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Evaluating Mixed Reality Technology for Enhancing Art Pedagogy

Kirana Hanifati [a,*], Sritrusta Sukaridhoto [a], Hestiasari Rante [a]

[a] *Department of Informatics and Computer Engineering, Politeknik Elektronika Negeri Surabaya*

Corresponding author: [*]kiranahani@pasca.student.pens.ac.id

***Abstract*—The lack of interest among students in studying art, particularly the traditional Indonesian art form of batik, poses a significant challenge for educational institutions. Despite its cultural significance, the education sector lacks effective strategies to introduce and enhance students' interest in batik within the art curriculum. Several consequences can arise if the education sector fails to implement strategic measures to address this issue promptly. This could lead to a gradual erosion of cultural heritage and a loss of artistic traditions passed down through generations, and students may miss out on valuable opportunities for self-expression and cultural exploration. This study addresses this issue by leveraging mixed reality and gamification in a batik creation application. This innovative approach not only enhances the pedagogy of art education but also aims to revive cultural interest. The study employs Software Testing and PIECES to evaluate user experiences, emphasizing user comfort and smooth interactions. By assessing the application with tools like Unity Profiler and Hololens 2 performance testing, the study ensures an optimal user experience, contributing to the broader goal of preserving Indonesia's cultural heritage through innovative and accessible educational solutions. The results fall within the range of 4.04 to 4.24, categorizing user satisfaction as "satisfied" and the application running at an optimal 60 frames per second (FPS). This implies that users responded positively to the application, indicating that implementing mixed reality technology in batik learning provides a satisfying experience.**

***Keywords*— Batik; education; gamification; mixed reality; pedagogy.**

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I. INTRODUCTION

Batik is an iconic emblem that embodies centuries-old traditions and storylines in the complex fabric of Indonesian cultural identity. However, the preservation of this esteemed art form encounters a formidable challenge within the educational realm, marked by a concerning decline in student enthusiasm [1], [2]. Despite batik's profound cultural richness, modern teaching methods need to catch up in capturing students' interest in mastering this intricate technique. The urgency of this issue transcends the educational landscape, posing a genuine threat to Indonesia's cultural legacy. The imminent risk lies in the potential loss of creative traditions passed down through generations, creating a rift in the very essence that sets the country apart. The gravity of the situation underscores the need for a strategic and innovative intervention to reignite passion and appreciation for batik among students.

Recognizing this pivotal juncture, this study is a proactive response to revive waning enthusiasm among students [3]. The core objective is to inject vitality into batik by embracing innovative pedagogical approaches within the art curriculum. Leveraging mixed reality technology and integrating gamification elements, our pedagogical methodology seeks to capture attention and foster a genuine appreciation for the intricate process of batik creation. This pedagogical approach engages students on a deeper level, making the learning experience immersive, enjoyable, and culturally enriching. The strategic utilization of immersive learning technologies, such as mixed-reality [4], [5] that combines the virtual and physical worlds [6], plays a pivotal role in our pedagogical framework. Mixed reality is also being utilized in the field of education, such as in the healthcare sector [7]-[12]. Unfortunately, in cultural heritage, especially in batik, the innovations that have been created are still in augmented reality and virtual reality [13]-[18]. These technologies enhance the overall educational experience, offering students a novel way to interact with and explore the rich cultural heritage of batik.

When creating an application that improves art education and captivates users, the author considers innovation and user experience essential components. The author focuses on user comfort, minimizing motion sickness, and guaranteeing a smooth experience, in addition to the innovative combination

of mixed reality and gamification the author examines in our study. This all-encompassing approach perfectly fits our main objective of protecting and advancing Indonesia's cultural heritage via easily accessible, attractive, and state-of-the-art learning materials. The situation's urgency is not merely an educational concern; it signifies a broader cultural crisis that demands immediate attention. The author assesses the application using the PIECES method and software testing to ensure it offers a rewarding educational experience while keeping an intuitive user interface. The study aims to rigorously evaluate the application's performance using tools like Unity Profiler and performance testing in Hololens 2. The performance metrics will be critical, ensuring the application runs smoothly and meets the benchmarks for optimal user experience.

The study's novel and urgent nature is underlined by the need to safeguard Indonesia's rich cultural legacy, facing a genuine risk of losing creative traditions passed down through the years. The application's success is measured in terms of improved art education and its ability to spark renewed interest and appreciation for batik, bridging the gap between traditional artistic practices and modern pedagogical methods.

Several studies have been conducted to introduce batik and enhance students' interest in learning it. Suciati et al. [19] explored the potential of digital storytelling as an interactive and engaging approach in batik pedagogy, a traditional art form. The research discussed the design and implementation of the Android application, which utilized 3D graphics and interactive features to present batik-related stories to learners. The findings contributed to understanding how technology-enhanced storytelling could be effectively integrated into batik education, offering a new and immersive way for learners to explore and appreciate the art form. Sobandi et al. [20] researched augmented Reality (AR) applications that gamified the process of batik design

Firmanda et al. [21] focused on creating an interactive learning experience for batik design, emphasizing the effectiveness of AR and gamification in boosting user motivation. Additionally, the study explored a virtual try-on platform for batik apparel, leveraging mobile augmented intelligence technology. Integrating computer vision algorithms and AI aimed to enhance the virtual try-on process, offering potential benefits for customer engagement and sales and reducing return rates in the batik apparel industry. Another study by [22] examined the impact of a virtual teacher on the learning achievement of special needs children in the batik context. The study aimed to investigate the factors that influenced the effectiveness of the virtual teacher in facilitating the learning process and improving the accomplishment of special needs children. The study concluded that the virtual teacher can be a valuable tool in promoting the learning accomplishment of special needs children in batik, offering a supportive and inclusive educational experience.

In recent years, several studies have been conducted on developing and utilizing mixed reality technology in art and cultural heritage. According to research, MR technology can transform museum guides into dynamic educational tools. Their study suggests that leveraging MR effects through mobile phones and cardboard allows for immersive experiences, addressing traditional guidebook constraints [23]. Back R's study indicates that MR technology significantly affects art instruction. Enabling students to investigate complex historical narratives and recreate physical settings transforms their interaction with art. This innovative method offers visitors immersive experiences at cultural heritage sites and enhances learning opportunities. With the use of MR technology, engaging and meaningful experiences that enhance knowledge and enjoyment of art and cultural heritage may be created [24]. Therefore, mixed reality is being developed in the field of cultural heritage and museums [25]-[27]. However, these studies have yet to apply mixed reality technology in the artistic field of education despite its potential for introducing art to the younger generation. Therefore, this research is conducted to explore the use of mixed reality technology in art pedagogy to facilitate batik-making.

In this research, we develop a batik application utilizing mixed-reality technology, introducing a more complex and immersive user experience. With this technology, we aim to deliver innovative learning and design an engaging user interface. The evaluation of this application was conducted using the PIECES Method [28]-[30], ensuring that performance, information delivery, economic aspects, user control, efficiency, and service meet the expected standards. This approach aims to create a learning experience that educates and enriches culture and traditions, leveraging mixed reality technology to elevate batik learning to a higher level.

II. Materials and Method

By employing the PIECES Method, the author endeavors to comprehensively evaluate the application system's performance within the specific context of this study. The primary objective of this study is to critically assess the extent to which the application aligns with its predefined requirements and objectives, utilizing the PIECES Method as a structured method. This evaluation seeks to uncover insights into the effectiveness of the batik application, offering valuable context on its overall functionality. Through this evaluation, the study aims to provide a nuanced understanding of the application's strengths and areas for improvement, contributing to the broader discourse on effective mixed reality educational tools.

The decision to utilize the PIECES Method for our evaluation stems from a strategic consideration for a meticulous and comprehensive analysis, considering the multifaceted aspects of the user experience within the mixed reality domain. This choice is mainly motivated by the limitations of alternative methods such as the System Usability Scale (SUS) and NASA Task Load Index (NASA TLX), which predominantly focus on singular dimensions like mental effort and usability, respectively. Given the intricate nature of mixed reality applications, PIECES provides an elaborate and systematic method that covers a spectrum of critical aspects, including Performance, Information Quality, Ease of Use, Control, Efficiency, and Satisfaction. This holistic approach ensures a nuanced understanding of user interactions and experiences, aligning seamlessly with the diverse goals of the MR Membatik application. The adaptability and flexibility inherent in PIECES make it well-suited for navigating the complexities and challenges specific to the mixed reality environment,

making it the preferred choice for a comprehensive and detailed evaluation.

A mixed reality (MR) application's system architecture is shown in Fig. 1, which also shows the flow from a user with an MR device (A) to the system's gamification components. Using an API gateway, the user's device communicates with a mixed-reality platform to launch a mixed-reality application that blends virtual and real-world elements (B) to create a scene. This includes 3D objects with corresponding meshes, materials, textures, lighting, and animation, all rendered from the user's point of view. Hand motions that the MR engine recognizes enable user interactions (C) with the system. This input is sent into the gamification interaction (D) layer, where user activities result in badges, levels, and scoring to increase engagement.

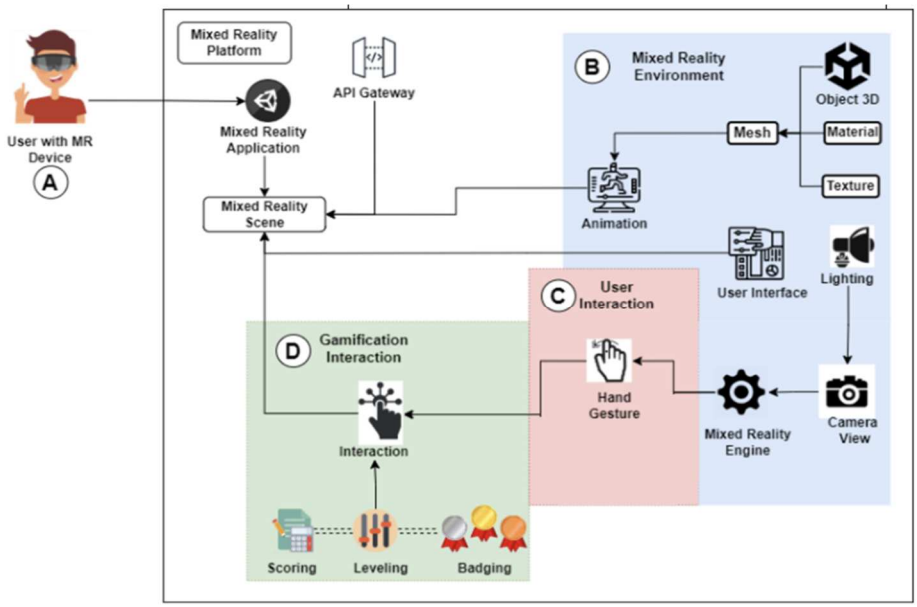


Fig. 1 System Design for The Application

The flowchart in Fig. 2 shows the exact steps involved in using the program. At the "Start" point, visitors are guided through an engrossing "Cut Scene" that establishes the mood and setting for their trip. After that, customers move on to the interactive "Choosing Pattern" step, choosing options according to their tastes. After that, the program moves smoothly to "Simulation Creating Batik," which immerses users in a digital batik-making environment. After completing this engaging simulation, customers are presented with a knowledge checkpoint via an enlightening "Quiz." The last feature of the program shows users' progress visually as a "Graph Progress Result." By choosing "Quit," users can end their experience or go on.

The flowchart in Fig. 3 outlines a decision-making process for adjusting a virtual pattern in a mixed-reality batik application. The method initiates with the system reading the user's input to determine the appropriate action for the virtual pattern. If the input corresponds to a rotation command, the system further checks whether the rotation is around the Y-axis or X-axis, performing the Rotate Pattern operation accordingly. If the input involves scaling, the system executes the Scale Pattern operation to resize the pattern. Similarly, if the input indicates a change in position, the Change Pattern Position operation is carried out to move the pattern. The process concludes after performing the specified operation or ends if the input doesn't match any predefined operations. This flowchart outlines the systematic decision-making steps in adjusting the virtual pattern, providing a clear path for user interactions within the mixed reality batik application.

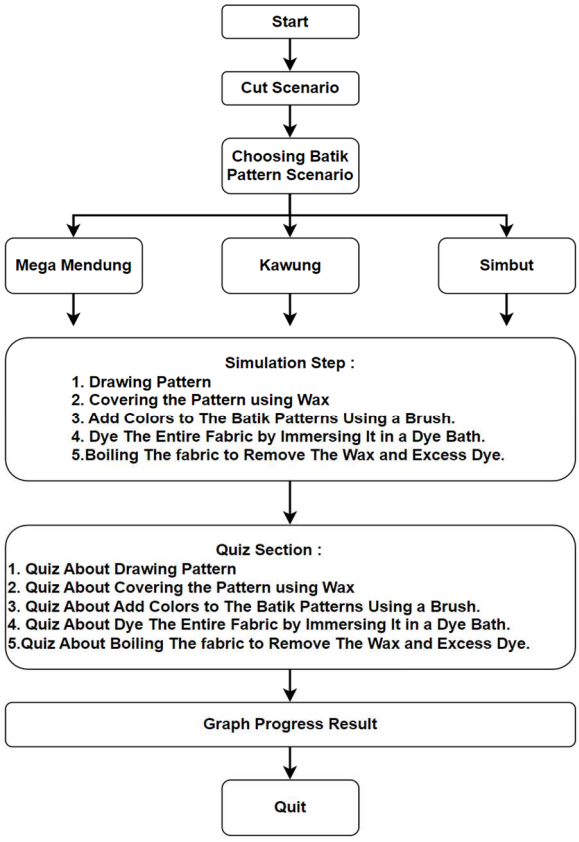


Fig. 2 Flowchart for MR Membatik Application

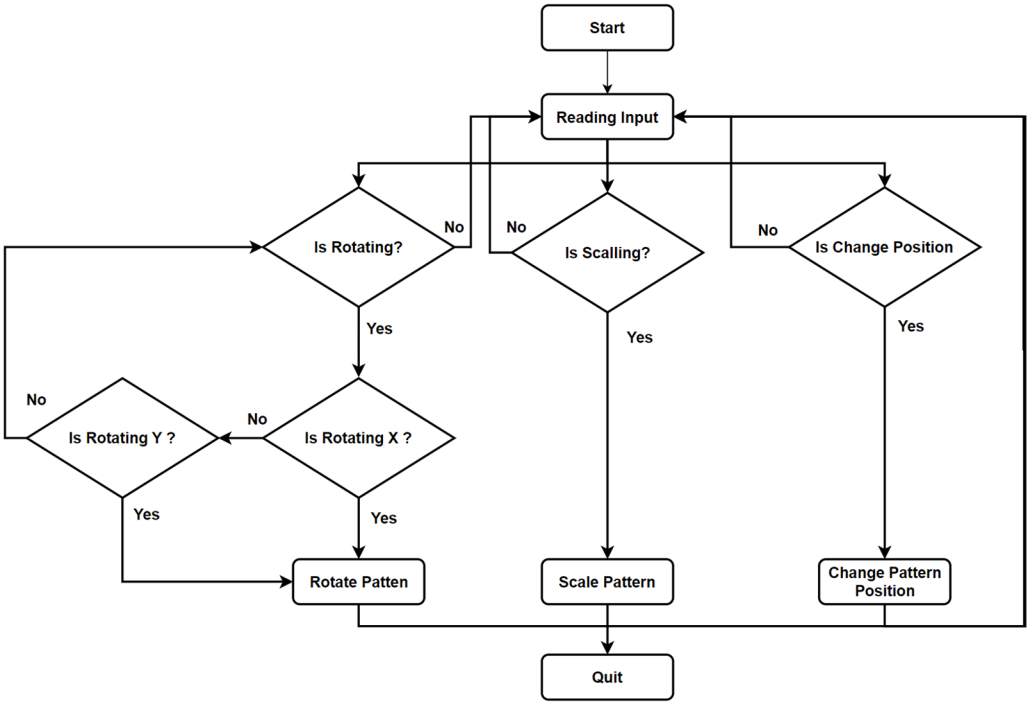


Fig. 3 Flowchart for Decision Making in Pattern Batik Interaction

The flowchart in Fig. 4 illustrates the quiz logic in the Membatik application. It starts with the quiz initiation, presenting users with questions. Correct answers increment the score, while incorrect answers maintain the current score. The flow repeats until the quiz is complete, displaying the final score at the end. This ensures a user-friendly and engaging quiz experience within the application's mixed-reality context.

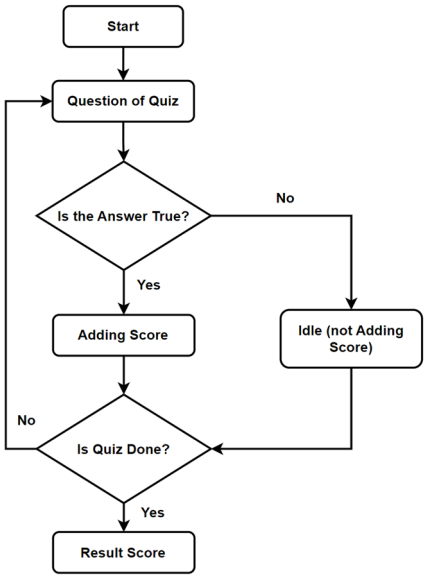


Fig. 4 Flowchart for Logic of Quiz Section

To rigorously evaluate the MR Membatik Application scenario and ensure optimal performance, this study utilizes the Hololens 2 device as the primary tool for running the mixed reality Membatik application. The device specifications are detailed in Table I, providing a comprehensive overview of the hardware employed in conducting the testing and validation processes.

TABLE I
DEVICE SPECIFICATION

Description	Specification
Processor	Qualcomm Snapdragon 850 Compute Platform
RAM	4-GB LPDDR4x system DRAM
ROM	64-GB UFS 2.1
Hand Tracking	Two-handed fully articulated model, direct manipulation
Display Resolution	2k 3:2 light engines
FPS	60 FPS

The PIECES method offers a thorough and organized method for assessing many facets of software programs and information systems. It is a diagnostic tool that analysts and developers use to pinpoint issues that might need to be fixed in an already-existing system or to clearly define the needs and goals of a system that is still in development.

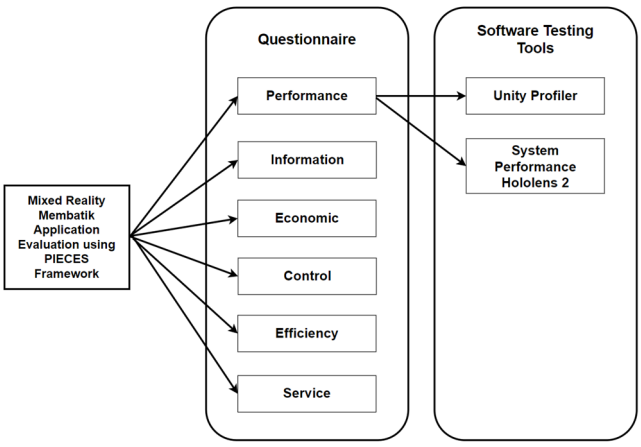


Fig. 5 Research Method in Evaluating Application

Fig. 5 presented above illustrates a bifurcation in data presentation, with the questionnaire encompassing variables such as Information, Economic, Efficiency, and Service. Concurrently, software testing, which focuses on the performance variable, involves the utilization of Unity Profiler and performance testing on Microsoft HoloLens 2. Unity Profiler analyzes and optimizes software performance, measuring key metrics like CPU and GPU usage and memory consumption. Simultaneously, performance testing on Microsoft HoloLens 2 is conducted to assess the responsiveness and overall efficiency of the application in a mixed-reality environment.

The author outlines in Table II the key assessment goals that serve as the foundation for determining the efficacy of the Batik application. Strategically formulated, these primary goals aim to assess the application's total service quality, user control, economic efficiency, information delivery, performance, and optimized procedures to provide a holistic Batik learning experience.

TABLE II
KEY EVALUATION OBJECTIVES FOR BATIK APPLICATION

Element	Objective
Performance	Evaluate the application's speed, responsiveness, and overall efficiency in delivering a seamless batik learning experience.
Information	Assess the effectiveness of the application in providing comprehensive and accurate information about creating batik techniques.
Economic	Examine how efficiently the application utilizes resources, ensuring it delivers educational value without unnecessary overhead.
Control	Evaluate the user's level of control over the learning experience, ensuring a user-friendly and interactive interface.
Efficiency	Assess how well the application streamlines the batik-making process, making it easy for users to understand and follow.
Service	Evaluate the overall service quality, including user support and guidance throughout the batik-making journey.

The PIECES method categorizes user satisfaction into five levels, as shown in Table III. "Very Dissatisfied" (VD) corresponds to scores from 1 to 1.79, "Not Satisfied" (NS) ranges from 1.8 to 2.59, "Doubt" (D) covers 2.6 to 3.39, "Satisfied" (S) spans 3.4 to 4.91, and "Very Satisfied" (VS) encompasses 4.92 to 5. These levels, represented by abbreviations and scores, offer a structured method for assessing and understanding user satisfaction within defined value ranges.

TABLE III
USER SATISFACTION PREDICATE

Satisfaction Level	Abbreviation	Scores	Value Range
Very Dissatisfied	VD	1	1 – 1.79
Not Satisfied	NS	2	1.8 – 2.59
Doubt	D	3	2.6 – 3.39
Satisfied	S	4	3.4 – 4.91
Very Satisfied	VS	5	4.92 – 5

The PIECES method for assessing the mixed reality Membatik application comprises variables with designated numbers of questions as shown in Table IV. "Performance" includes 12 questions on system speed and efficiency, "Information" has 10 questions assessing educational content delivery, "Economic" consists of 6 questions focusing on resource efficiency, "Control" involves 8 questions on user interaction, "Efficiency" comprises 6 questions for evaluating streamlined processes, and "Service" includes 8 questions for measuring user support quality. This structured method ensures a comprehensive evaluation across various aspects of the application.

TABLE IV
PIECES METHOD VARIABLE

Variable	Number of Question
Performance	12
Information	10
Economic	6
Control	8
Efficiency	6
Service	8

In evaluating a questionnaire using the PIECES method, the author calculated the average satisfaction or importance for each question using the formula:

$$Avg = \frac{TS}{NQ} \quad (1)$$

Where:
Avg: Average Satisfaction
TS: Total Score of the Questionnaire
NQ: Number of Questionnaires

"Avg" stands for Average Satisfaction in the context of the PIECES method questionnaire assessment procedure. This measure provides information about the average satisfaction or importance across all questionnaire items. This computed mean measures the respondents' general attitudes about the survey items. In the meantime, "TS" refers to the Total Score of the Questionnaire, which is the overall score obtained by adding together all of the answers to the questions. The letter "NQ" stands for "Number of Questions," representing the total number of questions in the questionnaire. This option is essential because it defines the extent and dimensions of the survey tool, which affects how the average satisfaction and total score are interpreted. Table V presents several sample questions presented to users.

TABLE V
EXAMPLE OF QUESTION IN PIECES METHOD

Variable	Example of Questions
Performance	1. Does the Membatik application consistently provide a smooth and lag-free user experience? 2. Does the application efficiently handle complex batik designs without significant delays? 3. Does the application maintain a consistent frame rate during all stages of batik creation? 4. Does the Membatik application respond promptly to user commands and interactions?

Variable	Example of Questions
	5. How quickly does the application load and initialize upon startup? 6. Do you experience any crashes or technical glitches while using the Membatik application? 7. How smoothly does the application transition between different screens and menus? 8. How efficiently does the application handle the rendering of complex batik patterns? 9. Can you perform actions such as zooming or rotating batik patterns without experiencing lag? 10. How quickly does the application respond to user inputs such as taps, swipes, and gestures? 11. Can you seamlessly switch between different tools and features within the application? 12. Are users satisfied with the overall performance and responsiveness of the Membatik application during batik creation?
Information	1. Is the information provided by the Membatik application regarding "njaplak" (the process of tracing the batik design onto fabric) detailed and accurate? 2. Does the application offer clear instructions and tips for "nglowongi" (applying wax to the fabric) step-by-step? 3. Does the application offer comprehensive information on dyeing techniques and color combinations? 4. Does the application offer comprehensive information covering ironing and finishing touches? 5. Does the application offer comprehensive information on removing wax from the fabric? 6. Does the application include visual aids or diagrams to enhance understanding of each step in the batik-making process? 7. Can users access historical or cultural background information about batik-making through the application? 8. Is the information presented in the Membatik application regarding batik creation techniques reliable? 9. Does the application provide clear and easily understandable guidance on each step of the batik-making process? 10. Is the information in the Membatik app practical and effective for users' hands-on batik creation experience?
Economic	1. How does the cost of using the Membatik application compare to traditional methods of batik creation? 2. Can users achieve cost savings by utilizing the Membatik application for their batik-making endeavors? 3. Are users satisfied with the value proposition the Membatik application offers in terms of cost-effectiveness?

Variable	Example of Questions
	4. How does the economic aspect of the Membatik application contribute to users' overall satisfaction and perceived value? 5. Is the Membatik application cost-efficient for batik creation? 6. Is the economic aspect of the Membatik application meeting user expectations?
Control	1. Are users able to easily navigate and access the various control features within the application? 2. Are there any limitations or constraints in the control mechanisms that hinder users' creative freedom? 3. How responsive are the control inputs within the application, such as touch gestures or stylus interactions? 4. Is the Membatik application designed to offer users effective control over the creative aspects of batik design? 5. Does the application allow users to control and adapt virtual batik patterns through its features? 6. Is the control mechanism responsive to hand gestures for manipulating batik elements? 7. Does the application offer tutorials or guidance on utilizing control features effectively for optimal batik design outcomes? 8. Are users satisfied with the overall control experience provided by the Membatik application for their batik creation endeavors?
Efficiency	1. How effectively does the application optimize resources during batik-making? 2. Does the Membatik application minimize resource wastage during batik-making? 3. How effectively does the Membatik application manage processing times for various batik-making tasks? 4. Does the application provide intuitive shortcuts or quick access features to streamline the batik creation process? 5. Are built-in tutorials or guidance features within the application that assist users in mastering advanced techniques and workflows for batik creation? 6. Does the Membatik MR application offer comprehensive performance monitoring tools, allowing users to track their efficiency and progress over time?
Service	1. Is the support service for hand gesture control in the Membatik application satisfying for users? 2. Is the support service for adjusting rotation, scale, and position features in the Membatik application satisfying for users? 3. Does the provided service effectively assist users in modifying and personalizing virtual batik patterns, including rotation, scale, and position adjustments? 4. Are users satisfied with the level of responsiveness and accuracy in the support service for adjusting rotation,

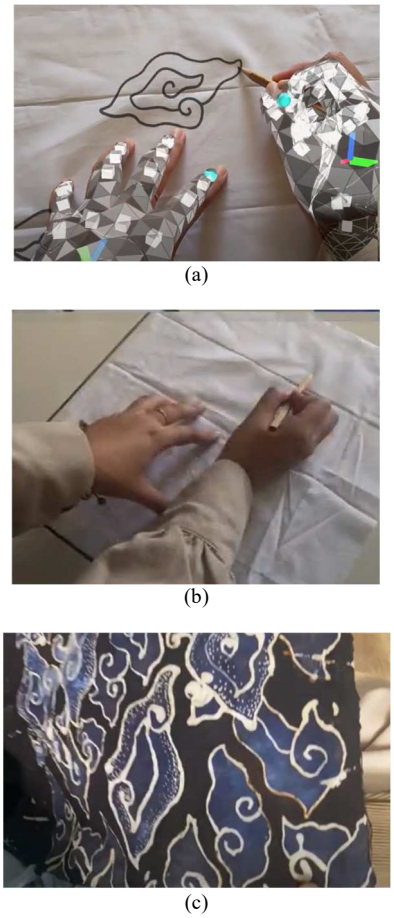
Variable	Example of Questions
	scale, and position features within the Membatik application? 5. How accessible and user-friendly are the self-help resources and knowledge base available to users seeking assistance with hand gesture controls in the Membatik application? 6. Does the application offer comprehensive tutorials and guides accessible within the interface to assist users in mastering various batik-making techniques? 7. How effectively does the introductory cut scene within the Membatik application educate users about the significance of batik as a cultural heritage and the importance of preserving this traditional art form? 8. Are users provided with clear and informative progress results at the end of each quiz session within the Membatik application, detailing their performance, areas of improvement, and achievements?

The questions cover performance, information accuracy, economic efficiency, control features, resource optimization, and user satisfaction with the provided services. Users are asked about the application's smoothness, information clarity, cost-effectiveness, control mechanisms, resource optimization, and support services. several factors may influence the variation between questions in the PIECES method questionnaire assessment procedure warrant further investigation. For example, additional questions may be needed to measure the performance variable to assess other metrics, such as the application's responsiveness, loading speed, or capacity to handle intricate batik patterns. This is because users often place a high value on application performance, and understanding the program's performance may need a more in-depth evaluation.

However, since the primary focus is on cost and value factors, elements like economic efficiency might not need as many queries. In this instance, it could be sufficient to determine the program's economic efficiency with a few queries to gauge application usage costs or user savings. Variations also influence the questions asked for each variable in terms of user experiences and preferences. The number of questions assigned to each variable may need to be changed to account for the diversity of usage and user expectations since users with varied requirements or backgrounds may view different things differently regarding what is essential in an application.

III. Results and Discussion

The evaluation combined the systematic analysis provided by the PIECES method with the more traditional aspects of software testing, specifically focusing on performance metrics. Fig. 6 illustrates the diverse perspectives in evaluating the application. In Fig. 3(a), users experience an immersive environment through the Mixed Reality (MR) headset, providing a dynamic platform for drawing batik. Fig. 3(b) offers the real-world view, seamlessly integrating virtual skills into physical batik creation. The tangible outcome of this process is depicted in Fig. 3(c), showcasing the batik result. These perspectives ensure a holistic and practical understanding of batik, emphasizing the effectiveness of the mixed reality and gamification-infused pedagogy.



(a) (b) (c)

Fig. 6 Research Method in Evaluating Application. (a) The View from Mixed Reality Headset, (b) The View from Real World, (c) The Batik Result.

A. User Testing PIECES Method

The study used user testing and the PIECES method to evaluate the usability and efficacy of the MR application in improving art instruction for high school students. The assessment included the delivery of a questionnaire to assess user satisfaction using the PIECES methodology. The study involved 31 high school students who participated as respondents in the user testing phase. Fig. 7 depicts the gender distribution of the respondents

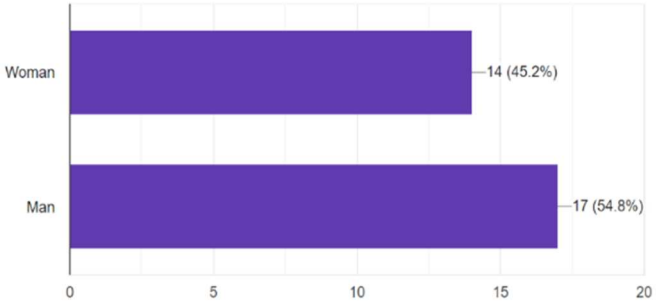


Fig. 7 Respondents Qualification

Thirty-one high school students were included in the user testing phase; 14 were female, and 17 were male, providing a well-rounded representation. To ensure a thorough grasp of the usefulness and attractiveness of the Membatik application, a purposeful distribution of genders was employed to collect a wide variety of opinions and experiences.

If we break down the gender distribution even further, the test group consisted of 45.2% female respondents and 54.8% male respondents. Gender-based differences in user preferences and interactions were attempted to be considered in this equal portrayal. The user testing sought to produce insights that are representative of a wide range of user demographics by involving both male and female participants, hence augmenting the validity and relevance of the results.

Fig. 8 Performance Result in User Testing

Fig. 8 presents the bar chart illustrating the satisfaction levels of 31 respondents regarding a performance test conducted over 12 questions. Five categories show the various levels of satisfaction, which are Very Dissatisfied (VD) in blue, Not Satisfied (NS) in orange, Doubt (D) in grey, Satisfied (S) in yellow, and Very Satisfied (VS) in dark blue. As the questions progressed, there was a variation in satisfaction levels, with a noticeable peak in Q10, where 24 respondents felt Very Satisfied (VS, dark blue). Similarly, Q12 shows a significant number of respondents (23) who are Very Satisfied (VS). The chart provides an overview of performance satisfaction over time, clearly indicating periods where respondents were predominantly doubtful or dissatisfied (as in Q1) and periods where performance was met with a high level of satisfaction (as in Q10 and Q12). These insights can be essential for understanding the effectiveness of the performance over the examined questions. This overarching positive feedback across questions culminates in an average result of 4.24.

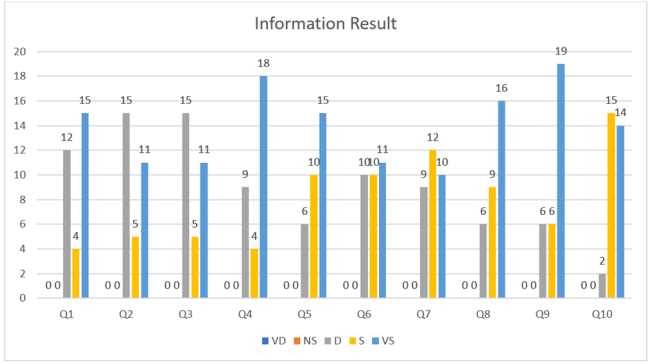


Fig. 9 Information Result in User Testing

Fig. 9 presents the results of the user testing utilizing the PIECES method, focusing on the "Information" variable with ten questions and 31 respondents for each question, revealing noteworthy insights. Across all questions, a consistent pattern emerges where a substantial majority of respondents express high levels of satisfaction, particularly in the categories of "Satisfied" and "Very Satisfied" (S and VS). This positive trend indicates a robust performance of the mixed reality Membatik application in providing comprehensive and accurate information about the batik creation process. Notably, questions Q4, Q5, Q6, and Q9 stand out with many respondents in the "Very Satisfied" category, showcasing the application's effectiveness in delivering educational content and supporting users in the intricate processes of batik making. This overarching positive feedback across questions culminates in an average result of 4.16.

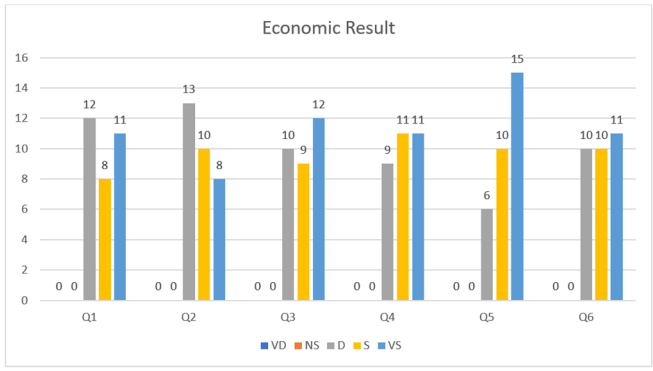


Fig. 10 Economic Result in User Testing

The user testing results on the "Economic" variable within the PIECES method as shown in Fig. 10, featuring 5-point satisfaction levels with 31 respondents for each question, demonstrate a positive trend in the application's economic aspects. Across questions, respondents predominantly fall into the "Satisfied" and "Very Satisfied" (S and VS) categories, indicating a favorable perception of the application's resource efficiency and value proposition. Notably, questions Q2 and Q3 stand out, with many respondents expressing high satisfaction levels. This collective feedback is reflected in the average result of 4.04, underscoring the application's success in efficiently utilizing resources without unnecessary overhead.

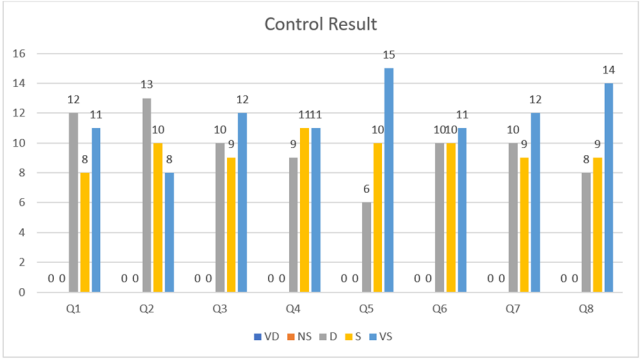


Fig. 11 Control Result in User Testing

Fig. 11 presents the user testing outcomes for the "Control" variable within the PIECES method. These outcomes reveal

consistently positive feedback, with respondents predominantly expressing satisfaction levels in the "Satisfied" and "Very Satisfied" (S and VS) categories across questions. Particularly notable are questions Q2, Q3, Q5, and Q8, where many users report high satisfaction, indicating a strong sense of control over their learning experience. This positive trend contributes to an overall average result of 4.04.

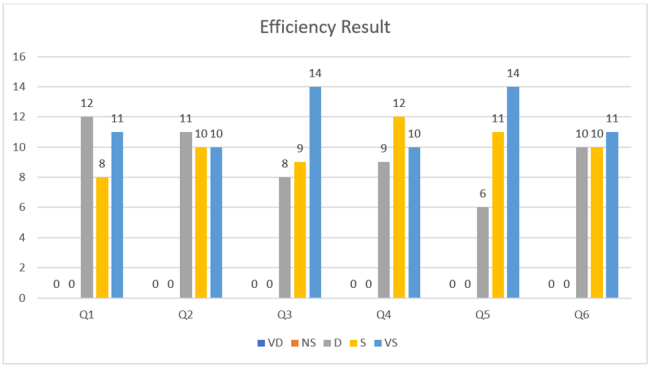


Fig. 12 Efficiency Result in User Testing

Fig. 12 shows the user testing outcomes for the "Efficiency" variable within the PIECES method. These outcomes underscore positive user sentiments, with respondents predominantly expressing satisfaction levels in the "Satisfied" and "Very Satisfied" (S and VS) categories across questions. Particularly noteworthy are questions Q2, Q4, and Q5, where many users report high satisfaction, indicating the application's success in streamlining the batik-making process and ensuring ease of understanding. This positive trend contributes to an overall average result of 4.07.

Fig. 13 Service Result in User Testing

Fig. 13 presents the user testing outcomes for the "Service" variable within the PIECES method, showcasing consistently positive feedback. Respondents predominantly express satisfaction levels in the "Satisfied" and "Very Satisfied" (S and VS) categories across questions. Questions Q1, Q3, Q5, Q7, and Q8 are particularly noteworthy, where many users report high satisfaction, indicating the application's success in delivering quality user support and guidance throughout the batik-making journey. This positive trend contributes to an overall average result of 4.15.

B. Software Testing

In the quest for a thorough assessment of the MR Membatik Application's performance, the authors employed a dual-tool approach, utilizing both the Unity Profiler and conducting performance testing on the Hololens 2 device. The Unity Profiler facilitated a detailed analysis of the application's internal workings, while performance testing on the Hololens 2 provided real-world insights into its capabilities within a mixed reality setting. By integrating these tools, the authors ensured a comprehensive evaluation, validating that the MR Membatik Application not only met but exceeded the required performance benchmarks, ensuring an optimal and immersive learning experience in the art of batik creation.

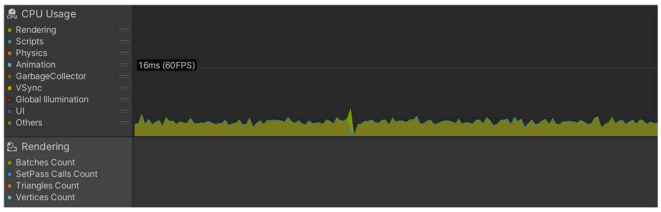


Fig. 14 Performance Result in Unity Profiler

Fig.14 displays the performance metrics of an application running at an optimal 60 frames per second (FPS) using Unity Profiler, which matches the target frame rate for the HoloLens 2 device. Each frame is processed within 16 milliseconds, indicating that the application is well-optimized and should provide a smooth and stable user experience. This frame time is critical for the HoloLens 2, as maintaining a consistent 60 FPS is essential for immersive augmented reality experiences.

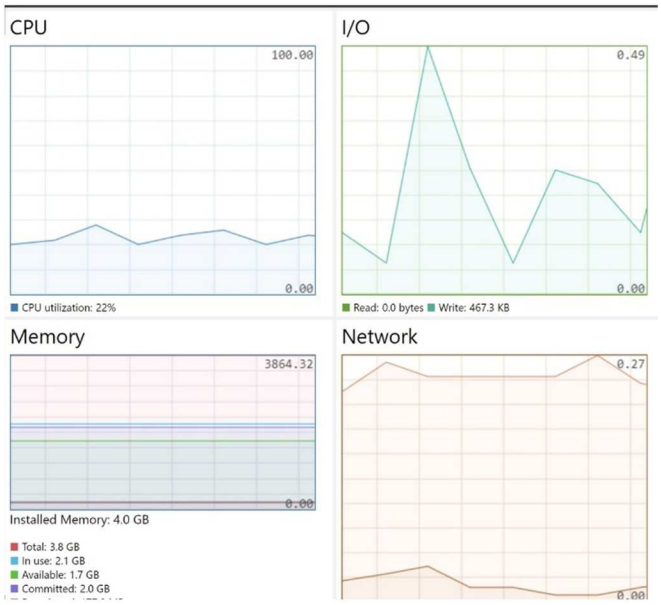


Fig. 15 Performance Result in System Performance Hololens 2

Fig.15 presents the performance results for the HoloLens 2, showing a range of resource utilization. Starting with the CPU, it's running comfortably at 22% utilization, indicating that the device is not being heavily taxed and has spare processing capacity for more demanding tasks. The I/O graph displays a spike, showing a peak in write operations at 467.3 KB, but no read operations during the same period, which could suggest a momentary increase in data recording or saving activities. Moving on to memory consumption, 2.1 GB of the 4 GB installed are in use, leaving 1.7 GB available. 3.8 GB of total capacity is detected. This indicates a memory use of more than half, although a sizeable portion remains available for other

operations. The committed memory stands at 2.0 GB, likely a combination of physical RAM and potentially virtual memory usage, indicating a good balance between the memory being used and what is available. With a peak of 0.27, which may represent either KBps or MBps depending on the size not shown in the picture, the network graph finally indicates a deficient network consumption. The HoloLens 2 may not be participating in network-intensive tasks at this time, or it may be linked to a network with insufficient bandwidth based on the low level of network activity.

IV. Conclusion

The study's effective resolution of the waning interest in traditional Indonesian batik in the context of education is its conclusion. The MR Membatik Application showed encouraging results when evaluated using the PIECES architecture. Positive results were found in many areas, including information, economics, control, efficiency, and service when the user testing was combined with performance evaluations using Unity Profiler and Hololens 2. The results of the performance tests indicated effective resource use, guaranteeing a smooth and engaging batik learning process on the HoloLens 2. The program stayed within the ideal frame rate range for augmented reality experiences, which is 60 frames per second. However, there are several restrictions to this study. The PIECES method's concentrated examination may miss certain features, and generalizability may be restricted according to the study's environment. Future research should investigate more expansive cultural and educational contexts while considering various user viewpoints. It is still essential to continuously improve the MR Membatik Application based on user input and technology developments. The program's educational impact might be further enhanced by looking at the integration of new immersive technologies and resolving issues in circumstances where the network is dependent on the application. This study establishes the foundation for further investigating and enhancing mixed reality applications within art education.

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