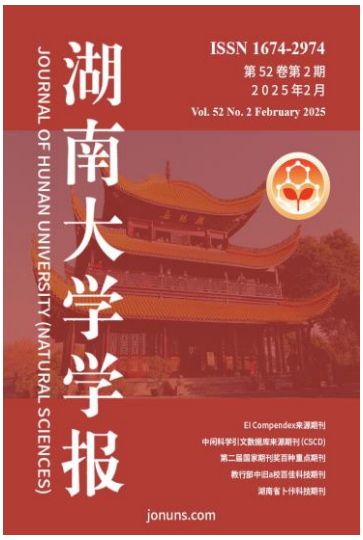

Journal of Hunan University

(Natural Sciences)

Vol. 52 No. 2

February 2025

Available online at

https://jonuns.com

Open Access Article

https://doi.org/10.55463/issn.1674-2974.52.2.7

Learning Revolution with Integrated Gamification Technology and Realistic Mathematics Education Models for Contextual and Interesting Learning

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Article History:

Received: January 20, 2025
Reviewed: February 28, 2025
Revised: March 7, 2025
Accepted: March 12, 2025
Published: March 31, 2025

Abstract: This research aims to explore the impact of RME (Realistic Mathematics Education)-based gamification in mathematics learning on student motivation and learning outcomes in elementary schools. The method used is qualitative research with a case study approach in several elementary schools that apply gamification in mathematics learning. Data were collected through interviews, observation, and analysis of documents and FGDs. The research results show that the application of RME-based gamification can increase students' motivation to take mathematics lessons. Game elements, such as points, levels, and badges, successfully create a fun atmosphere that motivates students to be more active and enthusiastic in learning. In addition, there was a significant increase in student learning outcomes, especially in problem-solving abilities involving the application of mathematical concepts

in real life. However, challenges in implementation, such as limited resources and time, as well as the need for training for teachers, were discovered during the research. Overall, RME-based gamification has proven to be effective in increasing motivation and mathematics learning outcomes and can be an interesting and relevant alternative approach to mathematics learning in elementary schools. This research suggests that teachers should be given sufficient training and schools should provide resources that support the implementation of gamification in learning. The novelty in this research is the integrated gamification of the Acehnese culture combined with a realistic mathematical approach that addresses everyday problems close to the students' environment. This gamification also functions to introduce the Acehnese culture to students and the public.

Keywords: Gamification technology, realistic mathematics education, interesting learning.

融合游戏化技术与现实数学教育模式的学习革命，实现情境化、趣味化的学习

摘要：本研究旨在探讨基于 RME（现实数学教育）的游戏化在数学学习中对小学学生学习动机和学习成果的影响。所采用的方法是定性研究，在几所将游戏化应用于数学学习的小学中采用案例研究方法。数据是通过访谈、观察和分析文件和焦点小组讨论收集的。研究结果表明，基于 RME 的游戏化应用可以提高学生上数学课的积极性。积分、级别和徽章等游戏元素成功地创造了一种有趣的氛围，激励学生更积极、更热情地学习。此外，学生的学习成果显著提高，尤其是在实际生活中应用数学概念解决问题的能力方面。然而，研究过程中发现了实施方面的挑战，例如资源和时间有限，以及需要对教师进行培训。总体而言，基于 RME 的游戏化已被证明能有效提高积极性和数学学习成果，并且可以成为小学数学学习的一种有趣且相关的替代方法。这项研究建议教师接受充分的培训，学校应提供支持游戏化学习实施的资源。这项研究的创新之处在于将亚齐文化与现实数学方法相结合，解决与学生环境密切相关的日常问题。这种游戏化还可以向学生和公众介绍亚齐文化。

关键词：游戏化技术，写实数学教育，有趣学习.

1. Introduction

Mathematics is often considered an abstract and difficult subject by many students. This causes students' low interest and motivation to learn mathematics, and impacts achieving less than optimal competencies. One of the main causes is learning methods that are still conventional, lack contextualization, and lack innovation. In fact, mathematics has great potential to be linked to real situations in everyday life, making it easier to understand and relevant for students.

Along with developments in technology and the needs of the 21st century, innovation in education is very necessary to address the increasingly complex learning challenges. One effective approach is to use technology as an interactive and interesting learning tool. In the context of mathematics, integrating technology with gamification is a potential solution to increase student engagement in learning. Gamification presents game elements, such as challenges, rewards and competition, to create a fun and motivating learning experience.

In addition, the Realistic Mathematics Education (RME) Model has been proven to be an effective approach in helping students understand mathematical concepts through real-world contexts. RME places students as active subjects who build knowledge through exploration and reflection. However, the implementation of RME in the field is often less than optimal due to limited media and innovative strategies to support this approach.

Realistic Mathematics Education (RME) is a mathematics learning approach with Dutch roots [1]. This approach was developed on the basis of the idea that mathematics learning should be based on students' real and contextual experiences, so that it is more meaningful and relevant. In the late 1960s and early 1970s, the mathematics education system in the Netherlands experienced criticism because it was

considered too abstract and disconnected from real applications in everyday life. Realistic Mathematics Education was developed by Hans Freudenthal at the Freudenthal Institute, Utrecht University, Netherlands [2]. Freudenthal believed that mathematics is a human activity (mathematics as a human activity), not just a science that must be studied passively. The RME principle views that Mathematics should be taught through the exploration of real situations that are relevant to students. Students must be involved in the process of discovering mathematical concepts through contextual experiences and social interactions. RME is designed to reflect Freudenthal's philosophy, with three main principles, namely Guided Reinvention, meaning that students are guided to rediscover mathematical concepts through structured learning experiences. Didactical Phenomenology means that mathematical concepts are introduced through real situations that are relevant to students' lives. Self-Developed Models Students develop an understanding of mathematical concepts through visual representations or models that they create themselves.

Realistic Mathematics Education (RME) offers a real context-based learning approach, but its application often does not take into account local cultural diversity [3, 4]. Gamification, which is known to be effective in increasing student engagement, is also rarely integrated into culture-based learning [5, 6]. Therefore, the development of Acehnese cultural gamification-based learning integrated with RME can be an innovation to improve students' numeracy literacy and mathematical problem-solving abilities.

Many students are less motivated to learn mathematics because learning is abstract .and monotonous [7, 8]. The cultural potential of Aceh has not been used optimally in mathematics learning, so students cannot relate mathematical concepts to everyday life [9, 10]. Most teachers have not used gamification strategies to increase student engagement and learning motivation [11, 12] Most research on gamification focuses on general approaches without integrating local culture [13]. Not much research has explored the integration of gamification with RME approaches in specific cultural contexts. Many studies on gamification and RME have been conducted at secondary or higher education levels, while implementation in elementary schools is still limited. RME theory emphasizes the importance of the real context in mathematics learning, but its application often ignores the cultural dimensions of students [14]. Gamification theory generally focuses on game mechanics without considering the influence of cultural context and learning approaches such as RME. There are not many learning models that combine RME theory, gamification, and ethnopedagogy holistic.

The Realistic Mathematics Education (RME) approach emphasizes the use of real contexts to facilitate the understanding of mathematical concepts [15, 16]. The integration of Acehnese cultural elements in RME can be done using the local cultural context as a starting point for learning [17, 18]. Architectural art, such as geometric patterns on songlet cloth, can be used to teach the concepts of symmetry, translation and rotation. Gamification creates more engaging and motivating learning through game elements [19].

Gamification technology in learning refers to the use of game elements and principles in educational contexts to increase student motivation, engagement and learning outcomes [20, 21]. These elements include providing challenges, rewards, leaderboards, level systems, avatars, stories (narrative), and other interactive elements. The gamification elements used are mathematical problems presented in the form of cultural challenges, such as completing a traditional Acehnese house pattern. Points or awards are given based on students' success in completing assignments. Next, there are levels used by students to solve problems with gradual levels of difficulty, such as from simple to complex symmetrical patterns. Encourage students to work together in teams, for example discussion groups solving measurement and geometry puzzles in Aceh. Gamification can be carried out using digital-based applications with Acehnese cultural themes, such as educational games that teach mathematical concepts through local cultural contexts.

The integration of gamification with the Realistic Mathematics Education (RME) approach creates innovative learning strategies that are not only fun, but also contextual and meaningful [22, 23]. Combining gamification with the RME approach produces contextual learning in the form of gamification elements such as missions, challenges and narratives that can be based on real situations that are relevant to students' lives, according to RME principles. Gamification makes learning mathematics fun and interesting [21, 24], so that students are more motivated to be actively involved in the learning process [25-27]. Challenges in games can motivate students to solve complex mathematical problems [28]. Furthermore, it is Student-Centered because RME prioritizes exploration by students [29, 30], while gamification provides space for students to be creative and complete missions in their own way [24, 31]. For this reason, integrating gamification technology into the RME model can be an answer to contextual and interesting mathematics learning challenges. Through this approach, students can learn in a relevant way, interactive, and fun. This innovation is also expected to improve students' problem-solving abilities and numeracy literacy, which is essential to prepare them to face real-life challenges.

With this background, in-depth study and development is needed to apply the integrated gamification technology of the RME model in mathematics learning in schools, especially to create learning that is more meaningful, interesting, and has a positive impact on student learning outcomes.

2. Methods

The research approach used mixed-methods (quantitative and qualitative) to obtain comprehensive data. The type of research is development research (Research and Development or R&D) using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation).

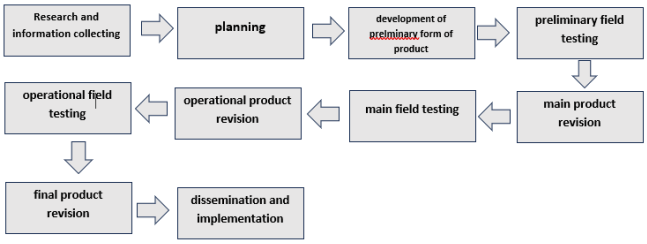

Figure 1. Research design (developed by the authors)

This model was chosen because it allows the systematic development of innovative learning products. The analysis stage begins with observations and interviews with teachers and students in elementary schools to identify the needs related to mathematics learning. Literature study on gamification, RME, and the integration of Acehnese culture in learning. Identify relevant Acehnese cultural elements to be included in mathematics learning. Identification of problems in implementing mathematics learning in elementary schools. Design Stage (Design) gamification model based on Acehnese culture integrated with RME. Development of learning tools, such as Learning modules. Gamification-based media (example: game cards, simple applications). Research instruments (observation sheets, questionnaires and tests). At the development stage of the prototype learning tools and gamification media. Expert validation: Validation by mathematics education experts, Acehnese culture experts, and gamification experts to ensure product suitability. Product revision based on input from the implementation experts. Limited trial in one elementary school in Aceh. The participants were teachers and class IV students. Data collection is through observation of the learning process. Teacher and student interviews regarding the application of the model. Test students' problem-solving abilities and numeracy literacy. The Evaluation Stage (Evaluation) is carried out during the trial process to improve the learning product. A summative evaluation was carried out after the trial to measure the effectiveness of the learning model in improving numeracy literacy and mathematical problem-solving abilities. Qualitative data collection was carried out by observing learning activities. In-depth interviews with teachers and students. Document analysis (student work results, teacher reflection). Quantitative Data Collection is reviewed through learning outcomes tests (problem solving abilities and numeracy literacy). Questionnaire to measure student learning motivation and acceptance of the gamification model. The Qualitative Data Analysis Technique uses Miles and Huberman's interactive analysis technique, which includes data reduction, data presentation, and drawing conclusions. Meanwhile, Quantitative includes descriptive statistical tests to see the average, standard deviation and distribution of the test result data. Test the effectiveness of the model using the t-test or N-gain test to measure the increase in student learning outcomes before and after implementing the model. Location: Elementary school in Aceh and subject of class IV students as students. Furthermore, the class teacher as the implementer of learning.

3. Results and Discussion

3.1 Analysis Stage (Analysis)

At this stage, an analysis of student and teacher needs for mathematics learning is carried out. Data were obtained through questionnaires, interviews and observations. The results of the statistical analysis are given in Tables 1 and 2.

Table 1 Student needs questionnaire (compiled by the authors)

Aspect	Average Score	Category
Difficulty in understanding mathematical concepts	4.2	High
Interest in learning mathematics	3.1	Currently
The need for context-based learning	4.5	High

Interpretation: Most students have difficulty in understanding mathematics because of the abstract approach. Students need context-based learning that is interesting and relevant.

Table 2 Teacher questionnaire (compiled by the authors)

Aspect	Average Score	Category
Difficulty in explaining abstract concepts	4.3	High
The need for innovative learning media	4.7	High

Interpretation: Teachers need innovative learning media that can help relate mathematics to students' daily lives.

3.2 Design Stage (Designing)

At this stage, an RME-based Acehnese culture gamification learning model was designed. Learning media prototypes and learning activity designs were developed (Table 3).

Table 3. Results of design validation by experts (compiled by the authors)

Validation Aspect	Validation Score (%)	Category
Compliance with the RME approach	87%	Very Valid
Relevance to the Acehnese culture	90%	Very Valid
Conformity to the curriculum	85%	Valid
Potential to increase student motivation	88%	Very Valid

Interpretation: The model design is considered very valid, but there are suggestions to enrich the variety of Acehnese cultural activities that are integrated into learning.

3.3 Development Stage (Development)

At this stage, learning media in the form of gamification-based game modules and tools are being developed (Table 4).

Table 4. Media trial results by experts (compiled by the authors)

Validation Aspect	Validation Score (%)	Category
Content suitability to Acehnese culture	88%	Very Valid
Visual clarity and appeal	85%	Valid
Ease of use	87%	Very Valid

Interpretation: Learning media is considered very valid, with a recommendation to add a step-by-step guide to using the media.

3.4 Implementation Stage (Implementation)

Mathematical Problem-Solving Ability Test was used to determine the effect of the RME-based Acehnese cultural gamification learning model on students' mathematical problem-solving abilities. The pretest and posttest data were analyzed using the N-Gain test and t-test to determine significant improvements (Table 5).

Table 5. Pretest and Post-test Results of the Mathematical Problem-Solving Ability (compiled by the authors)

Aspect	Pretest	Post-test	N-Gain	N-Gain Category
Average Score	60	85	0.67	Currently
Standard Deviation	8.5	6.2	-	-
Minimum	45	70	-	-
Maximum	75	95	-	-
Number of Students	30	30	-	-

Interpretation: The average score for problem-solving ability increased from 60 (fair category) to 85 (very good category). The N-Gain value = 0.67 indicates an increase in the ability in the medium category. The t-test produced a calculated t-value = 7.45 with a p-value < 0.05, which means this increase is significant.

The numeracy literacy test was carried out to measure students' ability to relate mathematical concepts to the Acehnese cultural context. The results of this test are given in Table 6.

Table 6. Numeracy Literacy Pretest and Post-test Results (compiled by the authors)

Aspect	Pretest	Post-test	N-Gain	N-Gain Category
Average Score	55	80	0.56	Currently
Standard Deviation	7,2	5,8	-	-
Minimum	40	65	-	-
Maximum	70	90	-	-
Number of Students	30	30	-	-

Interpretation: The average student numeracy literacy score increased from 55 (poor category) to 80 (good category). The N-Gain value = 0.56 indicates an increase in the ability in the medium category. The t-test produced a calculated t-value = 6.85 with a p-value < 0.05, which shows that this increase is significant.

A questionnaire was used to measure student responses to the gamification-based learning model of the Acehnese culture. Table 7 shows the results of the analysis of students' responses.

Table 7. Results of the analysis of student responses (compiled by the authors)

Statement	Average Score	Category
I feel happy studying mathematics	4.5	Excellent
Learning media is interesting and easy to understand	4.3	Good
I can relate mathematics to the Acehnese culture	4.6	Excellent

Statement	Average Score	Category
I feel more motivated to study	4.4	Good

Interpretation: The average score for all aspects is in the good to excellent category. Students feel happier and more motivated to learn mathematics with gamification media based on the Acehnese culture.

3.5 Evaluation Stage (Evaluation)

Evaluation was carried out through student and teacher response questionnaires regarding the learning model. Tables 8 and 9 show the results of the analysis of students' and teachers' responses.

Table 8. Student questionnaire results (compiled by the authors)

Statement	Average Score	Category
Interesting and fun learning	4.6	Excellent
Learning media is easy to understand	4.5	Excellent
I am more motivated to study mathematics	4.4	Good

Table 9. Teacher questionnaire results (compiled by the authors)

Statement	Average Score	Category
The learning model helps me teach	4.7	Excellent
Learning media are easy to use	4.6	Excellent

Interpretation: Students and teachers responded very positively to learning based on the gamification of the Acehnese culture. Learning media are considered practical and effective in increasing student motivation and learning outcomes.

4. Discussion

The process of developing a learning model based on the gamification of Acehnese culture integrated with Realistic Mathematics Education (RME) is carried out through the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework. The following is a discussion of the results at each stage. In the Analysis stage, learning needs, student conditions and the relevance of the Acehnese culture in mathematics learning are identified. The Main Findings Students show low interest in conventional mathematics learning, which tends to be abstract and less relevant to everyday life. Achenes cultural elements, such as traditional games and geometric patterns in local art, have not been used in learning. Teachers need innovative learning strategies to increase student engagement and learning outcomes. Implications This analysis points to the need to develop culture-based learning models to increase the relevance of mathematics learning and student motivation.

In the Design Stage, this stage involves designing a learning model based on Acehnese cultural gamification and preparing learning tools. Steps: Identify elements of the Acehnese culture that can be integrated into learning, such as geometric patterns on traditional Acehnese houses. Design learning tools, including modules, visual media, and educational games that are relevant to the cultural context. Obtained results The learning model was designed to combine the RME approach with gamification elements. For example, students are invited to solve problems based on the cultural context, such as calculating flat shapes in Acehnese Traditional Houses. Determining the levels and rewards in gamification is designed to increase student motivation.

In the Development Stage, the designed learning model product is developed into a learning tool that is ready to be used. The results are Achenes culture-based learning gamification products that contain RME-based activities, such as traditional trade simulations and geometric art patterns. Initial trials were conducted on a small group of students, showing increased engagement and positive responses to gamification-based learning.

The learning model was applied to experimental classes in elementary schools with direct observation. Pretest and Posttest Results: The average posttest score increased significantly compared with the pretest, with an N-Gain of 0.67 (medium category) for problem-solving ability and 0.56 for numeracy literacy. The t-test showed a significant difference ($p < 0.05$) between the pretest and posttest. Most students stated that learning became more interesting and relevant to everyday life. Teachers admit that this model helps them convey mathematical concepts in a more contextual and fun way.

The Evaluation Stage involves formative and summative evaluation of the effectiveness of the learning model. Formative Evaluation is carried out during the implementation process to improve the learning tools and implementation strategies. Teacher and student input is used to improve the learning modules and supporting media. Summative Evaluation Student learning results show significant improvements in both problem-solving abilities and numeracy literacy. The questionnaire results show that 87% of students feel motivated to learn mathematics using this model, and 92% of teachers feel this model is relevant and easy to apply.

In the aspect of increasing mathematical problem-solving abilities, the results of the research show that the Acehnese culture gamification-based learning model integrated with RME has succeeded in increasing

students' problem-solving abilities. This increase can be explained in several ways, namely the Relevance of Cultural Context with the RME Approach emphasizing learning that starts from real contexts. In this research, the Acehnese culture is used as a learning context, such as geometric patterns on traditional Acehnese houses and mosque carving patterns. In line with [32], this helps students relate mathematical concepts to everyday life, thereby improving their critical thinking skills. Furthermore, the context of using gamification includes gamification elements, such as modified traditional Acehnese games, which increase student involvement in the learning process in line with [33, 34]. Research results obtained in [35, 36] increased interest and motivation allows students to focus more on solving problems. The N-Gain test result of 0.67 in the medium category shows that although there is significant improvement, the implementation of gamification still has room for development, especially in perfecting aspects of game mechanics to more effectively support problem solving.

In the aspect of increasing numeracy literacy, the results of the pretest and post-test numeracy literacy showed a significant increase with an N-Gain value of 0.56. Numeracy literacy increases because of the integration of mathematical concepts with cultural activities. Students learn to use mathematical concepts through cultural contexts, such as calculations in processing Acehnese seafood or symmetry patterns in Acehnese houses. According to [37-40], this activity helps students understand that mathematics is not only an abstract theory, but is also relevant to their lives.

Furthermore, RME-based strategies help students solve real problems using the exploration, representation and generalization steps. However, the level of numeracy literacy is still in the medium category. This shows that cultural integration needs to be further strengthened with activities that involve higher-order thinking skills [15, 41].

In the aspect of model acceptance by teachers and students, the results of the questionnaire show that students responded very positively to this learning model. This reflects that learning media is interesting because the use of gamification-based media has succeeded in making learning more enjoyable [42-44]. Games based on Acehnese culture, such as guessing geometric patterns in traditional art, create an interactive learning atmosphere. There is an increase in motivation because the elements of challenge, reward and collaboration in gamification increase student enthusiasm [45]. Furthermore, the teacher's response also shows that this model is practical to apply in the classroom. Teachers consider that the Acehnese cultural context helps them explain mathematics material more easily. However, the challenge faced is the time required to prepare gamification-based learning media [26, 46].

This research contributes to the development of contextual learning. The integration of Acehnese culture in RME provides a new approach to making mathematics more meaningful for students. Culture-Based Gamification Innovation in the form of gamification elements developed not only increases learning motivation but also connects students with their cultural heritage. The combination of RME, gamification, and ethnopedagogy creates a unique and relevant learning model [47].

Practical Implications for Teachers This model can be applied as an innovative learning strategy to improve student learning outcomes, especially in problem solving abilities and numeracy literacy. Implications for Students Using a cultural context helps students understand the importance of mathematics in everyday life, while increasing their appreciation of Acehnese culture. This research opens up opportunities to develop gamification and culture-based learning models in other subjects or at higher educational levels.

The limitations of the research include that this research was only conducted at one elementary school in Aceh with a limited number of subjects. The results may not fully reflect the effectiveness of the model in various contexts. Limited implementation time may affect learning outcomes, especially in deepening students' higher-order thinking abilities. The gamification media used is still simple and not based on advanced technology, so its implementation requires further development. This model needs to be tested on a wider scale involving various elementary schools in Aceh to measure the generalization of the results. The use of digital applications based on the Acehnese culture can enrich the gamification experience and increase student engagement. Training is needed for teachers to effectively integrate local cultural elements and gamification in RME-based learning.

5. Conclusion

The conclusion of the research "Learning Revolution with Gamification Technology Integrated with a Realistic Mathematics Education Model for Contextual and Interesting Learning" is: Increased Learning Interest and Motivation. Integrating gamification technology with Realistic Mathematics Education (RME) creates a learning environment that is interactive, fun, and relevant to everyday life. This can increase students' interest and motivation in learning mathematics. Meaningful Contextual Learning. The RME model that emphasizes the real-world context is enriched with gamification elements such as challenges, points, and rewards. This approach helps students understand mathematical concepts through real experience, so that learning becomes more meaningful. Developing problem-solving abilities. Gamification elements designed with RME principles allow students to be

actively involved in solving contextual problems. This encourages the development of critical thinking and creative problem-solving skills. Encouraging Numeracy Literacy. The use of technology and gamification in mathematics learning helps students more easily understand, apply and analyze quantitative information, so that their numeracy literacy increases. Educational Innovations Relevant to the Digital Era. The combination of gamification and RME technology is an innovation that is relevant to the educational needs of the 21st century, providing a learning experience that conforms to developments in technology and digital culture.

This research makes a significant contribution to scientific knowledge in several aspects, especially in the fields of mathematics education, learning model development, and cultural studies. The following are the main contributions: Mathematics Learning Model Innovation because this research develops a learning model based on local (Aceh) culture gamification, which is integrated with the Realistic Mathematics Education (RME) approach. Combining a contextual approach (RME) with elements of gamification and local culture. This is an underexplored approach to teaching mathematics, especially at the elementary school level. This model can be a new reference in developing contextual-based learning in various other regions by integrating their respective local cultures.

The authors declare that there are no conflicts of interest in this research. The entire research process, from design, implementation, to reporting of results, was carried out independently and was not influenced by personal interests, institutions or certain sponsors. This research aims purely to develop knowledge and improve the quality of local culture-based mathematics learning in elementary schools. All research decisions are based on academic and professional considerations to produce valid and relevant findings for the world of education. The author declares that this article is free of plagiarism.

Declarations

Author Contributions

Conceptualization, H.A. and A.S.W.; methodology, H.A. and A.S.W; software, S., and W.; validation, H.A.; formal analysis, S., and W.; investigation, H.A. and A.S.W.; resources, H.A.; data curation, H.A.; writing—original draft preparation, H.A. and A.S.W.; writing—review and editing, H.A.; visualization, S., and W.; supervision, H.A.; project administration, H.A. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Funding

Funding information is not available.

Institutional Review Board Statement

Rigorous ethical guidelines were adhered to throughout the study to ensure participant privacy and data confidentiality in compliance with institutional and national research standards.

Informed Consent Statement

Participation in the study was voluntary, and informed consent was obtained from all participants prior to their involvement.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this manuscript. In addition, ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completely observed by the authors.

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Word count: 4,940 words, excluding references.

Peer review information:

Whether the manuscript was fast tracked? - No
Number of reviewer report submitted in first round: 3 reports
Number of revision rounds: 2 rounds
Final revised version submitted: March 10, 2025