Jurnal Ilmiah Teknologi Pendidikan
Volume 5, Issue 1, 14-23
e_ISSN: 2830-6813
https://ejournal.1001tutorial.com/finger/index
DOI: 10.58723/finger.v5i1.593

Effectiveness of Roblox-Based Metaverse Learning Media in Enhancing Digital Literacy among Primary School Students in Technology-Limited Areas

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Article Info

Article history:

Received: December 26, 2025
Revised: January 25, 2026
Accepted: February 6, 2026

Keywords:

Digital Literacy;
Game-Based Learning;
Inclusive Education;
Metaverse Learning;
Primary School Students.

Abstract

Background: The development of metaverse technology has opened up new opportunities in education, particularly through interactive platforms such as Roblox. However, most previous research has focused on schools with adequate technological access, leaving a gap in the implementation of the metaverse in areas with limited technology.
Aims: This study examines the effectiveness of Roblox-based metaverse learning media in enhancing digital literacy among primary school students in technology-limited regions, contributing to inclusive digital learning strategies.
Methods: The study employed a mixed-method approach with a quasi-experimental pretest–posttest design involving 118 students. A quantitative instrument in the form of a Likert-scale questionnaire was used to measure digital literacy, while qualitative data were obtained through open-ended interviews and documentation. The analysis was conducted using a paired sample t-test along with thematic analysis to enrich the interpretation of the results.
Results: Quantitative findings show a significant improvement in digital literacy scores ($t = -2.144$; $p = 0.034$), with all five dimensions scoring above 3—especially Educational Game Evaluation (Mean = 3.464) and Attitudes and Perceptions (Mean = 3.451). Qualitative results reveal enthusiasm, engagement, and improved understanding of digital content. However, limited devices and unstable internet may reduce the consistency of students' engagement.
Conclusion: This study demonstrates that Roblox, as a metaverse-based learning medium, can be effectively adapted in primary schools with limited technology. These findings underscore the importance of developing more adaptive learning media, providing clear instructions, and implementing educational policies that support equitable access to technology.

To cite this article: Sembiring, A., Jusuf, H., & Santoso, H. (2026). Effectiveness of Roblox-Based Metaverse Learning Media in Enhancing Digital Literacy among Primary School Students in Technology-Limited Areas. FINGER: Jurnal Ilmiah Teknologi Pendidikan, 5(1), 14–23. https://doi.org/10.58723/finger.v5i1.593

INTRODUCTION

The development of metaverse technologies in recent years has shown great potential for application across various fields, including education. The metaverse offers immersive learning experiences through interactive virtual environments that resemble the real world. Previous studies have emphasized that education using the metaverse can create diverse learning environments and resources for students, provide personalized learning recommendations, and enhance cost efficiency through edge computing technology (Niu et al., 2024). Transformative virtual reality–based education can also facilitate collaborative and project-based courses across regions (Zhou et al., 2024). In addition, metaverse-based learning has been proven to provide convenience for users, meet social needs, and have a positive impact on the willingness to adopt personalized learning (Wang & Shin, 2022). Since the COVID-19 pandemic, digital transformation has become increasingly urgent, and metaverse education has emerged as an important issue attracting global attention (Zhang et al., 2022). Accordingly, the metaverse has emerged as a pertinent innovation to tackle educational

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challenges in the digital era. Roblox was selected over other platforms such as Minecraft or Decentraland due to its relatively low data consumption, compatibility with low-spec devices, and ease of access without requiring high-end hardware or complex installation. These features make it more suitable for students in technology-limited areas, ensuring broader participation and smoother implementation. Moreover, Roblox is currently highly popular among students, making it a promising learning medium that can foster greater enthusiasm and engagement in the classroom.

Roblox, as one of the most widely adopted metaverse-oriented platforms, allows users to design and engage in game-based learning environments. Beyond offering a space for social interaction, Roblox serves as a medium for creative and collaborative pedagogy. Empirical studies highlight its capacity to enrich 3D business simulation experiences, though its influence on entrepreneurial learning outcomes appears to be constrained (Wenzel et al., 2025). Within the industrial domain, the Roblox Metaverse via the Game Factory Runner has demonstrated effectiveness in strengthening production engineers' analytical competencies in material testing, yielding notable gains in evaluative and relational thinking (Payonpak et al., 2025). Further research underscores that AR- and VR-based metaverse platforms, exemplified by Spark AR Studio, present significant opportunities for transformative advances in education and business through inclusive immersive experiences, while simultaneously demanding rigorous consideration of security, privacy, and usability concerns (Verma & Paul, 2025). Through its gamification and interactive features, Roblox demonstrates substantial potential in advancing digital learning within primary education.

Within this context, digital literacy constitutes a critical competency for primary school students in the contemporary technological era. As a fundamental requirement for the integration of the metaverse into education, the absence of such skills may hinder students and institutions in developing countries from inclusively leveraging the metaverse's full potential (Viswanathan & Kumar, 2025)s. Further research highlights the metaverse's substantial potential as a transformative avenue for sustainable development. However, its effective integration hinges on resolving legal, policy, and social challenges, most notably those concerning digital literacy and adaptive global regulatory frameworks (Isik, 2025). Generation Alpha, raised amidst smartphones and pervasive internet connectivity, demonstrates heightened responsiveness to interactive, visual, and collaborative media. Properly designed immersive metaverse-based learning environments have been shown to foster ethical reasoning, improve decision-making accuracy, and strengthen student engagement, while simultaneously providing cost-effective and scalable educational solutions (Oyefidein et al., 2025). In the Hong Kong context, metaverse-based learning incorporating avatars and interactivity has been shown to foster students' self-expansion, especially among experienced learners, with statistically significant differences identified among male university students (Zheng et al., 2025).

However, most studies have been conducted in schools with adequate technological access, leaving a research gap regarding the implementation of the metaverse in areas with limited technology. The main obstacles include limited devices and internet connectivity, low digital literacy among children, and uneven teacher readiness (Dreamson & Park, 2023; Tan et al., 2024). Technological gaps also arise due to differences in device access, digital literacy, and psychological readiness, thereby affecting both inclusivity and the effectiveness of its implementation (Maldonado-López et al., 2024). This situation prompts critical inquiry into the relevance and effectiveness of implementing platforms such as Roblox within rural primary schools or technologically constrained regions.

A growing body of prior research substantiates the relevance of metaverse integration in educational contexts. The convergence of gamification and immersive technologies has the capacity to generate interactive, engaging, and contextually relevant learning experiences tailored to the digital generation (Srdanović et al., 2025; Vieira et al., 2025). Since the COVID-19 pandemic, the metaverse has been increasingly recognized as a potential method to overcome the limitations of external activities, particularly in the field of education (Park & Sohn, 2023). Meanwhile, a new method of using the metaverse in education involves combining gamification, AI-based simulation, and 3D technology (Munde & Kaur, 2023). Conversely, there is a pressing need for broader exploration at the primary and secondary education levels, given that current metaverse research remains predominantly skewed toward university populations and VR-based technologies (Asiksoy, 2023).

These findings reinforce the urgency of this study to examine the implementation of Roblox as a learning medium in primary schools with technological limitations.

Based on these gaps, the purpose of this study is to examine the effectiveness of Roblox-based metaverse learning media in improving digital literacy among sixth-grade primary school students in areas with technological limitations. The focus on digital literacy is crucial, as this competency serves as a foundation for students to adapt to future technological developments. By addressing the shortcomings of previous research, this study is expected to provide significant empirical contributions to the development of metaverse-based learning strategies that can be widely applied, including in regions with limited technological resources (Lopes & Goncalves, 2021; Zamfir et al., 2023).

METHOD

Research Design

This study employs a mixed-methods approach, combining quantitative and qualitative techniques. The mixed-methods design has demonstrated that IVR is effective in enhancing EFL proficiency as well as transferable skills (Muthmainnah et al., 2025). The quantitative approach was conducted using a quasi-experimental design with a pretest–posttest model to measure the improvement of students' digital literacy after the intervention. A study that combines quantitative and qualitative approaches can provide a more comprehensive picture of the effectiveness of the metaverse in simulation-based education (Jans et al., 2025). Educational metaverse research enables comprehensive analysis by combining quantitative data (pre–post tests, statistical tests) and qualitative data (questionnaires, interviews, focus groups) to more holistically assess the impact of immersive experiences on students' academic performance, engagement, and cultural identity formation (Pazakou et al., 2025; Yang & Jamaludin, 2025).

Research Subjects

The research participants were sixth-grade students, totaling 118, from an primary school located in an area with limited digital technology. The selection of participants was carried out purposively, considering technological disparities that are relevant to the objectives of the study. In this context, "limited digital technology" refers to schools with low internet bandwidth, minimal access to personal devices such as laptops or tablets, and reliance on shared or outdated hardware for digital learning activities.

Research Instrument

The quantitative instrument consists of a Likert-scale questionnaire to measure students' digital literacy before and after the intervention. The reliability of the digital literacy questionnaire was tested using Guttman's λ2 in JASP, yielding a coefficient of 0.891 with a 95% confidence interval ranging from 0.860 to 0.923. This result indicates high internal consistency across the items, confirming that the instrument is suitable for measuring students' digital literacy. The qualitative instruments include open-ended interviews and documentation of the learning process during the use of Roblox to gain an in-depth understanding of students' experiences. Qualitative inquiry through interviews provides important insights into participants' experiences, perceptions, and emotional resonance in the use of extended reality and VR applications for education (Lampropoulos & Chen, 2025; Yang & Jamaludin, 2025). The five dimensions of digital literacy analyzed in this study Ease of Access, Motivation and Learning Engagement, Digital Literacy Skills, Attitudes and Perceptions, and Evaluation of Educational Games were adapted from established frameworks (Martínez-Bravo et al., 2022; Sogalrey, et al., 2024).

Research Procedures

The stages of the research included providing initial material to students to equip them with a basic understanding of digital literacy, followed by administering a pretest to measure their initial digital literacy skills. Subsequently, a treatment was administered in the form of implementing Roblox-based learning media, where students interacted within a metaverse environment designed according to learning needs. A posttest was then administered to measure the improvement in digital

literacy after the treatment. To obtain qualitative data, the researcher conducted interviews and documentation to gather insights into students' perceptions and experiences during the learning process.

Data Analysis Techniques

Quantitative data were analyzed using descriptive and inferential statistics to examine differences in pretest and posttest scores as well as Likert-scale results across five dimensions. Qualitative data were analyzed through a thematic approach to identify patterns of students' perceptions, motivations, and experiences in using Roblox-based learning media.

RESULTS AND DISCUSSION

This section presents the research findings on the implementation of Roblox-based metaverse learning media as an instructional approach to enhance digital literacy among primary school students in areas with technological limitations. The analysis was conducted through a quantitative approach using a pretest–posttest design and the measurement of five dimensions of digital literacy, and the analysis was further enriched with qualitative data obtained from interviews and documentation of the learning process.

Results

Quantitative data were obtained through the measurement of students' digital literacy before and after the implementation of Roblox-based metaverse learning media, as well as through a survey of five dimensions of digital literacy. The analysis revealed a significant increase in students' digital literacy scores following the intervention, as evidenced by the paired sample t-test results showing statistically significant differences between pretest and posttest scores ($p < 0.05$), thereby reflecting the effectiveness of the Roblox-based learning intervention.

Table 1. Results of the Paired Samples T-Test on Students' Scores and Digital Literacy

Measure 1		Measure 2	t	df	p
Pretest	-	Posttest	-2.144	117	.034

The results of the paired sample t-test indicate a statistically significant difference between students' digital literacy scores before and after the intervention ($t = -2.144$; $df = 117$; $p = 0.034$), suggesting that Roblox-based metaverse learning is effective in enhancing students' digital literacy.

Based on the results of the paired sample t-test, there was a significant increase in students' digital literacy scores after participating in Roblox-based metaverse learning. This finding indicates that the intervention successfully produced a positive impact on students' digital competence in areas with technological limitations.

The raincloud plot presented below illustrates the distribution of students' digital literacy scores before and after the intervention. It clearly shows an increase in the average posttest scores compared to the pretest, while also displaying individual variations, the median, and a more even spread of data following the implementation of Roblox-based learning. This visualization highlights not only the overall improvement but also the consistency of students' performance across different dimensions of digital literacy. The presence of overlapping data points further indicates that, despite initial disparities, students generally benefited from the intervention in a comparable manner.

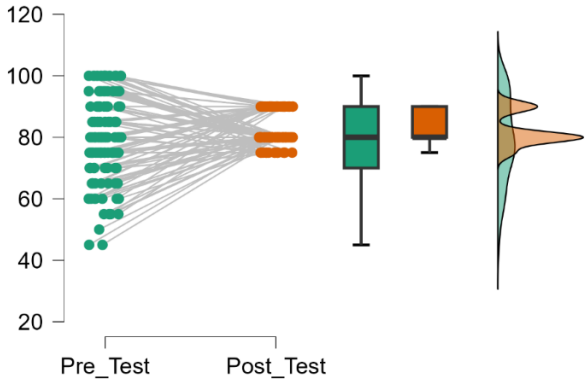

Figure 1. Visualization of the Raincloud Plot of Students' Digital Literacy Scores Before and After Roblox-Based Learning

In addition to measuring pretest and posttest scores, this study also employed a Likert-scale instrument to assess students' digital literacy across five key dimensions: ease of access, learning motivation and engagement, digital literacy skills, attitudes and perceptions, and evaluation. The analysis was conducted on the average scores of each dimension before and after the intervention to identify more specific patterns of competency improvement.

Table 2. Descriptive Statistics of the Five Dimensions of Students' Digital Literacy in Roblox-Based Learning

Dimension	Median	Mean	Std. Deviation	Minimum	Maximum
Ease of Access	3.400	3.344	0.468	1.600	4.000
Motivation and Learning Engagement	3.400	3.405	0.528	1.400	4.000
Digital Literacy Skills	3.400	3.366	0.460	1.800	4.000
Attitudes and Perceptions	3.600	3.451	0.475	2.400	4.000
Evaluation of Educational Games	3.400	3.464	0.411	2.400	4.000

Based on the results of the descriptive analysis of the five dimensions of digital literacy, all dimensions showed mean scores above 3, indicating a positive student response to Roblox-based learning. The dimensions with the highest scores were the Evaluation of Educational Games (Mean = 3.464) and Attitudes and Perceptions toward Metaverse Learning (Mean = 3.451), suggesting that students not only enjoyed the structure and challenges within the game but also held progressive views toward learning in virtual worlds. These dimensions are consistent with recent studies on digital literacy in education (Martínez-Bravo et al., 2022; Sogalrey, et al., 2024).

Qualitative analysis of students' responses revealed dominant themes of enthusiasm, engagement, and understanding of digital content, accompanied by several technical challenges and developmental suggestions that enriched the interpretation of the effectiveness of Roblox-based learning. These findings affirm that students' learning experiences are complex, influenced by the interaction between game design and individual perceptions. As illustrated in Figure 2, the visualization of thematic clusters highlights how enthusiasm and engagement consistently coexisted with technical barriers, reinforcing the need for adaptive instructional support. The figure also demonstrates that developmental suggestions offered by students were directly linked to their lived experiences in navigating the platform, thereby providing practical insights for future improvements in metaverse-based learning design.

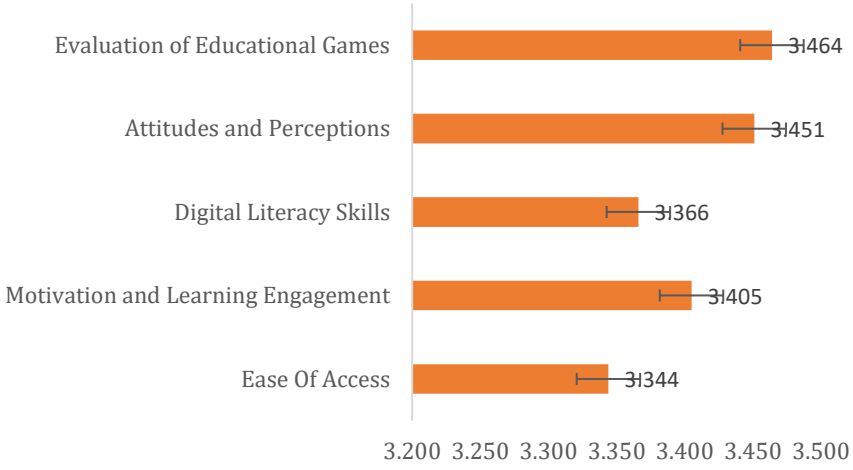

Figure 2. The average score of each dimension

The image below represents the visualization of the thematic network from the qualitative analysis, illustrating the relationships among categories and subthemes based on their frequency of occurrence and the strength of their connections. Each connecting line indicates the level of linkage between themes, where thicker red lines signify stronger or more frequently appearing relationships in the students' data, while thinner black lines represent weaker or less dominant connections.

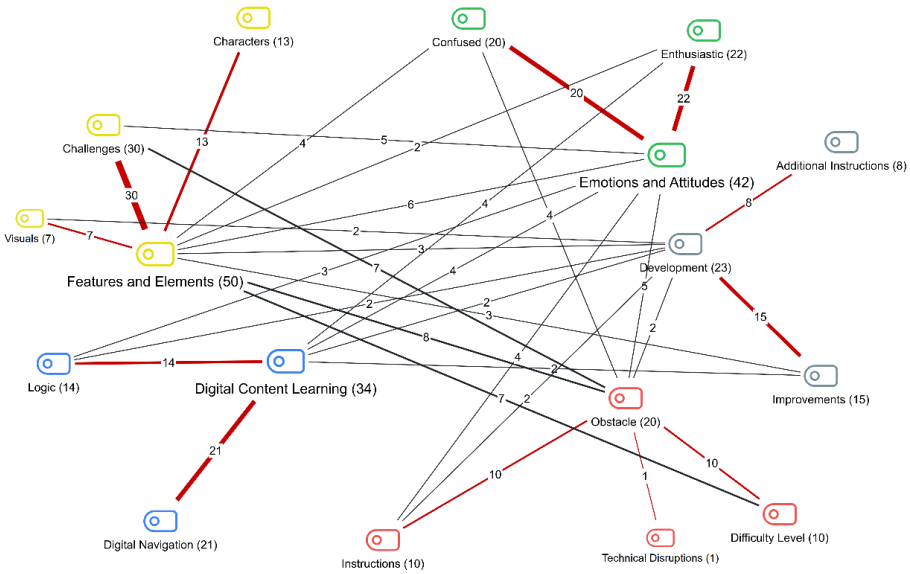

Figure 3. Thematic Network Visualization

The qualitative findings indicate that Roblox-based learning sparked enthusiasm, strengthened digital literacy, and encouraged active student engagement, although some technical challenges were also identified that may affect students' digital skill development.

Discussion

The findings of this study affirm that the implementation of Roblox-based metaverse learning media is effective in improving the digital literacy of primary school students in areas with technological limitations. Quantitatively, the paired-sample t-test showed a significant increase in digital literacy scores ($t = -2.144$; $p = 0.034$), while the descriptive analysis of the five dimensions revealed mean scores above 3, with the highest dimensions being the Evaluation of Educational Games (Mean = 3.464) and Attitudes and Perceptions (Mean = 3.451). These results are consistent with previous studies emphasizing that gamification in the metaverse can enhance students' motivation, engagement, and readiness to face the digital era.

Qualitatively, the thematic analysis shows that students experienced enthusiasm and active engagement in the learning process, while also gaining new understanding of digital content. However, several technical challenges such as navigation difficulties and confusing instructions still emerged. In areas with limited digital infrastructure, students often relied on peer collaboration and teacher guidance to overcome these problems. During the intervention, students helped each other interpret game mechanics and interface elements, while teachers provided simplified walkthroughs and visual aids to support understanding. These adaptive strategies enabled students to remain engaged despite technical constraints, highlighting the importance of scaffolding and community-based learning in digital environments, and underscoring the need for further development in game design to make it more adaptive to schools with technological limitations. The combination of quantitative and qualitative findings demonstrates that Roblox is not only positively received by students but also has the potential to serve as an inclusive and relevant alternative learning medium for primary education in areas with limited technology.

Implications

The findings of this study have important implications for the development of learning strategies in primary schools, particularly in areas with technological limitations. The significant increase in students' digital literacy scores indicates that metaverse-based learning media such as Roblox can serve as an innovative alternative to bridging the gap in technology access while strengthening basic digital skills. This underscores that the integration of gamification in virtual environments can enhance students' motivation, engagement, and positive attitudes toward digital learning, thereby supporting education policies oriented toward digital transformation. In addition, the qualitative results highlighting students' enthusiasm, improved digital literacy, and the emergence of technical challenges provide practical input for teachers and educational media developers.

The practical implication is the need for more adaptive educational game design, with clear instructions, gradual levels, and interactive features suited to the conditions of schools in low-technology areas. Thus, this study not only reinforces empirical evidence of the effectiveness of the metaverse in education but also provides direction for the development of inclusive and sustainable digital learning policies and practices.

Research Contribution

This study makes a significant empirical contribution to the literature on the application of the metaverse in primary education, particularly in areas with technological limitations. Quantitatively, the paired sample t-test results showed a significant improvement in students' digital literacy ($t = -2.144$; $p = 0.034$), while the descriptive analysis of the five dimensions revealed mean scores above 3, with the highest-scoring dimensions being the Evaluation of Educational Games (Mean = 3.464) and Attitudes and Perceptions (Mean = 3.451). Qualitatively, the study enriches understanding of how students' enthusiasm, engagement, and experiences in using Roblox can support the enhancement of digital literacy, while also uncovering technical challenges that need to be addressed in the design of learning media.

The main contribution of this study is to demonstrate that metaverse-based media such as Roblox are not only relevant in schools with adequate technological access but can also be effectively adapted in areas with limited technology. Thus, this research opens opportunities for the development of more inclusive digital learning strategies and provides a foundation for education policies oriented toward equitable access to technology and the enhancement of digital literacy at the primary school level.

Limitations

This study has several limitations that need to be considered, including the limited research context, which was conducted in only one primary school in an area with minimal technological access, making the results not yet generalizable on a broader scale. The sample size was restricted to 118 students, so the variation in learning experiences may not be fully represented. In addition, the use of qualitative instruments such as interviews and documentation relied on students' subjective responses, which may introduce interpretive bias. Furthermore, limitations in devices and internet

connectivity during the learning process also affected the smooth implementation of Roblox as a metaverse-based medium, meaning its effectiveness may differ if applied in schools with more adequate technological conditions.

Suggestions

Based on the research findings, it is recommended that the development of Roblox-based metaverse learning media be directed toward the creation of clear instructions, gradual game levels, and the addition of interactive features relevant to the learning material, so as to minimize technical obstacles and enhance learning effectiveness. Furthermore, follow-up studies should be conducted with a broader range of schools and diverse technological conditions to strengthen the generalization of the findings and provide recommendations for more inclusive digital education policies.

CONCLUSION

This study demonstrates that the implementation of Roblox-based metaverse learning media is effective in enhancing the digital literacy of primary school students in areas with limited technology. Quantitative results show a significant increase in digital literacy scores after the intervention ($t = -2.144$; $p = 0.034$), with all dimensions of digital literacy achieving mean scores above 3, particularly in the Evaluation of Educational Games (Mean = 3.464) and Attitudes and Perceptions (Mean = 3.451). These findings affirm that students are not only able to access and effectively utilize digital media but also hold positive attitudes toward learning in virtual environments.

From a qualitative perspective, the thematic analysis highlights students' enthusiasm, active participation, and emerging comprehension of digital and robotics-related content, despite persisting technical obstacles such as navigation difficulties and ambiguous instructions. Students' feedback, expressed through developmental suggestions, underscores that learning experiences within Roblox are inherently complex and multidimensional, shaped by the dynamic interplay between game design and individual perceptions.

Overall, this study makes an important contribution to the digital education literature by demonstrating that metaverse-based media can be effectively adapted in primary schools with technological limitations. The practical implications highlight the need for more adaptive digital learning media, clear instructions, and educational policies that support equitable access to technology. As a direction for future research, subsequent studies may broaden the scope to various educational levels, integrate metaverse technologies into more diverse curricula, and explore the long-term impact on students' 21st-century digital skills.

ACKNOWLEDGMENT

The authors express their gratitude to SD Sint Yoseph Kabanjahe for granting permission and providing support in the implementation of this study, as well as to all students and teachers who actively participated in the Roblox-based learning process. Appreciation is also extended to the institutions that offered technical assistance and supporting facilities, enabling the research to proceed smoothly and yield meaningful findings.

AUTHOR CONTRIBUTION STATEMENT

AS assumed the lead responsibility for field data collection and undertook both quantitative and qualitative analyses to ensure the validity of the study's findings. In turn, HJ and HS contributed substantive insights to the research design, refined the instruments and manuscript, and engaged in data analysis to reinforce the interpretation of the results. Collectively, the three authors collaborated in drafting, composing, and revising this article, culminating in a cohesive scholarly work that adheres to rigorous academic standards.

AI DISCLOSURE STATEMENT

The authors used Microsoft Copilot in preparing this work to assist in improving sentence structure and language clarity. After utilizing the tool, the authors conducted a thorough review, made

necessary edits, and affirmed that full responsibility for the accuracy, integrity, and overall content of this publication remains with the authors.

CONFLICTS OF INTEREST

The authors affirm that no financial, institutional, or personal conflicts of interest are associated with the conduct of this research or the publication of this article.

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