional books into interactive tools through AR technology, where there are 10 workshop tool target objects that can be scanned with AR.

2.3. Development

The development phase focused on building the AR application using industry-standard tools. Blender was used to create and animate 3D models of workshop tools. These models were imported into Unity, which served as the main development platform for programming app logic and user interactions. Vuforia was used to enable AR tracking, allowing users to scan images of workshop tools and visualize corresponding 3D models in real-time. The three software tools worked together to enable smooth animations, stable AR tracking, and seamless user interaction. The app was developed to be compatible with Android devices (version 10 or lower) to ensure accessibility for a broad range of students.

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2.4. Implementation

The AR application was tested with 48 students from workshop practicum and OHS courses at an Indonesian university. This sample size aligns with usability testing guidelines, which recommend a minimum of 30-50 users to ensure sufficient evaluation reliability (Sauro & Lewis, 2016). Respondents used the app to interact with 3D models, scan image targets, and complete quizzes. Their feedback was collected and used to identify technical issues, such as AR marker recognition errors, which were addressed in subsequent development iterations.

2.5. Evaluation

The usability of the AR application was evaluated using the System Usability Scale (SUS), a widely used tool for measuring user experience (Brooke, 1996). The SUS questionnaire consists of 10 items rated on a 5-point Likert scale, with alternating positive and negative items to reduce response bias. The list of items in the SUS questionnaire is shown in Table 2. Positive items (Q1, Q2, Q4, Q6, Q7, Q9) were scored as $X_i - 1$, while negative items (Q3, Q5, Q8, Q10) were scored as $5 - X_j$. The SUS score was calculated using the following formula:

$$SUS = \left(\sum_{i=1}^{n} (X_i - 1) + \sum_{j=1}^{n} (5 - X_j) \right) \times 2.5$$

In this formula, X_i denotes the score for the positive items (Q1, Q2, Q4, Q6, Q7, Q9) and X_j represents the score for the negative items (Q3, Q5, Q8, Q10). The total score ranges from 0 to 100, where a higher score indicates better usability. This scoring method provides a standardized way to assess user satisfaction, comfort, ease of use, and functional integration of the AR application. The final SUS score is then used to classify the usability of the application into categories such as Excellent (85-100), Good (70-84), Fair (50-69), Poor (25-49), and Unacceptable (0-24), based on the classification system proposed by Bangor et al. (2009). This approach ensures an objective, quantifiable measure of the application's usability, providing insight into areas for potential improvement.

Table 2. Questionnaire Questions (Brooke, 1996).

Question	Code	Type
I feel comfortable using this application.	Q1	Positive
I find this application easy to use.	Q2	Positive
I feel that I need to learn a lot before I can use this application effectively. (reversed)	Q3	Negative
I feel this application is well integrated.	Q4	Positive
I find too much inconsistency in this application. (reversed)	Q5	Negative
I think most people will quickly learn to use this application.	Q6	Positive
I feel very confident using this application.	Q7	Positive
I feel that I need to learn a lot before I can use this application. (reversed)	Q8	Negative
I find this application very easy to use.	Q9	Positive
I feel I need technical assistance to use this application. (reversed)	Q10	Negative

Note: Questions ending with (reversed) indicate that the score for that question must be reversed when calculating the total SUS score. For example, if the rating scale is 1-5, then a score of 5 becomes 1, a score of 4 becomes 2, and so on.

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3. RESULTS AND DISCUSSION

This section presents the results and discussion of the study, divided into three key aspects. The first focuses on the development and structure of the AR application for workshop tool recognition. The second highlights the usability evaluation results, including user feedback from the System Usability Scale (SUS). Finally, the third aspect discusses the findings' significance, comparisons with previous studies, study limitations, and recommendations for future work.

3.1. The Developed AR Application

This section discusses three main aspects. First, it outlines the AR application developed as an introductory learning tool for workshop tool recognition. Second, it presents and analyses data from questionnaires distributed to students, offering insights into user reception and application effectiveness. Lastly, it discusses research findings, comparisons with prior studies, and the potential contribution of the AR application to workshop practicum and Occupational Health and Safety (OHS) learning.

The AR application serves as a tool for recognizing workshop tools, with Indonesian as its language to accommodate students from an Indonesian state university.

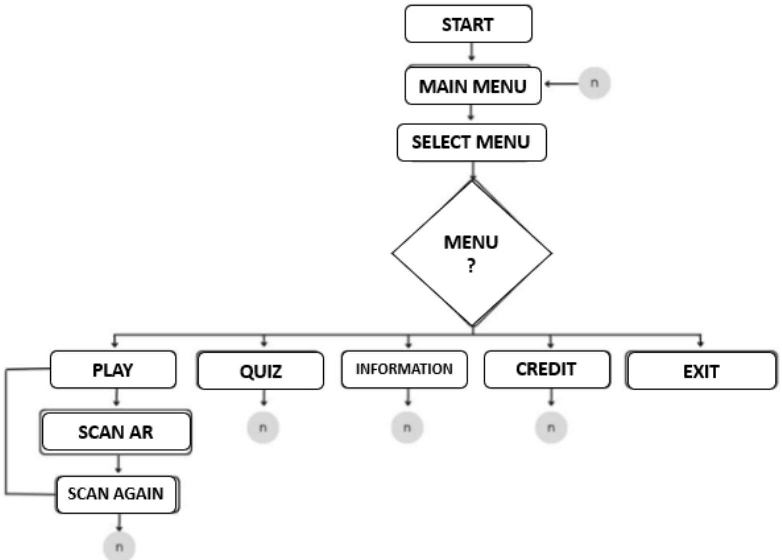

Figure 2. AR Application Workflow Diagram

Figure 2 explains how the application workflow, illustrated in Figure 2, begins at the main page with five menu options: 'Play', 'Information', 'Credits', 'Quiz', and 'Exit'. The 'Play' option activates the AR Camera, allowing users to scan markers with their smartphone cameras, triggering the display of 3D objects or videos corresponding to the markers. Users can capture new markers or return to the main menu. The 'Information' menu provides usage instructions, 'Credits' lists the app developers, and 'Quiz' tests users' knowledge of workshop tools after using the AR Camera. The 'Exit' option closes the application.

The Android-based application supports Android 10 (Android Q) and earlier versions. Its icon is shown in **Figure 3 (a).**

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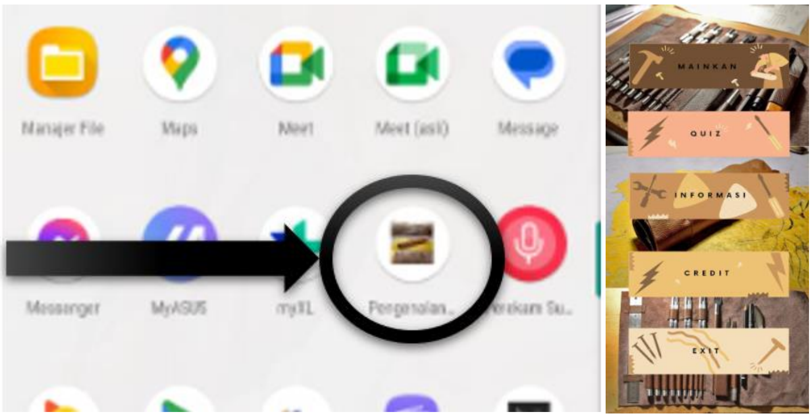
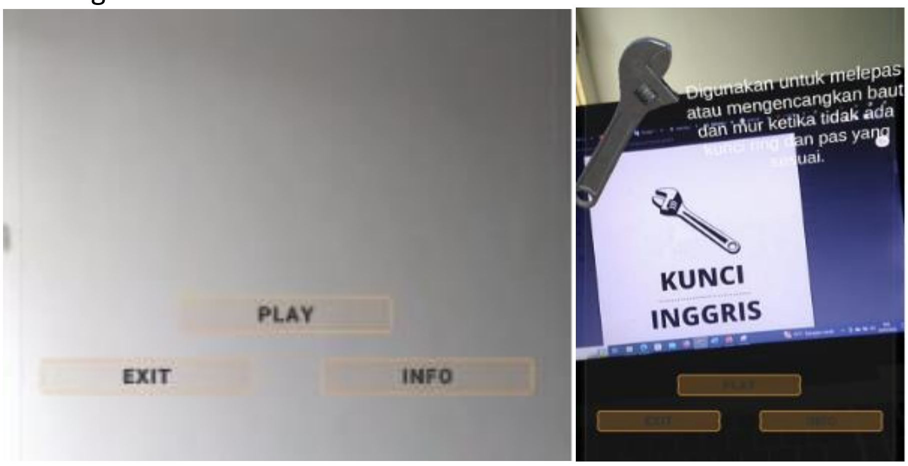


(a) (b)

Figure 3. (a) AR Application Icon for Workshop Tool Recognition, (b) AR Application Main Menu

After clicking on the icon, users enter the application's main menu, as shown in **Figure 3(b)**, which offers five key functions: Play, Quiz, Information, Credits, and Exit. Selecting the Play button grants users immediate access to the AR feature, where the display, as illustrated in **Figure 5(a)**, initially shows a blank AR view without an image target, meaning no 3D image is displayed until a target is detected.



(a) (b)

Figure 5. (a) AR Scan Display Without Image Target, (b) With Image Target

When an Image Target is provided, the expected AR image will appear, as shown in **Figure 5(a)** where the target image is a wrench, displaying a 3D model of the wrench. In the AR Scan feature, there are three buttons: "Play", "Info", and "Exit". When the "Play" button is clicked, the 3D object will move as if operating. When the "Info" button is clicked, information about the scanned workshop tool will be displayed, as shown in **Figure 5(b)**, while clicking the "Exit" button will return the user to the Main Menu.

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(a) (b)

Figure 7. Display When the Quiz Button is Pressed

Another feature of the AR application is the Quiz feature. When the "Quiz" button is clicked, the initial screen shown is as displayed in **Figure 7(a).** This figure shows 14 questions, consisting of 5 easy questions, 5 medium-level questions, and 4 hard-level questions. **Figure 7(b)** shows the display when the quiz starts, where a timer is visible in the upper right corner. The green circle in the center represents the number of attempts remaining, and the upper left shows the score.

In the main menu, there is an Information button that contains the Manual Instructions for the AR Workshop Tool Recognition application. The display when the "Information" button is clicked is shown in **Figure 8(a)**.

(a) (b)

Figure 8. (a) Application Manual Instructions, (b) List of Image Targets in the AR Application

In this application, the Image Targets in the AR Book consist of 10 workshop tools, as shown in **Figure 8(b)**.

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3.2. AR Application Usability Evaluation Results

The usability of the AR application was evaluated using the System Usability Scale (SUS), which measures key aspects of the user experience, including comfort, ease of use, functional stability, and user engagement. The evaluation involved 48 students from workshop practicum and Occupational Health and Safety (OHS) courses. Each student was asked to complete a 10-item questionnaire based on the SUS framework, with each item rated on a 5-point Likert scale. The items are classified as positive (Q1, Q2, Q4, Q6, Q7, Q9) and negative (Q3, Q5, Q8, Q10) questions, which ensures a balanced approach to capturing user perceptions.

The results of the SUS evaluation are presented in Table 1, which shows the maximum, minimum, and average scores for each question. The table also highlights the SUS-adjusted score, which reflects the application of the SUS scoring method. Overall, the results demonstrate positive user feedback, particularly in the areas of ease of use, comfort, and functional stability. The total SUS score for the AR application was 50.5, which is classified as Fair based on the usability classification proposed by Bangor et al. (2009).

Table 3. SUS Evaluation Results for AR Application

Code	Type	Max	Min	Average	SUS Adjusted Score
Q1	Positive	2	5	3.8	2.8
Q2	Positive	3	5	4.1	3.1
Q3	Negative	3	5	4.3	0.7
Q4	Positive	3	5	3.7	2.7
Q5	Negative	3	5	4.5	0.5
Q6	Positive	3	5	4.2	3.2
Q7	Positive	3	5	3.9	2.9
Q8	Negative	3	5	4.6	0.4
Q9	Positive	2	5	3.7	2.7
Q10	Negative	3	5	3.8	1.2

The results show that users rated the application positively in terms of comfort (Q1, Q7), ease of use (Q2, Q9), and ease of learning (Q6). However, there were lower scores for items such as Q3 and Q8, which relate to the learning curve and user reliance on guidance. This suggests that some users may need additional support or tutorials when first using the application. To address this, the development team could introduce an interactive onboarding tutorial to improve the user experience.

3.3. Discussion

The usability evaluation findings indicate that the AR application provides a positive learning experience for students, aligning with previous studies (Zagoranski, 2003) (Gloria, 2021) that highlight the potential of AR to enhance student engagement and technical learning. The SUS score of 50.5 categorizes the application's usability as Fair, reflecting general usability while identifying specific areas for improvement, such as reducing the learning curve for new users. The use of interactive 3D models within the AR system fosters

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deeper student engagement by allowing them to explore complex workshop tools interactively. This approach supports findings by Zagoranski (2003), which demonstrated that interactive AR models improve student comprehension and learning outcomes in technical education.

4. CONCLUSION

The study successfully designed and evaluated an Augmented Reality (AR) application for workshop tool recognition using the ADDIE model, with a usability assessment conducted through the System Usability Scale (SUS) involving 48 students. The application provides an interactive, safe, and engaging learning experience, enabling students to visualize 3D workshop tools, access real-time information, and complete quizzes to reinforce their understanding. The overall SUS score of 50.5 indicates a Fair usability rating, with strengths in ease of use, comfort, and functional stability. However, areas for improvement include addressing the learning curve (Q3, Q8) and reducing reliance on technical support, which can be mitigated through interactive onboarding tutorials and in-app guidance. The limited scope of the study, with participants from a single institution, highlights the need for future evaluations with a broader, more diverse user base. Future work should focus on optimizing AR-based workshop tool recognition, incorporating features such as adaptive learning paths, voice control, and gesture navigation. This focused development could further enhance the effectiveness and usability of AR applications in technical education and support the broader goals of Industry 4.0-driven learning environments.

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