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Indonesia - Shinta Puspasari.docx

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Improving Student's Cognitive Performance during the Pandemic through a Machine Learning-Based Virtual Museum

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Abstract **– This study presents the investigation of the innovative virtual application developed for cultural education through museum collections. It designed an innovative virtual museum model for learning media containing various contents. Furthermore, it integrates machine learning to predict student interests expected to be effective in improving cognitive performance. The conceptual model design continued with the development of an innovative virtual museum application tested on students, and the effectiveness was evaluated by taking a sample of N1 = N2= 32 participants in experimental and control group. Meanwhile, the pre-test and post-test were conducted to measure the user's cognitive performance before and after using the innovative virtual museum application. The experimental group results show that the proposed application strongly affects students' cognitive performance improvement in cultural education. The effect size value is 1.396, where the average score of post-test = 57.946 and the standard deviation = 21.421. Therefore, the proposed application strongly affects museum learning, while the t-test results show a significant difference between the experimental and control groups.**

Keywords **– Virtual museum, machine learning, culture education, cognitive performance.**

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

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Received: -----.
Accepted: -----.
Published: -----.

1. Introduction

The COVID-19 pandemic has transformed the way of life into new normal for people can continue to carry out activities during the pandemic. The rapid and easy spread of the COVID-19 virus requires the implementation of policies to limit the public's physical activity in various fields [1], including education and recreation in museums. The closure of museums during the pandemic has impacted the museums' visits and impacted the performance of museums' roles for education. Museums have a role in managing collections and educating the public through museum collections. For example, at the SMBII museum in Palembang, Indonesia. This museum stores various collections of Palembang cultural objects from the era of the Srivijaya kingdom in the 7th century to the Palembang Darussalam Sultanate in the 18th century. By learning through the SMBII museum collection, visitors' knowledge of Palembang culture is expected to increase. Not only for educational purposes, but visitors can also have recreation by exploring the museum exhibition, which contains hundreds of collections to see while increasing the motivation of visitors to preserve Palembang culture.

The closure policy requires the transformation of physical museums into digital form to carry out their roles for education and recreation. A virtual museum development that can be accessed directly without the barriers of distance, space, and time is presented as a solution to the problem. Students can enhance their learning experience to improve cognitive knowledge about Palembang culture at the SMBII museum or complete assignments given by the teacher. They can explore the museum exhibition through virtual media [2]. Some virtual museums have been developed but are limited to recreation, learning engagement, and provide museum information systems. The virtual museum model should be developed as an educational media, where learning outcomes can be measured by improving learning engagement [3], and performance [4]. To support the Society 5.0 era, an artificial

intelligence-based model is needed to analyze the profile of museum visitors and significantly increase cognitive performance [5], [6]. Therefore, this study investigates the effectiveness of the proposed innovative machine learning-based virtual museum application in improving the cognitive performance of visitors, especially students.

2. Materials and Methods

This study investigates the effectiveness of an innovative virtual museum model developed based on a learning model to improve the cognitive performance of students and visitors in SMBII museum. Furthermore, the museum stores thousands of collections of Palembang cultural objects. It investigates the effectiveness of the virtual museum for improving students' and visitors' cognitive performance in Palembang culture education through learning. The formulated research question is, what are the differences in cognitive performance between students and visitors who learn with and without the proposed innovative virtual museum?

2.1 Conceptual Model Design

The proposed concept of the innovative virtual museum is constructed based on the interactive technology conceptual model in the physical museum [7]. It integrates learning outcome indicators and machine learning for the content features. Figure 4 shows the proposed conceptual model of a virtual museum to enhance cultural education during the COVID-19 pandemic. The definition of each content in the proposed conceptual model of the innovative virtual museum is described in Table 2.

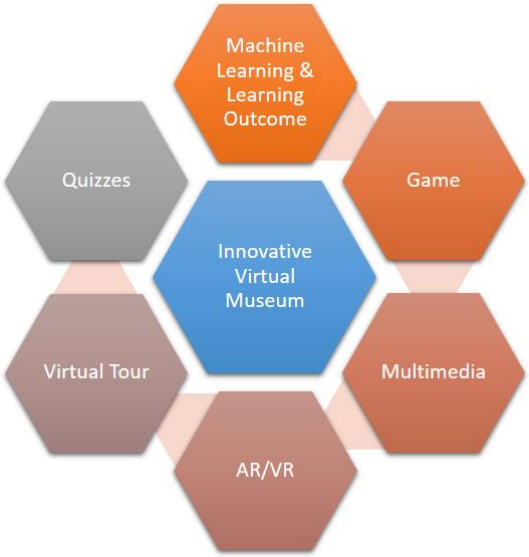

Figure 1. Proposed conceptual model of the machine learning based virtual museum

Table 1. The content definition of proposed virtual museum model

Content	Definition	References
Game	Fun game for visitor experience enhancement in museum education	[8]–[10]
AR/VR	Provides 3D object reconstructions of virtual environments or combined with real physical museum environments	[11], [12]
Virtual tour	A 360-degrees virtual tour that users can access when they want to explore the museum environment interactively	[13], [14]
Multimedia	Technology that integrates text, image, video, and audio processing for museum applications	[15], [16]
Quizzes	A list of questions to measure the knowledge ability of museum visitors	[7], [17]
Learning outcome	Measurement of learning outcome by stimulating students in the learning domains	[18], [19]
Machine learning	Artificial intelligence-based algorithm with the ability to learn and extract information in museum domain datasets	[20], [21]

The research procedure was continued by developing the proposed conceptual model into an application to improve the cognitive performance of students and visitors. This can evaluate the differences in implementing machine learning methods to identify user profiles for improving cognitive performance.

2.2 Virtual Museum Application Development

The development of the proposed innovative virtual museum model into an application applies the Multimedia Development Life Cycle software consisting of Concept, Design, Material Collecting, Assembly, and Testing.

a. Concept

At this stage, a concept analysis of the model was carried out for modeling application functionality. The model was made based on a systemic literature review, interviews, and observations of the research object. The output was used to design an innovative virtual museum in the case of SMBII proposed with a conceptual model, as shown in Figure 1. A use case diagram is used to model the application functionality represented by each symbol [22]. As the virtual museum application actor, the visitor can directly

access tour guide, exploration, and education features, including machine learning and outcome, to enable the functionality (Figure 1).

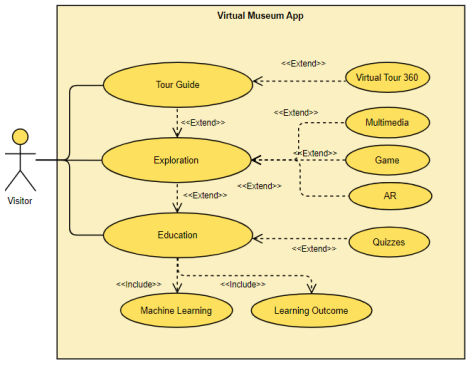

Figure 2. Use case diagram of proposed virtual museum model

b. Design

The user interfaces, databases, and application assets of the proposed application are designed at this stage. For example, the application interface is constructed using a programming language. Therefore, it is necessary to design an interface that aligns with the virtual museum's requirements for the learning of Palembang culture. The database is designed to manage input and output transactions related to collections and other functionalities of the model. Virtual application assets are used to construct attractive and interactive multimedia products for users, significantly enhancing cultural learning in SMBII.

The design was based on the proposed virtual machine learning (ML) model. Figure 2 shows the workflow of machine learning classifier implementation in quizzes content.

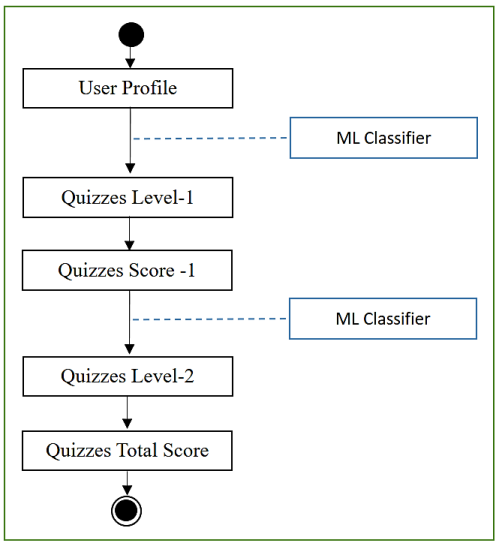

Figure 2. Machine learning based quizzes feature workflow on innovative virtual museum application

A machine learning classifier (ML classifier) can analyze user profiles for question classification and selection at level-1. After presenting the level-1 quizzes to the user, the ML classifier can analyze the score to select question for knowledge improvement on the collection and history of the SMBII museum. The implemented machine learning model is K-Nearest Neighbor (KNN) because the effectiveness has been tested for analyzing visitors' profiles [23].

c. Material Collecting

The innovative virtual museum contained multimedia as material presenting information for visitors. For example, the exhibition collection material is collected by observing and searching related documents. Although a wealth of information is available in museum archives, not all of it can be removed and analyzed. There are primary data that should be collected or constructed. For example, 3D objects, 360-degree images, and videos related to the proposed virtual museum model. The material collecting stage conducted a data collection procedure to generate a dataset for the SMBII virtual museum content and functionality.

d. Assembly

The assembly integrates all materials collected into an application to be tested in the real environment. The assembly process ensures each unit effectively carries out its functionality and is integrated with others for the innovative virtual museum application. A prototype of an innovative virtual museum application for Palembang cultural learning becomes the output of this stage.

e. Testing

Testing ensures the prototype of the virtual museum application effectively performs the required function to improve cognitive performance. It is conducted using two different treatments of learning, with and without the innovative virtual museum for evaluation. Meanwhile, pre-test and post-test are performed to measure learning performance. The effectiveness of the proposed model is measured by using effect size value (*d*) formulated in equation (1)

$$d = \frac{mean(posttest) - mean(pretest)}{\sqrt{(SD^2_{posttest} + SD^2_{pretest})/2}} \quad (1)$$

The interpretation of the effect size value is presented in Table 1 based on Cohen's criteria [24]. The testing was continued by conducting Technology Acceptance Model (TAM) instrument [25] to measure user acceptance of the proposed innovative virtual museum application.

Table 1. The effect size interpretation

Effect Size	Category
0- 0.20	Small effect
0.21-0.50	Medium effect
0.51-01.00	Large effect
> 1.00	Strong effect

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2.3 Museum Learning Activity Design

The research sample consists of students aged 17-30 years as participants in testing the proposed innovative virtual museum application. The selection of a homogeneous sample aims to obtain the participants' initial learning performance to be almost uniform or with no difference. Unlike the control, the experimental group assesses museum learning performance by applying innovative virtual museums. The machine learning implementation is removed from the application to determine the difference between the control and experimental group performance. Each group was asked to learn about Palembang culture for 30 minutes as indicated in Figure 3.

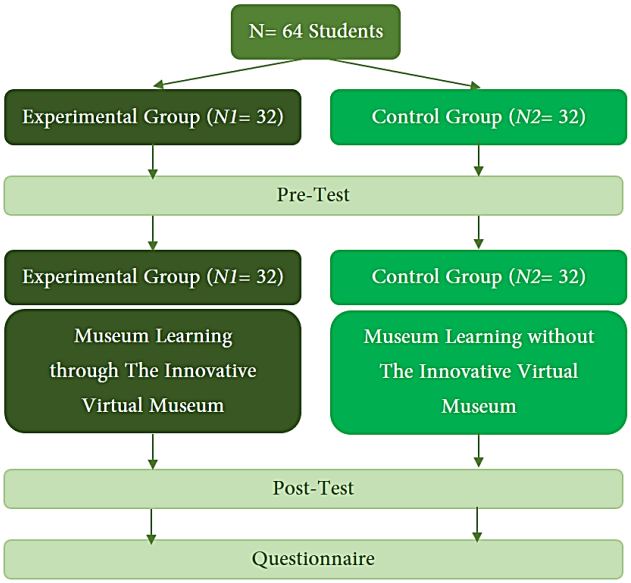

Figure 3. Learning activity scenario

The test participants were asked to conduct a post-test, and the results were evaluated to answer the research questions [26]. Questionnaires were given using the TAM instrument for testing user acceptance of the proposed virtual museum application.

3 Results and Discussion

3.1 Virtual Museum User Interface

The innovative virtual museum model based on machine learning constructed for SMBII museum has user interfaces, as shown in Figures 5-9. Visitors can access the application features for Palembang culture education purposes as shown in Figure 5. The apps has three main menu namely Tour Guide, Exploration, and Education. Museum visitors can access the tour guide feature if they need guidance for touring the museum exhibition. A smart guide feature was designed to provide museum exhibition recommendations that match the visitor profile and has an interface, as shown in Figure 5. With recommendations based on machine learning methods, visitors can directly explore the exhibition recommended by the virtual museum as the output of user-profiles analysis conducted by machine learning. Visitors can explore the SMBII museum exhibition spaces through a virtual museum containing 360-degree images [23]. Figure 6 illustrates the 360 virtual tour interface for SMBII exhibition exploration information about museums and their collections, part of the innovative virtual museum content, becomes an interactive learning method that is expected to be effective in improving the cognitive performance of SMBII museum visitors, especially students, in learning Palembang culture.

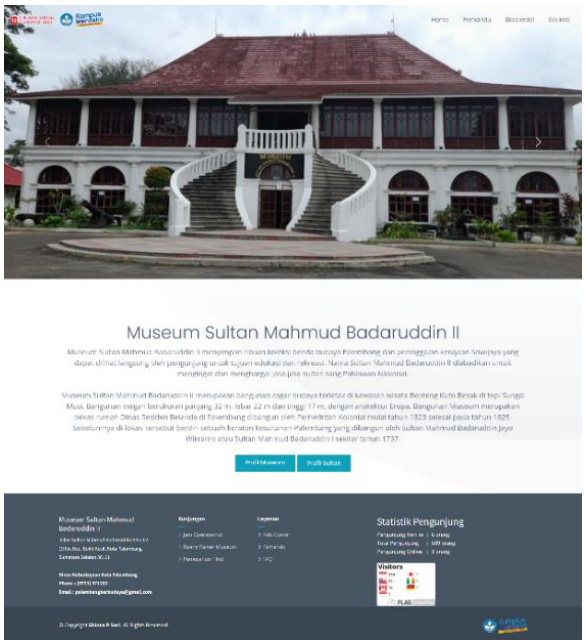

Figure 4. The SMBII innovative virtual museum homepage screenshot

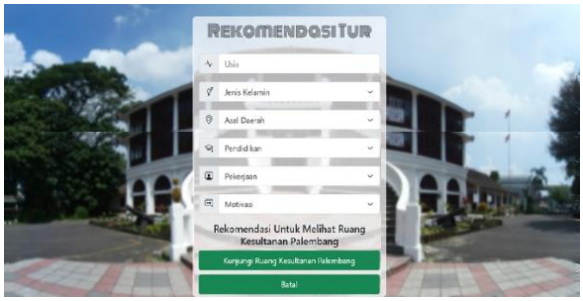

Figure 5. Exhibition recommendation screenshot

Figure 6. SMBII museum virtual tour 360º screenshot

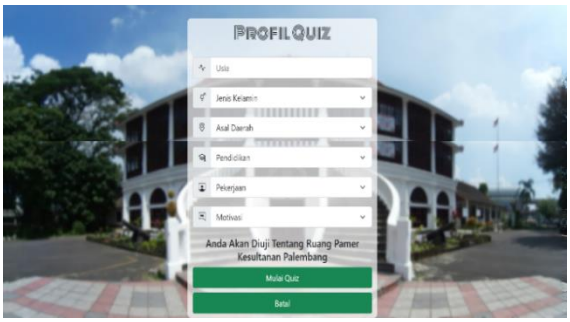

Figure 7. Quizzes user profile analysis results screenshot

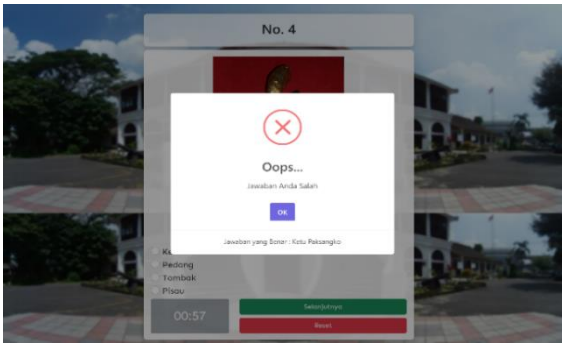

Figure 8. Quizzes false answer notification screenshot

The users were asked to input profile information, and the application will analyze the profile and provide exhibition recommendations according to machine learning results (Figure 6). They can interact with the museum's exhibition virtually by accessing the hotspot on the tour 360^{o} feature interface (Figure 7). Visitors can take advantage of exhibition recommendations from the analysis of machine learning models. Therefore, it is easier to obtain exhibition rooms to reduce boredom in exploring museums.

Machine learning is also applied to educational features, namely the quizzes feature. User profiles are processed to select questions that match the user profile (Figure 8) interests and are classified as complex. The clustered question dataset becomes difficult and easy, and asking difficult cluster questions is expected to increase knowledge. Previously, users did not know about the topic being asked but were interested in knowing more in line with their interests. It is intended that the user's learning performance will rise by using the quizzes feature, as the application will make the correction when questions are wrong (Figure 9). AR game features are also presented in educational features that provide fun for students in learning while playing, especially the introduction of the SMBII museum collection as part of Palembang's cultural artifacts.

The quizzes feature can measure the knowledge of visitors of Palembang culture. The score indicates learning outcomes through the innovative virtual museum application. Level-1 presents questions containing pictures of museum collections, while level-2 shows questions in question-word sentence format about the SMBII museum. The feature is also designed by applying machine learning to analyze user profiles for question selection in museum learning to improve cognitive performance. The testing was conducted to measure the effectiveness of the proposed innovative virtual museum model in improving the cognitive performance of visitors. The sample as participants or respondents were asked to use the application and fill out questionnaire instruments for the application evaluation.

3.2 Virtual Museum Effectiveness Assessment

An innovative virtual museum application, a web app, was tested in the experimental group (*N1*), and the results were compared with the control *(N2)*. The two test groups, *NI* and *N2*, pre-test and post-test, were assessed to answer the research questions. The small number of samples based on testing scenarios conditioned to be supervised in the lab ensures student learning media only uses the innovative SMBII virtual museum application. In addition, the pandemic situation requires several students in the lab, and the implementation of the study from home policy affects the number of participants. A total of *N*=64 samples were divided into two groups, where *N1=N2*=32 conducted a pre-test to measure their cognitive performance on Palembang culture before museum learning. The assessment situation of the experimental group is illustrated in Figure 9.

Figure 5. Innovative virtual museum testing by students

A questionnaire containing questions about the SMBII museum and the collections was given to each experimental and control group participant and was divided into two levels. Level-1 questions contain text-based questions about the collection and history of the SMBII museum related to Palembang culture, while level-2 contains image-based questions. For level-2, respondents were asked to name a picture of the museum collection shown. The test contained 35 questions about Palembang culture related to the SMBII museum. Furthermore, the score was normalized to 0-100, and the pre-test and post-test results for the two test groups are presented in Table 3.

Table 2. Learning performance t-test results

Test	Group	M	SD	t	F
Pre-Test	E	32.41	14.50	0.027	1.697
	C	32.31	11.14		
Post-Test	E	57.95	21.42	2.38	0.997
	C	45.18	21.45		

** p<0.05 ; E= Experimental group ; C = Control group*

The experimental group's pre-test mean score (*M*) and standard deviation *(SD*) are 32.411 and 14.507, while 32.314 and 11.135 for the control group. The *t*-test result *(t* = 0.027, *p* < 0.05) shows no significant difference between the two groups for the pre-test. In the post-test, the experimental group mean and the standard deviation are 57.946 and 21.420. The control group mean and the standard deviation are 45.179 and 21.448. The *t*-test result (*t* = 2.383) shows a significant difference between the two groups for the post-test. The two groups of students had the same cognition level of cultural education before the learning activities. However, after the learning activities, there is an improvement in the cognitive level and a significant difference between experimental *(E*) and control group *(C)* learning performance. Cognitive performance improvement in the experimental group is due to the emergence of motivation and creativity in learning through machine learning-based virtual museums that provide information through application features designed for learning purposes. This fact was obtained based on the results of TAM testing. An increase in students' engagement is directly proportional to the level of success in learning [27].

The TAM questionnaire was given to the participants. The Cronbach's alpha score > 0.78 shows the reliability of the questionnaire, showing that the machine learning-based virtual museum is easy to use for cultural education. The ease of use significantly moderated the application engagement [25]. The participants believed that the behavioral intention of use affects the usage. The application will be used for Palembang cultural education at home or outside the physical museum, especially during the pandemic. The habitual use of ICT seems highly embodied in students as young people [28] might also affect the acceptance level of the proposed virtual museum. Furthermore, learning through the application improves motivation and creativity in cultural learning. Participants were satisfied with using the proposed virtual museum based on machine learning, which has been proven to improve cognitive performance.

The effect size of machine learning-based virtual museum was also evaluated to confirm their effectiveness as learning media. Studying from home during the pandemic requires learning media that affects student performance in cultural learning, which may be boring. Table 4 shows the effect size values based on the experimental group pre-test and post-test.

Table 3. The effect size values (d) of the experimental group

Test	M	SD	d	Category
Pre-test	32.411	14.507	1.396	Strong effect
Post-test	57.946	21.420		

The effect size value is *d*= 1.396, which is > 1.00, meaning a strong effect on cultural education through SMBII. The significant improvement of student or user cognitive performance is affected by the machine learning-based virtual museum proposed, especially during the pandemic. This research question was answered based on the differences in cognitive performance between students who learn with and without the virtual museum. Based on the investigation results, a machine learning model is recommended to support museum educational performance.

4 Conclusion

This study presents the investigation of the proposed machine learning model in improving cognitive performance in cultural learning through museum collections. The conceptual model for education has content that integrates machine learning and indicators. The features include games, multimedia, virtual tours, AR/VR, and quizzes. A web-based application was developed based on the proposed conceptual model and tested on the experimental and control groups of 64 participants (*NI=N2*=32) each. Unlike the control, the experimental group was given learning treatment using an innovative virtual museum model. Furthermore, the pre-test and post-test shows that the proposed model strongly affects the significant improvement of cognitive performance in cultural learning. The TAM instrument's user acceptance testing shows that the application is easy to use and satisfies learning. The implementation of machine learning for analyzing user cognitive performance needs further research to optimize museum educational roles performance in the post-pandemic and Society 5.0.

Acknowledgements

The authors are grateful to the Ministry of Education and Culture, the Republic of Indonesia, for Doctoral Research Grand 2022, contract ID. 0145.012/UN9.3.1/PL/2022.

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