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Research Article

Augmented reality as a game changer in experiential learning: Exploring its role cultural education for elementary schools

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This study examines the role of Augmented Reality (AR) in enhancing cultural understanding through experiential learning. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) with Smart PLS 4.0, we analyzed how different AR-based experiences—Simulation, Experiment 1, and Experiment 2—affect cultural diversity comprehension. Data were collected from 100 fifth-grade students at SDN Kademangan 5. Findings reveal that AR significantly enhances cultural understanding and serves as a key mediating factor. Among the experiential components, Simulation positively influences both AR and cultural understanding. Experiment 2 strongly impacts AR but has a limited direct effect on cultural understanding. Conversely, Experiment 1 shows a positive but statistically insignificant relationship. These results highlight the importance of optimizing experiential learning components and leveraging AR as a transformative educational tool to foster cultural appreciation and understanding in diverse learning environments.

Keywords: Augmented reality in education; Experiential learning; Indonesian cultural diversity; Elementary education; Educational innovation

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1. Introduction

Education plays a crucial role in fostering an understanding of generational and cultural diversity, particularly in Indonesia, a country renowned for its rich and diverse cultural heritage. Although Indonesian culture is taught in schools, traditional teaching methods—often reliant on textbooks and passive learning—have limitations in fostering engagement and deep comprehension among students (Asad et al., 2021). These methods struggle to provide interactive and immersive learning experiences, making cultural education less appealing and difficult for students to relate to in their daily lives. Experiential learning presents a viable alternative to bridge this gap by offering direct engagement with cultural elements, enabling students to actively participate in their learning process (Corriveau, 2020). In this context, AR technology emerges as a transformative tool that addresses the shortcomings of traditional approaches. By integrating AR into cultural education, students can directly interact with Indonesian cultural elements in a visual and immersive manner.

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Unlike conventional teaching strategies, AR creates an engaging, interactive, and contextualized learning environment that enhances students' interest and comprehension.

This study aims to explore the effectiveness of learning models that integrate AR with experiential learning to bridge gaps in cultural education and enhance students' understanding of Indonesia's diverse cultural heritage (Pranata, 2024). Through AR technology, students can more easily comprehend and experience various aspects of Indonesian culture—such as dance, music, clothing, customs, and traditions—in a more interactive, engaging, and contextually rich manner (Akçayır, 2017). By providing a multisensory learning experience, this approach is expected to overcome the limitations of conventional teaching methods, increase students' motivation and interest, and foster a deeper appreciation and pride in Indonesia's cultural diversity.

2. Literature Review And Hypothesis

2.1 Experiential Learning

Experiential Learning is a learning approach that emphasizes direct experience as a means of acquiring knowledge, skills, and understanding. This approach encourages active participation in real-world activities, followed by reflection to enhance deeper learning.

David Kolb introduced the Experiential Learning Cycle, which consists of four interconnected stages (Morris, 2020). The first stage, Concrete Experience, involves direct engagement in an activity or situation, often in the form of Simulation, where participants gain practical experience (Morris, 2020). The effectiveness of a simulation is influenced by three key factors (Wang, 2018). First, the relevance of the simulation to real-world conditions (X7) is crucial for helping participants connect their experience to practical contexts. Second, interactivity within the simulation (X8) enhances active engagement, which improves understanding and skill development (Kuhail, 2023). Third, immediate feedback (X9) during or after the simulation allows participants to assess their actions, correct mistakes, and refine their learning. These factors make Simulation a powerful approach to experiential learning. Following this, learners enter the Reflective Observation stage, where they analyze their experience through Experiment 1 to understand what happened and identify key insights. Similar to the simulation, the effectiveness of this stage is influenced by three main factors. First, the relevance of the experience to real-world conditions (X10) helps participants establish meaningful connections. Second, active engagement in reflection (X11) enhances understanding (Busse, 2020; Hallinger, 2020). Third, receiving immediate feedback (X12) enables learners to refine their insights and deepen their comprehension. In the Abstract Conceptualization stage, participants integrate their reflections into theoretical frameworks, forming new understandings. Finally, in the Active Experimentation stage, they apply these insights to new situations through Experiment 2, allowing them to test and validate the concepts they have learned (Soltani, 2020). The success of this stage depends on three key factors. First, access to the appropriate equipment and materials ensures that experiments can be conducted effectively and safely (Chang, 2023). Second, clear experimental planning helps students understand objectives, steps, and procedures, ensuring smooth execution and valid results (Yip, 2019). Third, analyzing and reflecting on experimental results enables students to evaluate their findings and connect them to theoretical knowledge, further deepening their understanding of the material. By progressing through these four stages, learners engage in a structured, immersive, and reflective learning process that enhances both conceptual understanding and practical application.

2.2. Augmented Reality

AR is a technology that integrates real-world elements with virtual objects to enhance users' perception of their environment (Pellas, 2019). Through AR, users can experience digital elements—such as images, sounds, or animations—overlaid in real time onto the physical world using devices like smartphones, tablets, or AR glasses (Thohir et al., 2023). This technology has significant potential across various fields, including education, healthcare, entertainment, and industry.

Two key factors contribute to the effectiveness of AR applications, particularly in education. The first is interactivity and immersive visualization (ZA9), which serve as the core strengths of AR. This technology enables students to grasp complex concepts by directly engaging with visual representations (Szalavári, 1998). By interacting with virtual elements in a realistic manner, students move beyond theoretical learning and gain hands-on experiences that enhance their understanding (Ras et al., 2017). The second factor is technology accessibility (ZA10), which plays a crucial role in AR integration. With the widespread availability of smartphones and AR-based applications, the technology has become increasingly user-friendly and accessible (Küçük, 2016). This accessibility allows AR to be implemented across various learning environments, making it a versatile tool for education.

2.3. Understanding Diversity Indonesian Culture

Indonesia's cultural diversity is one of the nation's greatest assets, encompassing a wide range of elements such as language, customs, traditional clothing, art, music, dance, and religion (Martina, 2022). Understanding this diversity is crucial for strengthening national identity, promoting unity, and fostering tolerance among different social groups (Syairofi, 2023). Three main factors influence the understanding of Indonesia's cultural diversity. First, education and information (YB1) play a key role in raising cultural awareness. An interactive and engaging curriculum, such as the integration of AR technology, can enhance students' understanding of culture in a more immersive and in-depth way (Pranata et al., 2024). Second, intercultural interaction (YB2) enriches individuals' understanding through direct experiences, such as cultural festivals, visits to cultural sites, or Experiment 1 activities that introduce them to other cultural groups. Third, technology and media (YB3) have become vital tools in spreading cultural information, especially to younger generations. By providing immersive visualizations and engaging digital content, they offer a more accessible and dynamic way of learning about culture (Agus et al., 2020). Through the integration of these factors, the younger generation can gain knowledge, appreciate, and develop pride in the diverse cultures that characterize Indonesia.

Table 2
Outer Loading

Indicators	*Description*
Experiential Learning 1	
X7	Relevance of simulation to real-world conditions
X8	Interactivity in simulations for active involvement
X9	Feedback during/after simulations for improvement
Experiential Learning 2	
X10	Relevance of Experiment 1 to real-world conditions
X11	Interactivity in Experiment 1 for active learning
X12	Feedback in Experiment 1 for error correction
Augmented Reality	
ZA9	Interactivity and immersive Visualization in AR
ZA10	Interactivity and vimmersive Visualization in AR
Understanding diversity Indonesian culture	
YB1	Role of education and information in cultural awareness
YB2	Intercultural interaction through cultural activities
YB3	Role of technology and media in promoting cultural knowledge

The hypothesis study following is designed for a test effectiveness approach.

H1: Simulation (X1) has a positive effect on Augmented Reality (Z).

H2: Experiment 1 (X2) has a positive effect on Augmented Reality (Z).
H3: Experiment 2 (X3) has a positive effect on Augmented Reality (Z).
H4: Augmented Reality (Z) has a positive effect on Understanding Cultural Diversity (Y).
H5: Simulation (X1) directly influences Understanding Cultural Diversity (Y).
H6: Experiment 2 (X3) directly influences Understanding Cultural Diversity (Y).

3. Method

This study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze the relationships between variables (Dorninger, 2021). The analysis was conducted using Smart PLS 4.0, a tool that allows for data analysis with small sample sizes and supports model testing with both reflective and formative indicators.

3.1. Sample

The sample for this study consisted of 100 fifth-grade students from SDN Kademangan 5 Elementary School. Data was collected through a structured questionnaire administered to the students as respondents (Thohir et al., 2023). The study's instruments included several key constructs: Simulation, Experiment 1, Experiment 2, understanding of cultural diversity, and the effectiveness of AR. Each construct was measured using a 5-point Likert scale (Pranata et al., 2021), ranging from "Strongly Disagree" to "Strongly Agree."

3.3. Process

The intervention consists of three steps: preparation, execution, and assessment. During the preparation stage, we select traditional homes and regional dances, along with AR applications that feature interactive 3D objects. Teachers integrate AR into their lessons to enhance cultural learning. In the execution stage, students use tablets or smartphones to explore cultural artifacts in interactive 3D, try on virtual traditional clothing, and view animations of regional dances. The software's audio and text tools help users understand cultural histories. After exploring, students engage in discussions and reflections on their experiences. For the assessment stage, we employ interactive quizzes, student observations, and questionnaires to evaluate AR's impact on cultural knowledge. AR enables self-exploration in a digital world, making learning more dynamic and engaging. It also facilitates a deeper understanding of cultures that are difficult to convey through words or static images alone. AR applications—such as 3D models of traditional homes, virtual traditional attire, and regional dance animations—highlight the rich cultural diversity of Indonesia. The following image shows an example of an AR design, which includes an AR product name ('ARIUM') (see Figure 1), an AR object with an explanation of each component (see Figure 2), and a control button that allows users to rotate or shift the object to highlight specific parts (see Figure 3).

Figure 1
Product name AR (main display)

Figure 2
Example of an AR display

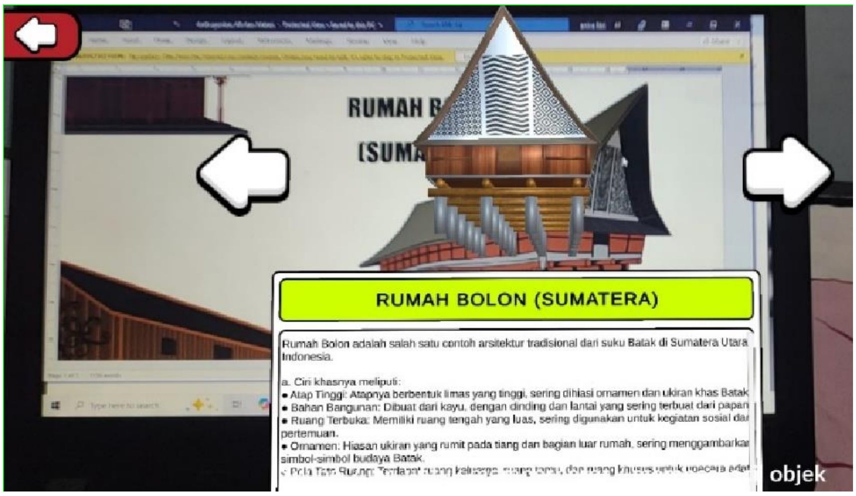
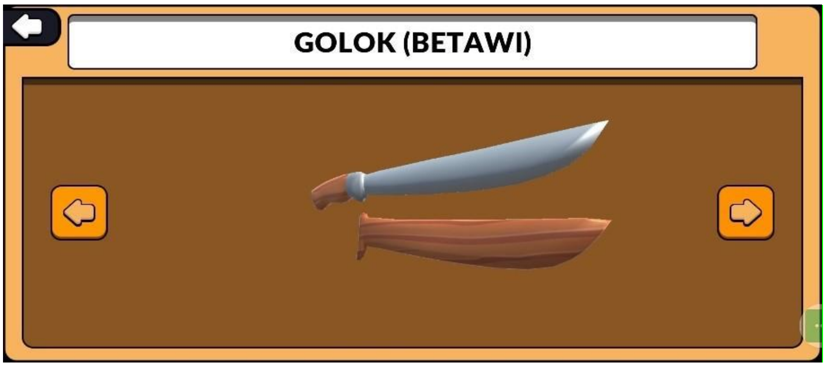


Figure 3
Object Catalogue



3.2. Data Analysis

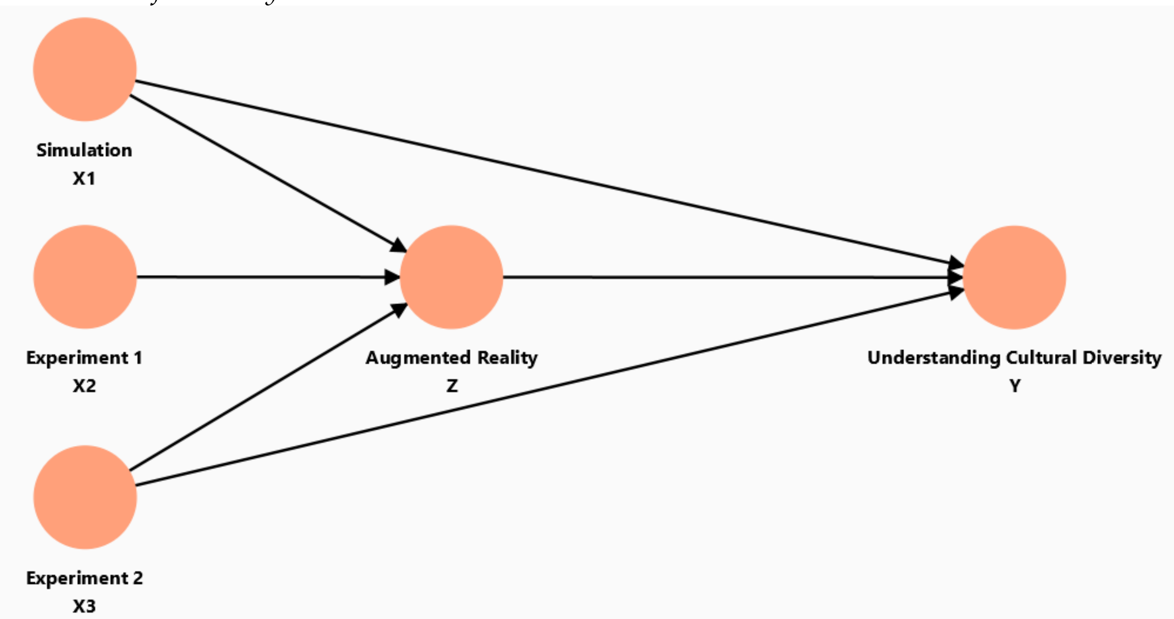
Data analysis in this study was conducted using Smart PLS 4 to test the relationships between variables in the proposed model. Smart PLS 4 was chosen due to its capability to handle models involving both reflective and formative data constructs.

The first step in the analysis was the Outer Model Evaluation (Thohir et al., 2021), which focuses on testing the validity of the constructs and the reliability of the indicators (Sarstedt, 2020). At this stage, factor loadings for each indicator measuring the latent variables were analyzed. Indicators with a factor loading greater than 0.7 were considered to meet the conditions for construct validity, while those with values below 0.7 required modification (Vishwanathan, 2020). Additionally, discriminant validity was tested to ensure that each construct was distinct from the others (Cheung, 2024).

The second stage, Inner Model Evaluation, focused on testing the relationships between the constructs in the model (Roemer, 2021). During this stage, a path coefficient test was performed to measure the strength and direction of the connections between the independent variables.

The study framework in Figure 4 illustrates the relationship between the learning components—Simulation, Experiment 1 activities (Thohir et al., 2021), and Experiment 2—and their impact on students' understanding of diversity in Indonesian culture, with AR technology serving as a mediator.

Figure 4
Framework of the study



4. Findings

Figure 5 illustrates the structural relationships among key variables in the study, focusing on the impact of AR on enhancing cultural understanding within an Experiential Learning framework. The model highlights the connections between three experiential components—Simulation (X1), Experiment 1 (X2), and Experiment 2 (X3)—and their influence on AR (Z) and the ultimate goal of fostering an understanding of cultural diversity (Y). Each variable is represented alongside its corresponding indicators, demonstrating their contribution to the model's predictive power. Path coefficients, R^2 values, and statistical significance are provided to emphasize the strength and direction of these relationships

Figure 5
Fit Model of the study

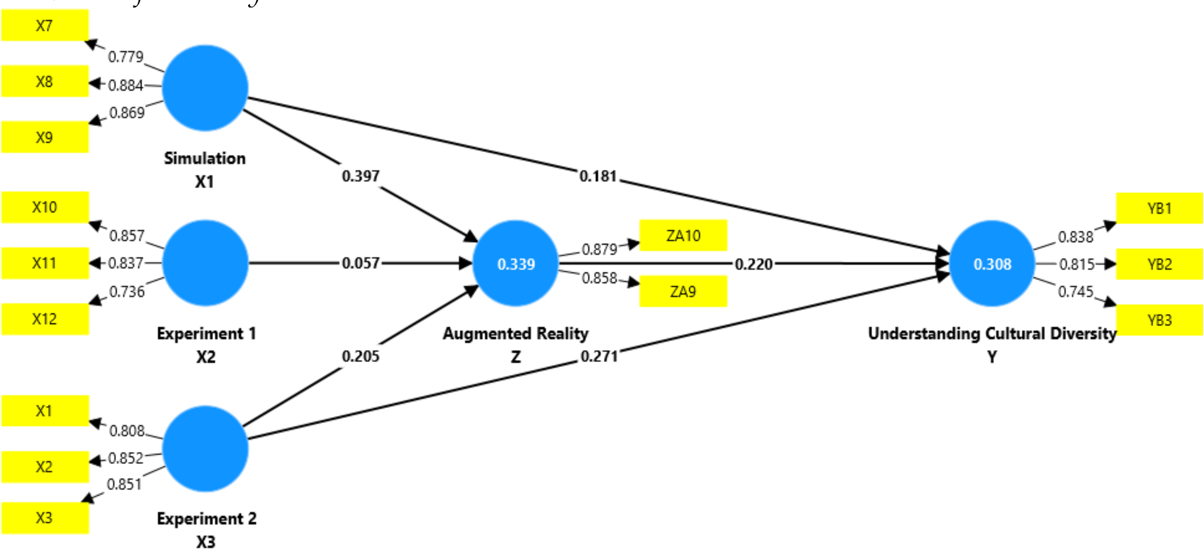


Figure 5 illustrates the pivotal role of Augmented Reality (Z) in enhancing cultural diversity understanding (Y), with a path coefficient of 0.271 and an R^2 of 0.339. This suggests that AR serves as a significant mediator in cultural education. Among the experiential learning components, Simulation (X1), Experiment 1 (X2), and Experiment 2 (X3) exert varying degrees of influence on

AR. Specifically, Simulation (X1) has the strongest impact, with a path coefficient of 0.397, while Experiment 1 (X2) and Experiment 2 (X3) contribute coefficients of 0.057 and 0.205, respectively.

AR further enhances cultural understanding (Y) with a path coefficient of 0.271. In contrast, the direct contributions of Simulation (X1), Experiment 1 (X2), and Experiment 2 (X3) to cultural understanding are relatively minimal, with coefficients of 0.181, 0.057, and 0.205, respectively. These findings highlight AR's central role in fostering cultural understanding, while other components, such as Simulation and the Experiments, may require further refinement to maximize their impact within the experiential learning process.

4.1. Outer Loading

Table 2 presents the Outer Loading values for the constructs and indicators used in the study, assessing the validity of the measurement model. Outer Loading values indicate the strength of the relationship between observed variables (indicators) and their respective latent constructs (Steffen, 2019). A value above 0.7 is considered acceptable, demonstrating that the indicator effectively represents the construct. Table 2 highlights the contributions of each indicator to constructs such as Simulation (X1), Experiment 1 (X2), Experiment 2 (X3), Augmented Reality (Z), and Understanding Cultural Diversity (Y). These values provide a foundation for evaluating the reliability and validity of the model's measurement framework.

Table 2
Outer Loading

	Augmented Reality Z	Experiment 1 X2	Experiment 2 X3	Simulation X1	Understanding Cultural Diversity Y
X1				0.818	
X2				0.873	
X3				0.911	
X4		0.784			
X5		0.815			
X6		0.892			
X7			0.834		
X8			0.805		
X9			0.782		
Y1					0.905
Y2					0.850
Y3					0.916
Z2	0.727				
Z3	0.871				

The outer loading analysis confirms that the indicators for each construct effectively measure their respective variables, with most values exceeding the 0.7 threshold, demonstrating strong convergent validity. For the Simulation (X1) construct, indicators X1, X2, and X3 exhibit high loading values of 0.818, 0.873, and 0.911, respectively, ensuring reliable representation. Similarly, Experiment 1 (X2) is well-measured by indicators X4, X5, and X6, with values of 0.784, 0.815, and 0.892, where X6 contributes the most. Experiment 2 (X3) is effectively reflected by indicators X7, X8, and X9, with values of 0.834, 0.805, and 0.782, demonstrating consistent reliability. For the Augmented Reality (Z) construct, indicators Z2 and Z3 have loading values of 0.727 and 0.871, respectively, with Z3 being the stronger contributor, while Z2 remains within the acceptable range. Lastly, Understanding Cultural Diversity (Y) emerges as the most robust construct, with indicators Y1, Y2, and Y3 showing strong values of 0.905, 0.850, and 0.916, respectively, confirming its reliability, with Y3 being the strongest contributor. Overall, the analysis validates the measurement model and underscores the high reliability of the constructs and their indicators, though slight improvements in specific areas, such as Z2, could further strengthen the model.

4.2. Cross Loadings

Table 3 below presents the cross-loadings analysis, which assesses the discriminant validity of the measurement model by examining the correlations between each indicator and all constructs. An indicator is considered valid if it loads higher on its intended construct than on others.

This analysis ensures that each indicator distinctly represents its corresponding construct and is not significantly influenced by unrelated constructs. By evaluating cross-loadings, we can confirm the structural adequacy of the model and the clarity of relationships between indicators and their respective latent variables.

Table 3
Cross loadings

	Augmented Reality Z	Experiment 1 X2	Experiment 2 X3	Simulation X1	Understanding Cultural Diversity Y
X1			0.808		
X10		0.857			
X11		0.837			
X12		0.736			
X2			0.852		
X3			0.851		
X7				0.779	
X8				0.884	
X9				0.869	
YB1					0.838
YB2					0.815
YB3					0.745
ZA10	0.879				
ZA9	0.858				

The cross-loadings analysis confirms that the model exhibits strong discriminant validity, with each indicator loading highest on its respective construct. For the Simulation (X1) construct, indicators X7, X8, and X9 show high loadings of 0.779, 0.884, and 0.869, respectively, indicating reliable measurement. Similarly, Experiment 1 (X2) is well-represented by indicators X10, X11, and X12, with strong loadings of 0.857, 0.837, and 0.736, reinforcing the validity of the construct. Experiment 2 (X3) is also reliably measured by indicators X1, X2, and X3, with loadings of 0.808, 0.852, and 0.851, respectively, demonstrating consistent alignment with the construct.

For Augmented Reality (Z), indicators ZA9 (0.858) and ZA10 (0.879) exhibit strong loadings, further validating the construct. Similarly, the Understanding Cultural Diversity (Y) construct is robustly measured by indicators YB1, YB2, and YB3, with loadings of 0.838, 0.815, and 0.745, respectively, confirming its reliability.

Overall, the analysis confirms the model's discriminant validity, with each indicator strongly aligned with its respective construct. It also highlights the distinct and interdependent roles of the constructs within the experiential learning framework, demonstrating that the measurement model is both reliable and capable of capturing the theoretical relationships among the constructs.

4.3. VIF Validity

The Variance Inflation Factor (VIF) analysis in Figure 2 confirms that the model meets the statistical assumption of low multicollinearity, ensuring reliable regression estimates. All variables have VIF values below the critical threshold of 5, indicating that multicollinearity is not a significant issue. Among the variables, the Understanding Cultural Diversity (Y) construct shows slightly higher VIF values, with Y1 (2.762) and Y3 (2.728), reflecting moderate intercorrelation. However, these values remain within the acceptable range and do not pose a concern for the analysis.

Figure 4
VIF Validity

Variables	*VIF values*
X1	1.601
X10	1.481
X11	1.537
X12	1.486
X2	1.681
X3	1.675
X7	1.524
X8	1.985
X9	1.847
YB1	1.340
YB2	1.668
YB3	1.469
ZA10	1.350
ZA9	1.350

The Simulation (X1–X9) variables exhibit VIF values ranging from 1.481 to 1.985, with X8 (1.985) and X9 (1.847) being on the higher end, though still within the acceptable range. Similarly, the Experiment 1 (X10–X12) and Experiment 2 (X1–X3) constructs show VIF values between 1.481 and 1.675, indicating moderate correlations among the predictors but no significant multicollinearity concerns. The Augmented Reality (ZA9 and ZA10) construct shows consistent VIF values of 1.350, highlighting minimal correlation and strong independence from other predictors. Lastly, the Understanding Cultural Diversity (YB1–YB3) construct has VIF values ranging from 1.340 to 1.668, with YB2 (1.668) being the highest, still within acceptable thresholds.

In summary, the VIF analysis confirms that multicollinearity is well-controlled in the model. All variables exhibit VIF values below the critical threshold of 5, ensuring the stability and reliability of the regression coefficients and supporting the validity of the model's findings.

4.4. Reliability and Validity

Table 4 presents the reliability and validity analysis, evaluating the internal consistency, reliability, and convergent validity of the constructs used in the study (Pranata et al., 2021). The key metrics—Cronbach's Alpha, Composite Reliability (rho_a and rho_c), and Average Variance Extracted (AVE)—are essential for assessing the quality of the measurement model.

Cronbach's Alpha and Composite Reliability assess how well the indicators consistently measure the underlying construct, while AVE measures the proportion of variance explained by the construct relative to measurement error. This analysis provides valuable insights into the robustness and validity of the constructs, confirming their suitability for further study.

Table 4
Reliability and Validity

	Cronbach's alpha	*Composite reliability (rho_a)*	*Composite reliability (rho_c)*	*Average variance extracted (AVE)*
Augmented Reality_Z	.775	.677	.860	.754
Experiment 1_X2	.750	.792	.852	.659
Experiment 2_X3	.788	.794	.876	.701
Simulation_X1	.800	.817	.882	.715
Understanding Cultural Diversity_Y	.728	.764	.842	.640

The reliability and validity analysis demonstrates that most constructs in the model exhibit strong internal consistency, reliability, and convergent validity. Augmented Reality (Z) shows solid reliability, with a Cronbach's Alpha of 0.775, Composite Reliability of 0.860, and a high AVE of 0.754, indicating its strong ability to explain the variance in its indicators. Similarly, Simulation (X1) and Experiment 2 (X3) display strong reliability and convergent validity, with Cronbach's Alpha values of 0.800 and 0.788, respectively, and AVE values of 0.715 and 0.701, confirming their robustness in measuring experiential learning components.

Experiment 1 (X2) also performs well, with a Cronbach's Alpha of 0.750 and an AVE of 0.659, reflecting its consistency and relevance. Understanding Cultural Diversity (Y) shows reliable measures, with a Cronbach's Alpha of 0.728, Composite Reliability of 0.842, and an AVE of 0.640, demonstrating its validity in capturing cultural diversity aspects.

These results collectively highlight the model's strong foundation, with all constructs demonstrating high reliability and validity. The metrics confirm the model's robustness and appropriateness for further analysis, providing a reliable basis for evaluating the relationships between constructs.

4.5. Discriminant Validity

The discriminant validity analysis, shown in Table 5, evaluates the extent to which the constructs in the model are distinct from one another. Discriminant validity is established when the correlations between constructs are lower than the correlations within their respective indicators, ensuring that each construct measures a unique concept.

By examining the relationships between Augmented Reality (Z), Simulation (X1), Experiment 1 (X2), Experiment 2 (X3), and Understanding Cultural Diversity (Y), the table provides insights into how well the constructs are separated while also reflecting their interdependencies within the experiential learning framework.

Table 5
Discriminant validity

	Augmented Reality Z	Experiment 1 X2	Experiment 2 X3	Simulation X1
Augmented Reality_Z				
Experiment 1_X2	.605			
Experiment 2_X3	.624	.702		
Simulation_X1	.744	.703	.705	
Understanding Cultural Diversity Y	.604	.661	.590	.577

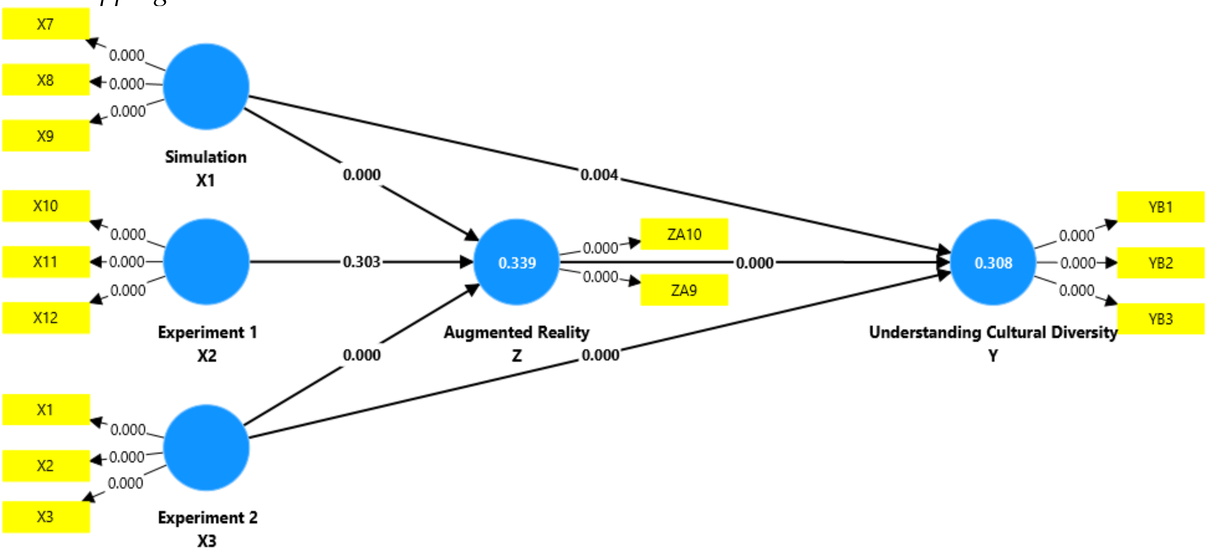
The discriminant validity analysis confirms that all constructs in the model are sufficiently distinct while maintaining meaningful interrelationships. The results highlight the mediating role of Augmented Reality (Z), which shows the strongest correlation with Simulation (X1) and moderate correlations with other experiential learning components. Experiment 1 (X2) and Experiment 2 (X3) are strongly interconnected, emphasizing the complementary nature of these activities within the experiential learning framework. Understanding Cultural Diversity (Y), as the outcome, is moderately influenced by all constructs, particularly Experiment 1 (X2) and Augmented Reality (Z).

These findings underscore the importance of leveraging the synergistic effects of experiential learning components and AR to enhance students' cultural understanding. Overall, the model demonstrates strong discriminant validity, supporting the reliability and robustness of the theoretical framework.

4.6. Bootstrapping Analysis

The bootstrapping model in Figure 6 illustrates the structural relationships among the variables examined in this study using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. The model demonstrates the influence paths between the independent variables—Simulation (X1), Experiment 1 (X2), and Experiment 2 (X3)—on the dependent variable, Understanding Cultural Diversity (Y), mediated by Augmented Reality (Z). The bootstrapping analysis presents path coefficients, R^2 values, and statistical significance, which serve as the basis for assessing the strength of relationships among the variables and the effectiveness of each component in enhancing students' cultural understanding.

Figure 6
Bootstrapping Model



The bootstrapping model presented in Figure 6 highlights the structural relationships among the constructs in the study, including Simulation (X1), Experiment 1 (X2), Experiment 2 (X3), Augmented Reality (Z), and Understanding Cultural Diversity (Y). The bootstrapping analysis is used to assess the statistical significance of these relationships by calculating path coefficients, standard errors, and p-values through repeated sampling.

Figure 6 shows that Augmented Reality (Z) serves as a key mediator between the experiential learning components and the outcome variable, Understanding Cultural Diversity (Y). The path coefficients, depicted along the arrows, indicate the strength and direction of the relationships, with p-values supporting the robustness of the connections (see Table 6).

Simulation (X1), Experiment 1 (X2), and Experiment 2 (X3) each contribute differently to Augmented Reality (Z), with Experiment 1 showing the strongest path coefficient of 0.303. Augmented Reality (Z), in turn, has a direct and significant impact on Understanding Cultural Diversity (Y). The model highlights the importance of combining experiential learning methods with innovative technologies like Augmented Reality to foster a deeper understanding of cultural diversity (Ibáñez, 2020).

5. Discussion

5.1. Simulation (X1) has a Positive Effect on Augmented Reality (Z)

"Recent studies support the significant role of simulations in enhancing the effectiveness of AR within experiential learning frameworks. For instance, Soilis et al. (2024) highlights that Virtual Reality simulations can be transformative pedagogical tools for learning about social issues, fostering critical reflection, dialogue, and transformative learning. The study emphasizes that VR provides unique opportunities to enhance experiential learning in ways that traditional methods cannot fully achieve.

Table 6
Path coefficients

	Original sample (O)	*Sample mean (M)*	*Standard deviation (STDEV)*	*T-statistics (|O/STDEV|)*	*p*
Augmented Reality_Z → Understanding Cultural Diversity_Y	0.220	0.219	0.052	4.204	<.01
Experiment 1_X2 → Augmented Reality_Z	0.057	0.059	0.056	1.031	.303
Experiment 1_X2 → Understanding Cultural Diversity_Y	0.013	0.013	0.013	0.967	.334
Experiment 2_X3 → Augmented Reality_Z	0.205	0.204	0.057	3.607	<.01
Experiment 2_X3 → Understanding Cultural Diversity_Y	0.316	0.317	0.053	6.004	<.01
Simulation_X1 → Augmented Reality_Z	0.397	0.397	0.057	6.923	<.01
Simulation_X1 → Understanding Cultural Diversity_Y	0.268	0.270	0.053	5.051	<.01

Similarly, Huang (2015) discusses the application of AR in experiential learning. The study illustrates how AR technology allows educators to design courses utilizing simulation, visualization, and interaction with virtual objects and real environments, thereby reducing the complexity of presented concepts and facilitating better knowledge acquisition and understanding among learners.

These findings underscore the crucial role of well-designed simulations in bridging the gap between theoretical knowledge and practical application, creating a strong foundation for integrating technologies like AR. By providing interactive and context-rich experiences, simulations not only support immersive learning environments but also act as key drivers in maximizing the potential of AR to foster engagement and understanding among learners.

However, despite its enormous potential, AR-based simulations face several challenges in their implementation, particularly in terms of technological accessibility and infrastructure limitations. For instance, a study found that AR-based simulations in schools were not very useful due to the high hardware resource demands, such as devices compatible with AR. Additionally, educators may require specialized training to effectively integrate AR technology into the curriculum, highlighting the need for more targeted professional development programs (Mena et al., 2023).

5.2. Experiment 1 (X2) has a Positive Effect on Augmented Reality (Z)

Recent studies emphasize the importance of designing interactive and engaging activities to enhance the effectiveness of AR in educational settings. A study by Jdaitawi et al. (2023) found that integrating AR with interactive elements significantly improved students' motivation and learning outcomes. Similarly, research by Videnovik et al. (2020) suggests that incorporating game-based learning elements into AR applications can increase the quality of the learning experience by making it more engaging and immersive. These findings indicate that revising Experiment 1 activities to include more interactive and reflective components could better align them with the capabilities of AR, thereby enhancing their impact within the experiential learning framework.

One of the main challenges in implementing AR-supported experiential learning is the digital divide, which results in differences in access to technology between schools in urban and rural areas. Key issues include a lack of internet infrastructure, devices compatible with AR, and insufficient teacher readiness (Perifanou et al., 2022). Additionally, economic factors play a significant role, as schools with limited budgets struggle to invest in necessary devices and infrastructure, widening the gap in students' learning experiences and affecting their preparedness for global challenges.

A comprehensive strategy involving the government, educational institutions, and the private sector is necessary to address this. For example, schools or governments could distribute AR devices, open-source AR apps could be developed, and AR content could be made accessible offline, allowing schools with limited internet access to use the technology. To ensure optimal use of AR in learning, teachers must also receive training in its implementation. With an inclusive approach, AR technology can be more evenly distributed, enabling all students, regardless of location or economic condition, to benefit from a more interactive and innovative learning experience.

5.3. Experiment 2 (X3) has a Positive Effect on Augmented Reality (Z)

Recent studies underscore the significant role of experiential learning activities in enhancing the effectiveness of AR within educational settings. For instance, Indrianingsih (2020) developed an AR application incorporating experiential learning activities and multiple external representations. The findings revealed that the AR application significantly increased students' knowledge gains, highlighting the importance of integrating hands-on and interactive approaches in AR-based learning environments.

Similarly, a meta-analysis by Xu et al. (2022) examined the impact of AR on students' academic achievement in science learning. The study reported a medium-to-large significant positive effect, indicating that AR technology, when combined with experiential learning activities, substantially enhances students' academic performance.

These findings support the notion that well-designed experiential learning activities, such as those in Experiment 2, synergize effectively with AR's immersive capabilities, leading to deeper cognitive processing and improved learning outcomes. This reinforces the importance of aligning experiential learning activities with technological tools like AR in educational frameworks.

5.4. Augmented Reality (Z) has a Positive Effect on Understanding Cultural Diversity (Y)

Recent research emphasizes the powerful role of AR in enhancing cultural understanding within experiential learning contexts. For example, Moorhouse et al. (2015) examined the use of AR in cultural heritage tourism and discovered that AR experiences significantly increased learner engagement and knowledge, aligning with Kolb's Experiential Learning Cycle (Moorhouse et al., 2017). Similarly, Bekele and Champion (2019) compared several immersive technologies and found that AR is particularly effective in promoting cultural learning by offering interactive, context-rich experiences (Bekele & Champion, 2019).

These findings highlight AR as a groundbreaking educational tool that connects theoretical knowledge with real-world application, ultimately fostering greater cultural awareness and appreciation among students.

5.5. Simulation (X1) Directly Influences Understanding Cultural Diversity (Y)

Recent research highlights the value of simulation-based learning in promoting cultural awareness and sensitivity. For example, Kourgiantakis and Bogo (2017) examine how simulation-based learning addresses difficulties in teaching cultural sensitivity within counseling programs, emphasizing its role in fostering cultural competence.

In a similar vein, Adewole et al. (2020) investigate the use of dialogue-based simulations for cultural awareness training, showing how these simulations can enhance cultural competence through realistic interactions. These studies reinforce the idea that well-crafted simulations are powerful educational tools for promoting cultural understanding, which aligns well with the goals of the experiential learning framework.

5.6. Experiment 2 (X3) Directly Influences Understanding Cultural Diversity (Y)

Recent research emphasizes the crucial role of experiential learning activities in promoting cultural understanding in educational environments. For example, Binbin et al. (2024) highlight that incorporating experiential learning theory into courses on *Intangible Cultural Heritage* enables students to deeply engage with and appreciate cultural heritage, leading to more effective learning. Similarly, Tohani et al. (2019) underscore that providing concrete learning simulations on cultural literacy, coupled with reflection and social learning activities, significantly enhances students' understanding of cultural diversity.

These findings reinforce the importance of well-designed experiential learning activities, like those in Experiment 2, in bridging the gap between theoretical knowledge and practical application. Through interactive, hands-on, and reflective activities, educators can effectively foster cultural understanding and appreciation in their students.

6. Conclusion

This research highlights the essential role of experiential learning components and AR in promoting cultural understanding within educational settings. The findings reveal that AR acts as a crucial mediator, bridging the gap between theoretical knowledge and practical applications, thereby enhancing students' awareness and appreciation of cultural diversity. Simulation (X1) was shown to have a significant effect on both AR and cultural understanding, serving both as an independent educational tool and complementing AR in immersive learning environments. Experiment 2 (X3) also had a strong and meaningful impact on AR and cultural understanding, emphasizing the value of hands-on, interactive activities in fostering deeper engagement with cultural concepts. On the other hand, Experiment 1 (X2) had a minimal and statistically insignificant effect on AR, indicating the need for refinement through more interactive and reflective design elements.

The study further demonstrates the transformative power of AR in enriching cultural education. Through immersive visualizations, interactive features, and real-time engagement, AR enables learners to form a deeper cognitive and emotional connection with cultural concepts. The study stresses the need to design experiential learning activities that are contextually rich, engaging, and well-aligned with AR’s capabilities to optimize their effectiveness in cultural education. Improving underperforming components like Experiment 1 and integrating additional technological tools could enhance the overall framework.

Overall, this research provides strong evidence that combining experiential learning with innovative technologies such as AR offers a transformative approach to cultural education. This method not only fosters a deeper cultural appreciation but also equips learners with the skills and perspectives necessary to navigate and value cultural diversity in a globalized world.

7. Research Limitations and Further Research

While this study presents promising results, it is important to acknowledge its limitations. One key limitation is the small sample size, which may not fully represent the diversity of student learning experiences across different educational contexts. Additionally, the study focuses primarily on short-term learning outcomes, leaving the long-term impact of experiential learning with AR unexplored. Technological challenges such as connectivity issues, incompatible devices, and varying levels of teacher readiness may also influence the consistency of student learning, particularly in resource-limited schools. These factors should be considered when interpreting the study's findings and assessing the broader feasibility of adopting AR in educational settings.

To address these limitations, future research should aim to increase the sample size and diversity of participants to enhance the generalizability of the findings. Longitudinal studies could provide valuable insights into the lasting effects of AR on students' cultural understanding. Moreover, integrating adaptive learning technologies, such as AI-based AR systems, could help create more personalized learning experiences. To ensure broader accessibility, further research could also explore cost-effective and offline AR solutions, addressing the digital divide and making AR more feasible for a wider range of educational environments. Filling these gaps in future studies will help better demonstrate AR's effectiveness and facilitate its adoption in cultural education.

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Ethical statement: All participants provided informed consent before their involvement in the study. They were informed about the purpose of the study, its procedures, and their right to withdraw at any time without any consequences.

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