

Ethno-Gamification Platform for Mathematics Learning Based on Balinese Local Wisdom Challenges

I Ketut Lokasanti[✉], Dewa Gede Hendra Divayana^{*}[✉], I Gde Wawan Sudatha[✉]
I Wayan Sukra Warpala[✉]

Universitas Pendidikan Ganesha, Udayana St. No.11, Singaraja, Bali, 81116, Indonesia

*Corresponding author, email: hendra.divayana@undiksha.ac.id

<https://doi.org/10.17977/um065.v6.i8.2026.14>

Article History

Submitted: 20 June 2026

Revised: 2 July 2026

Accepted: 9 July 2026

Published: 11 July 2026

Keywords

Ethnomathematics

Gamification

Mathematics learning

Abstract

The gap between the abstraction of middle school mathematics material and the real-life challenges faced by students in Bali creates an urgent need to implement a pedagogical innovation that not only utilises technology but is also rooted in the local Balinese cultural context to reduce declines in learning motivation and math anxiety in middle school. The purpose of this research is to develop an Ethno-Gamification Platform as a medium for mathematics learning, based on the challenges of local Balinese wisdom, for junior high school students. This research is a development study using the Borg and Gall development model, modified into five main stages: research and field data collection, planning, design development, initial testing, and revision of initial testing. The research subjects were selected using the Purposive Sampling technique, which involved IT experts, education experts, IT education evaluators, teachers, and junior high school students in Bali. The data collection technique in this study employed a 5-point Likert-scale questionnaire. The data analysis technique applied is a quantitative descriptive approach, using a percentage calculation formula to categorise the platform's level of validity and effectiveness. The research shows that the effectiveness of the Ethno-Gamification Platform for Mathematics Learning Based on Local Wisdom Challenges in Bali is 86.5%, categorising it as very effective. This research successfully developed the Ethno-Gamification Platform as a highly effective, innovative, and responsive medium for teaching mathematics based on local wisdom challenges in Bali for junior high school students.

1. Introduction

Background of the study: Mathematics is one of the main pillars in the development of science, technology, and human logical thinking abilities. In the current digital era, mastery of mathematics is no longer just an academic necessity, but rather a foundation for essential problem-solving and critical thinking skills (Mendrofa, 2024; Novita & Herman, 2021). However, for students at the Junior High School (SMP) level, mathematics often becomes one of the most avoided and feared subjects. Psychologically, middle school students are in a transitional phase of cognitive development from concrete to abstract thinking. At this level, they begin to encounter more complex mathematical concepts such as algebra, spatial geometry, and statistics. Unfortunately, the conventional and monotonous learning approach makes it difficult for students to grasp the meaning behind those rigid formulas, leading to a decline in learning motivation and low numeracy literacy achievements at the early adolescent level. To bridge the gap between the abstraction of middle school mathematics and the reality of students' lives, a pedagogical innovation is needed that not only utilises technology but is also rooted in the local cultural context where the students grow up. Contextual learning that is close to the surrounding environment has been proven to enhance the retention of understanding among middle school students because it provides a real visualisation of abstract concepts.

In this context, Bali, as a region rich in cultural heritage, has great potential in the application of ethnomathematics (Darmayasa et al., 2019; Atmaja et al., 2024). Bali's local wisdom, such as dimension calculations in traditional architecture (Asta Kosala Kosali), symmetry patterns in coconut leaf weaving (mejejaitan), comparison and flow concepts in the subak irrigation system, and geometric transformations in the decorative patterns of Endek woven fabric, are highly relevant to the mathematics curriculum for junior high school. Integrating this local wisdom not only gives "soul" to mathematics lessons but also fosters a sense of pride in cultural identity from a young age. However, merely transferring cultural concepts into regular textbooks is no longer sufficient to capture the attention of middle school students who are digital natives. The characteristics of middle school teenagers tend to favour challenges, social interactions, and dynamic activities. Therefore, adaptive media that utilises the concept of ethnomathematics combined with gamification is needed. The use of game design elements such as points, badges, level tiers, and adventure narratives is very effective in triggering active engagement among middle school students. When complex mathematical material is packaged

into reality challenges based on local Balinese wisdom, students will be encouraged to explore mathematical formulas not as a burden of memorisation, but as a tool or "key" to completing game missions. Until now, platforms for middle school mathematics learning that comprehensively combine the concept of Balinese ethnomathematics with modern gamification mechanics are still very limited (Iriandre et al., 2025; Riski et al., 2024). Most of the digital media available in schools is still one-way or merely transfers question banks into digital form without any contextual narrative connection for teenagers.

The main rationale of this research is based on the urgent need to bridge the cognitive transition phase of junior high school students who are moving from concrete to abstract thinking. At this early adolescent age, students are forced to master more complex formal mathematics concepts such as algebra and spatial geometry. Forcing students to understand pure mathematics theoretically without any visual and contextual bridges has been proven to trigger math anxiety and decrease learning motivation. Therefore, this research is crucial to provide a robust cognitive scaffolding structure, where abstract mathematical concepts are brought closer to the realities in the students' surroundings to make them easier to understand and internalise. Culturally, this research is based on the importance of decolonising mathematics education, which has often been labelled as a rigid Western product detached from students' emotional lives. Bali has a living mathematics laboratory through its rich local wisdom, such as dimension calculations in Asta Kosala Kosali, the concept of symmetry and fractals in *mejejaitan*, and water flow modelling in the Subak system.

Integrating Balinese ethnomathematics into the junior high school curriculum through this research provides scientific justification that mathematics is not an alien science, but rather a part of the heartbeat of their ancestral culture. This approach not only enhances the perceived usefulness of mathematics but also fosters cultural pride among the younger generation from an early age. From a methodological and technological aspect, the rationale of this research responds to the psychological characteristics of middle school students who are digital natives. Adolescents at this age greatly enjoy challenges, healthy competition, and visual recognition, but tend to have a short attention span for conventional textual media. The concept of ethnomathematics combined with gamification mechanics (such as point systems, difficulty levels, and leaderboards) emerges as a solution to ride this digital trend for educational purposes. Game elements not only serve as extrinsic motivators to initially capture students' attention but also gradually transform it into intrinsic motivation in the form of curiosity to solve challenging math missions. Finally, this research is driven by a significant research gap in the current literature and learning media. Although studies on Balinese ethnomathematics have been extensively researched, their implementation is often limited to conventional printed modules or linear videos that are passive in nature. On the other hand, the math gamification platforms available in the global market are generally universal and lack the touch of Indonesia's local cultural context. Therefore, the design of this Ethno-Gamification Platform is of high urgency to fill that gap, presenting a novelty that synergises the digitalisation of learning, challenge-based methods, and the preservation of Balinese local wisdom within a complete digital ecosystem for junior high school students.

Ethnomathematics is a study that bridges culture and mathematics, viewing that mathematics is not culture-free but rather grows as a social practice within certain community groups (Batiibwe, 2024). In the context of Balinese society, local wisdom is not only religious and aesthetic in value but also rich in manifestations of applied mathematical concepts. Previous research shows that traditional Balinese architecture, Asta Kosala Kosali, uses an anthropomorphic measurement system based on human body dimensions that involves concepts of estimation, comparison, and complex spatial geometry (Pandawa & Sedhana, 2020; Sitinjak et al., 2020). Additionally, daily activities such as *mejejaitan* or making ceremonial offerings from coconut leaves inherently apply the principles of symmetry, rotation, reflection, and fractals. On an environmental scale, the Subak irrigation system reflects the application of distribution algorithms, water flow management, and basic statistical concepts in resource allocation. Integrating these aspects of Balinese ethnomathematics into learning has been shown to enhance students' emotional attachment to the material and change their perception of mathematics as a foreign and abstract science in their real lives. To present this cultural content interactively, the implementation of gamification becomes relevant through the utilisation of game design elements such as points, badges, leaderboards, levels, and narratives within the educational environment (Almufarreh, 2026). In mathematics learning, which is often coloured by math anxiety, gamification aims to enhance student engagement and intrinsic motivation. Through the mechanism of immediate feedback, students can instantly see their learning progress, which stimulates sustained cognitive engagement.

Literature reviews show that effective gamification is not merely about transferring question banks into a digital format but rather integrating game mechanics into instructional content in a meaningful way (meaningful gamification) (Triantafyllou et al., 2025). When gamification elements are combined with strong cultural narratives, digital platforms can create immersive learning environments, where failure to solve math problems is no longer seen as an academic punishment but rather as an opportunity to try again in a game mission. This hybrid approach combining ethnomathematics and gamification is well-suited to the cognitive development characteristics of Junior High School (SMP) students, who are generally in the early adolescent age range.

(Simanjuntak et al., 2024). Psychologically, their ego and social identity are rapidly developing, where they greatly enjoy challenges, interactions with peers, and need recognition for their achievements (Ragelienė, 2016). However, from an academic perspective, middle school students often experience a drastic decline in interest in mathematics because the curriculum begins to shift towards abstract concepts such as algebraic variables, functions, and geometric proofs. If this transition is not facilitated with adaptive learning media, students tend to experience cognitive frustration. Therefore, the integration of interactive media, visually challenging and based on the familiar Balinese cultural environment, is a crucial literary strategy to maintain focus and build a solid numeracy foundation at the junior high school level.

The gap analysis in this study is identified through three interrelated main dimensions, starting with the theoretical-contextual dimension, where there is a significant gap between the theoretical potential of Balinese ethnomathematics and its implementation reality in the classroom (Andang et al., 2025). Ideally, ethnomathematics studies aim to bring students closer to real mathematical applications through local cultures that are familiar in their daily lives, such as *Asta Kosala Kosali*, *Subak*, and *Mejejaitan* (Wijayanti et al., 2019). However, empirical facts on the ground show that the utilisation of ethnomathematics is largely still confined to the level of scientific documentation or presented in the form of static printed text supplements. As a result, the contextual essence of that culture fails to transform into a dynamic learning experience, causing mathematics to continue to be perceived by students as a collection of abstract formulas detached from their daily reality. This condition is exacerbated by the technological-methodological dimension, which reveals a research gap in the development of existing digital learning media. On one hand, global math gamification applications available in the market have very advanced game mechanics such as point systems, badges, and leaderboards. Still, they lose cultural relevance because the content presented is universal and Westernised (Jun & Lukas, 2025).

On the other hand, locally developed culture-based learning applications or media generally remain one-way, linear, and merely transfer conventional question banks to digital screens (digitised worksheets) without any narrative engagement or meaningful challenges (Afiah et al., 2025). Until now, there has been no hybrid platform that comprehensively combines the aesthetics and philosophical values of Balinese ethnomathematics with a modern gamification framework. The final gap is found in the psychological-developmental dimension, where there is a misalignment between the learning characteristics of middle school students as digital natives and the formal curriculum mathematics teaching methods. Middle school students are in the cognitive transition phase from concrete operational to formal operational, which requires strong visualisation to understand abstract material such as algebra and geometry, while also being highly responsive to challenges, achievements, and social interactions (Weinhandl et al., 2025). The gap is that the current learning system still predominantly relies on passive and rigid rote learning methods, which do not adequately facilitate the active and digitally literate characteristics of these students, ultimately triggering math anxiety and a drastic decline in their interest in learning numeracy (Ersozlu, 2024). Through the identification of these three dimensions of the gap, the design of the Ethno-Gamification Platform for Mathematics Learning Based on Local Wisdom Reality Challenges in Bali specifically aims to bridge the existing gap. This platform not only digitises local content but also reconstructs Balinese local wisdom into an interactive and adaptive "digital reality challenge" for middle school students. By utilising gamification mechanics as a driver of extrinsic-intrinsic motivation and ethnomathematics as a problem-solving framework, this platform becomes a hybrid solution capable of facilitating the cognitive transition needs of adolescent students while preserving local cultural values within a modern digital ecosystem.

This research aims to develop an Ethno-Gamification Platform for Mathematics Learning Based on Local Wisdom Challenges in Bali for Middle School Students. Through this innovative platform, it is expected to create a digital learning ecosystem that is solution-oriented, interactive, and enjoyable, capable of transforming the rigid stigma of middle school mathematics into a digital adventure relevant to their cultural reality. To ensure the objectives of this study are achieved, it is necessary to clarify the research questions that must be answered. The research question is, "What is the effectiveness of the Ethno-Gamification Platform for Mathematics Learning Based on the Challenges of Balinese Local Wisdom for Junior High School Students in Bali?"

2. Method

This research uses a development approach. The development model is Borg and Gall. The development stages in this 2026 research focus on 5 stages. These stages include: (1) research & field data collection; (2) planning; (3) design development; (4) initial testing; and (5) revision of initial testing (Divayana et al., 2019; Divayana et al., 2021; Suandi, 2017; Wulandari et al., 2023).

The subjects involved in 2026 in the initial trial of the effectiveness of the ethno-gamification platform for mathematics learning based on challenges of local Balinese wisdom include education experts, informatics experts, IT education evaluators, teachers, and junior high school students in Bali. The reason for selecting public junior high schools in Bali (specifically the South Bali region) as the research location is based on several strategic considerations: (1) schools in this region have adequate technological infrastructure readiness (such as computer laboratories and stable internet connections) needed to run a digital-based ethno-gamification platform optimally; (2) the characteristics of students in this area, which combines urban modernization and strong traditional traditions, are very relevant for testing the effectiveness of media that combines modern game

mechanics with local wisdom content; and (3) initial observation results show indications of a fairly high level of math anxiety in students at the target school, thus requiring an interactive cognitive scaffolding media solution.

The population in this study consists of informatics experts, education experts, educational evaluators, teachers, and students from public junior high schools in Bali. The subjects of this research were determined using the Purposive Sampling technique, where the parties involved in the study were identified from the beginning and are directly related to the ethno-gamification platform for mathematics learning based on the challenges of local Balinese wisdom. The subjects in the initial trial of the effectiveness of the ethno-gamification platform included two informatics experts, two education experts, eight IT educational evaluators, 30 teachers, and 70 students from public junior high schools in Bali (specifically Southern Bali). The eight IT education evaluators have backgrounds in IT education or learning technology and have a track record of research in multimedia learning evaluation or digital-based curriculum design. Teachers involved in the testing must have at least a working knowledge of and be adaptable to game-based learning. Students involved in the testing must also have knowledge of basic gamification concepts and be familiar with using devices that support game-based learning. The students participating in this testing were seventh and eighth-graders aged 13–14. This age range was chosen based on the cognitive transition phase of early adolescence, when students begin to encounter abstract, formal mathematical concepts. Of the 70 participating students, 36 were male, and 34 were female, ensuring balanced gender representation in the usability assessment.

The questionnaire is used to obtain quantitative data from subjects who have undergone initial trials. This quantitative data is used as a basis to determine the effectiveness level of the ethno-gamification platform for mathematics learning based on the challenges of local Balinese wisdom. The validity of the questionnaire items was tested by two experts using the Gregory formula. Based on the assessment results of the two experts, a content validity coefficient of 1.00 was obtained (or in the Very High Validity category). All statement items (Items 1 to 13) were deemed substantively relevant. The measurement scale for each item in the instrument uses a Likert scale consisting of five scales. The five scales are: scale 1 for strongly disagree, scale 2 for disagree, scale 3 for neutral, scale 4 for agree, and scale 5 for strongly agree (García-Pérez, 2024; Koo & Yang, 2025). The instrument reliability test was conducted to determine the internal consistency of the responses given to this 5-point Likert scale instrument. Based on the results of statistical analysis of the initial trial response data from all subject groups (experts, evaluators, teachers, and students), a Cronbach's Alpha reliability coefficient of 0.84 was obtained. In accordance with the criteria for interpreting reliability values, a coefficient in the range of 0.80 - 1.00 indicates a high level of reliability. These results prove that the developed questionnaire instrument has excellent stability for consistently measuring user perceptions of the mathematics ethno-gamification platform.

Questionnaires are used as data collection instruments in this research. The number of instrument items used in the initial trial of the effectiveness of the ethno-gamification platform was 13 items. The items in question can be seen in Table 1.

Table 1. Initial Test Item of the Ethno-Gamification Platform for Mathematics Learning Based on the Challenges of Local Balinese Wisdom Reality

Aspect	Statement item
Platform Appearance	I feel that the menus within this platform are easy to understand and use from the first time I open the application.
	I feel that the size of the buttons, text, or images within this platform is too confusing and difficult to click.
	The combination of colours and visuals themed around Balinese culture in this platform looks cool and appealing to me.
	This platform often feels slow (lag) or errors out when I am trying to complete challenges within it.
	I can easily find instructions on how to play or how to answer questions within the platform without having to ask the teacher.
Cultural Narratives & Ethnomathematics	The storyline of the reality adventure based on Balinese local wisdom made me interested in reading the introductory story.
	The math problems connected to Balinese culture on this platform actually make me even more confused trying to find the formulas.
	Seeing math applied in the daily lives of the Balinese people makes me realise that math is useful in the real world.
	I feel proud and happy because I can learn math while also getting to know my own cultural heritage more closely.
Game Mechanics	The awarding of points and badges after I successfully complete a problem makes me feel appreciated and want to keep playing.
	The presence of a leaderboard makes me feel too pressured and afraid of competing with friends.
	When I answer incorrectly, the immediate feedback feature or the "lives/retry" system motivates me to try again without fear of making mistakes.

Aspect	Statement item
	Using this platform makes math study time feel like it passes more quickly because it is packaged in the form of a game adventure.

The procedure for conducting this research is based on the development stages of the Borg and Gall model, which focuses on five stages. These five stages can proceed well if the timing is also planned properly. The research procedures and their implementation timeline can be seen in detail in Table 2.

Table 2. Procedures and Timeline of the Research on the Ethno-Gamification Platform for Mathematics Learning Based on Local Balinese Wisdom Reality Challenges

Research Procedure	Time (Day)
Research & field data collection	7
Planning	3
Design development	31
Initial testing	14
Revision of initial testing.	5
Total	60

The collected data were then analysed using quantitative descriptive techniques with percentage descriptive calculations. The results of the descriptive percentage calculations were used as the basis for interpreting the research findings on the ethno-gamification platform for mathematics learning based on challenges of local Balinese wisdom. The formula for the descriptive percentage calculation referred to is as follows (Cakir & Adiguzel, 2020; McGowan, 2023; Naibaho, 2021).

$$Effectiveness\ Percentage = \frac{\sum x}{\sum x_{max}} \times 100 \tag{1}$$

Where:

$\sum x$ = total acquisition score

$\sum x_{max}$ = total maximum score

Effectiveness Percentage Score > 80% categorises the platform as "Very Effective and ready for implementation." Effectiveness Percentage Score between 61% - 79% indicates the category "Effective with Minor Revisions." Effectiveness Percentage Score < 61% indicates the category "Ineffective with Major Revisions".

3. Results and Discussion

3.1. Results

3.1.1. Results of the Research and Field Data Collection Stage

At this stage, data on the subject matter and its level of difficulty have been obtained and incorporated into the Ethno-Gamification Platform for Mathematics Learning Based on Local Wisdom Challenges in Bali. The details of the subject matter can be seen in Table 3.

Table 3. Subject Matter and Difficulty Levels Included in the Ethno-Gamification Platform for Mathematics Learning Based on the Challenges of Balinese Local Wisdom Reality

Learning Outcomes	Learning Objectives	Difficulty Level	Gamification and Ethnomathematics-Based Indicators	Sample Questions
Understanding the Concept of Linear Equations in One Variable	Students are able to determine the truth value of a mathematical statement by utilising the cultural context of Bali as a learning resource that is close to everyday life.	Easy (Nista)	Identifying the truth of simple statements about the number of elements in Balinese tradition (for example: the number of colours in <i>Tridatu</i> is 3).	 A tour guide explained that the number of colours on this bracelet (x) satisfies the equation $(x+2=5)$. Based on the <i>Tridatu</i> customary rule, is that statement correct?
		Medium (Madya)	Comparing two quantitative statements related to ceremonial facilities (e.g., comparing the number of fruits in two different types of <i>Pajegan</i>).	 Mrs. Wayan made two types of <i>Pajegan</i> as shown in the picture. <i>Pajegan</i> A contains 15 pieces, while <i>Pajegan</i> B contains (x) pieces. If the total number of fruits from both baskets is 40 ($x+15=40$), what is the value for the statement to be true?
		Difficult (Utama)	Evaluating complex statements involving hidden variables in the <i>Subak</i> water distribution system or the <i>Wewaran</i> calendar.	 In the <i>Subak</i> water distribution system, Block A has an area of 3 hectares and Block B has an area of 1 hectare. The <i>Subak</i> management sets fairness rules based on land area: each 1-hectare rice field is entitled to a water flow of 5 liters/second. One day, the gatekeeper divided the flow so that Block A received 15 liters/second and Block B received 15 liters/second (the water flow of both blocks was made equal). Evaluate whether this equal distribution of water is fair.

Learning Outcomes	Learning Objectives	Difficulty Level	Gamification and Ethnomathematics-Based Indicators	Sample Questions
	Students are able to create a modelling simulation from a closed statement through problems related to Balinese culture, making the learning experience closer to real life.	Easy (<i>Nista</i>)	Solving a one-step linear equation related to the addition/subtraction of the number of <i>Canang Sari</i> in one container.	 On a tray, there are several <i>Canang Sari</i>. After Wayan added 7 more <i>canang</i>, the total became 15 ($x+7=15$). What was the initial number of <i>canang</i>?
		Medium (<i>Madya</i>)	Formulating a closed mathematical sentence based on the narrative of preparing for the <i>Galungan</i> holiday (e.g., the total number of <i>janur</i> purchased).	The Made family bought 3 bundles of young coconut leaf (<i>janur</i>) for <i>Galungan</i>. After using 12 sheets, 48 sheets remain. If x is the number of <i>janur</i> per bundle, what is the correct mathematical model? $3x - 12 = 48$ $3x + 12 = 48$ $x - 12 = 48$
		Difficult (<i>Utama</i>)	Constructing a visual/graphic simulation from cultural celebration data that is certain in value to validate a mathematical statement.	In preparation for the Ogoh-Ogoh parade ahead of the Nyepi Day celebration, three banjars (communities) sent participants as follows: Banjar Sari: 28 participants Banjar Kaja: 24 participants Banjar Kelod: 20 participants Based on that data, make two statements and evaluate their truthfulness.
Solving a Linear Equation in One Variable	Students are able to apply the rules of addition and subtraction to solve problems involving one-variable linear equations through contextual problems inspired by Balinese culture, making the learning experience more meaningful and closer to everyday life.	Easy (<i>Nista</i>)	Operation multiplication of Kecak Dance tickets.	 One day, a Russian tourist watched a kecak performance with some of his friends. The price of one Kecak dance ticket is x rupiah. If 5 tourists pay Rp500,000, model and determine the price per ticket.

Learning Outcomes	Learning Objectives	Difficulty Level	Gamification and Ethnomathematics-Based Indicators	Sample Questions
Finding the concept of linear inequality in one variable	Finding the concept of linear inequality in one variable. Students are able to find the concept of linear inequality in one variable through everyday problems related to Balinese culture.	Medium (<i>Madya</i>)	Distribution of <i>Subak</i> harvests.	Distribution of <i>Subak</i> harvest. Distribution of <i>Subak</i> harvest. The rice harvest of 1,200 kg will be distributed to x groups of krama/ <i>Subak</i> members. If each group receives 150 kg, create the equation and calculate how many groups of krama there are!
		Difficult (<i>Utama</i>)	Solving a multi-stage contextual problem regarding resource management in Banjar that involves balancing variables (left and right side balance).	A traditional village manages social funds. A fund of Rp10,000,000 is divided for the repair of the temple/ <i>Pura</i> (x) and community assistance. If the cost of the <i>Pura</i> is three times the assistance plus Rp2,000,000, create the model and solve it to maintain the transparency of the Community/ <i>Banjar</i> funds!
		Easy (<i>Nista</i>)	Distinguishing between "more than" or "less than" situations regarding the maximum audience capacity in temple areas or art performances.	The capacity of the audience area at the temple is 100 people. If there are already 60 people, then the additional audience (x) is expressed as $(x+60 \leq 160)$. Is this model correct for avoiding excessive crowds?
		Medium (<i>Madya</i>)	Limitations on silver craft raw materials.	 A silver craftsman in Celuk (a village in Bali) has a stock of silver no more than 500 grams. He wants to make x rings, each requiring 15 grams. Translate the situation into an equation model.
	Students are able to create a mathematical model in the form of a one-variable linear inequality from everyday problems related to the activities of the Balinese community.	Difficult (<i>Utama</i>)	Optimisation of work time vs. Traditional Obligations (<i>Yadnya</i>).	Wayan has 24 hours. The time for work (w) and the time for <i>Yadnya</i> preparation (y) must be balanced. If the time for <i>Yadnya</i> is at least 4 hours longer than the work time, and the total time cannot exceed 24 hours, analyse the possible work time for Wayan in the form of a Linear Inequality in One Variable!
		Easy (<i>Nista</i>)	Writing an inequality symbol to state the minimum age requirement for child dancers in the village.	In Kuta Village, Bali, the "Putra Daerah" Dance Studio is opening registration for a group of young dancers who will perform at the traditional village cleansing ceremony. To ensure that the complex dance movements can be followed well, the committee has set a requirement that the minimum age for prospective dancers is 7 years. If the age of the prospective dancer is represented by the variable x, write the appropriate mathematical inequality to express that age requirement!
		Medium (<i>Madya</i>)	Formulating a Linear Inequality Model from the problem of limited raw material availability for traditional cloth.	Ni Wayan is a craftsman of traditional Endek woven fabric in Sidemen Village, Karangasem. As the Galungan Holy Day approaches, she receives many orders to make Endek shawls (<i>anteng</i>) with typical Balinese motifs. Currently, Ni Wayan only has a remaining stock of 450 meters of special golden silk thread. To weave a single piece of Endek scarf, 80 meters of that gold thread is required. In addition, due to the complex Balinese ikat weaving technique, there is always a portion of thread at the end of the Handloom (ATBM) amounting to 30 meters that

Learning Outcomes	Learning Objectives	Difficulty Level	Gamification and Ethnomathematics-Based Indicators	Sample Questions
				is wasted and cannot be woven (as the leftover ties/edges of the fabric). If the number of Endek shawls to be made is represented by the variable k , formulate the appropriate mathematical inequality to describe the limitation of the gold thread raw material owned by Ni Wayan!
		Difficult (Utama)	Designing an inequality system for the optimisation problem of allocating time between work and fulfilling customary obligations (<i>yadnya</i>).	I Ketut is a wood carving artisan in the Gianyar region of Bali. Next month, the Banjar (traditional organization) where he resides will hold the Piodalan Agung (<i>yadnya</i>) ceremony. As a member of the local community (<i>krama banjar</i>), Ketut must divide his time allocation in a month (30 days) between working on wood carvings for sale (denoted as x days) and participating in <i>ngayah</i> (voluntary communal work without pay for the preparation of the ceremony at the Pura, denoted as y days). Ketut sets several time allocation limits to maintain a balanced life management: Out of the 30 days available, Ketut allocates a total of at most 26 days for work and social work (<i>ngayah</i>), as the remaining days must be used for rest and family gatherings. To meet basic kitchen needs and pay mandatory ceremony fees (<i>paturunan banjar</i>), Ketut must work at least 12 days in that month. Based on the results of the Banjar meeting, every resident is required to participate in <i>ngayah</i> for at least 6 days leading up to the peak of the ceremony. To maintain his commitment to the social environment and not be considered too materialistic by the indigenous community, the number of days used for work must not exceed twice the number of days used for <i>ngaya</i>. Based on the above problem, design an appropriate system of mathematical inequalities to describe I Ketut's time allocation constraints!

3.1.2. Planning Stage Results

The planning stage is a crucial phase that underpins the smooth execution of the research. At this stage, detailed results are obtained regarding the research phases, the human resources involved, and the completion time for each research phase. The complete details of the planning results can be seen in Table 4.

Table 4. Results of the Planning Stage

Research Stages	Resources Involve	Completion Time
Research & field data collection	Chief researcher, Research team members, students	7
Planning	Chief researcher	3
Design development	Chief researcher and Research team members	31
Initial Testing	IT experts, education experts, IT education evaluators, teachers, and junior high school students in Bal	14
Revision of Initial Testing	Chief researcher and Research team members	5

3.1.3. Development Stage Results

At this stage, several designs of the Ethno-Gamification Platform for Mathematics Learning Based on Local Wisdom Challenges in Bali have been obtained. There are 14 designs produced at the development stage. The fourteen designs can be seen in figures 1-6.



Figure 1. Form Login



Figure 2. Dashboard Form



Figure 3. Course Overview Form

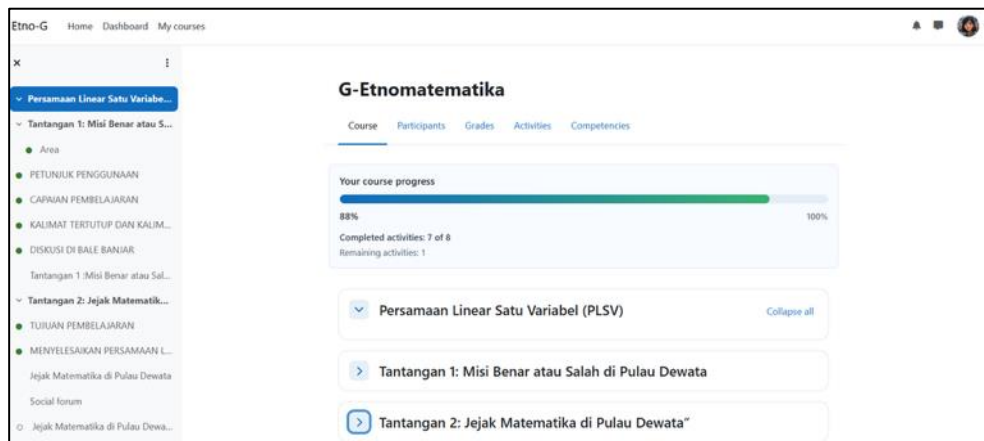


Figure 4. Form that Displays Ethnomathematics Gamification Material

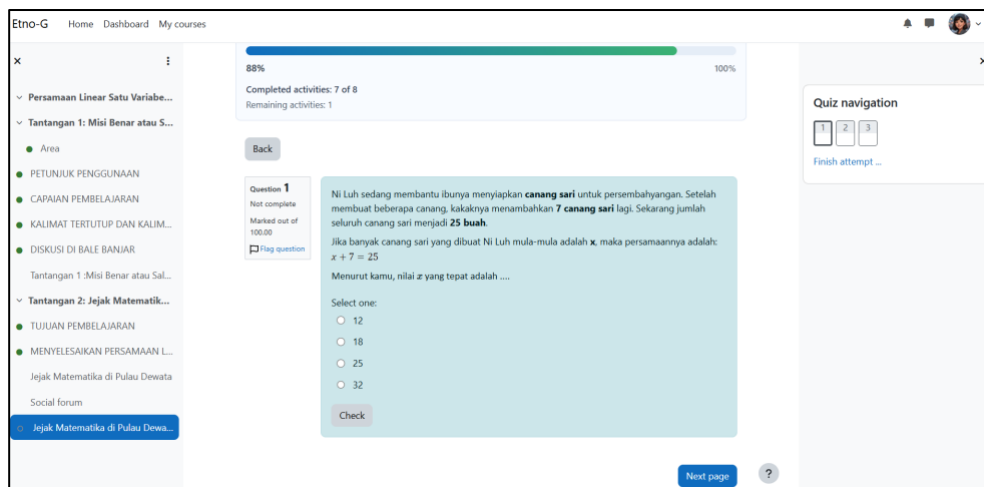


Figure 5. Form that Displays Quiz

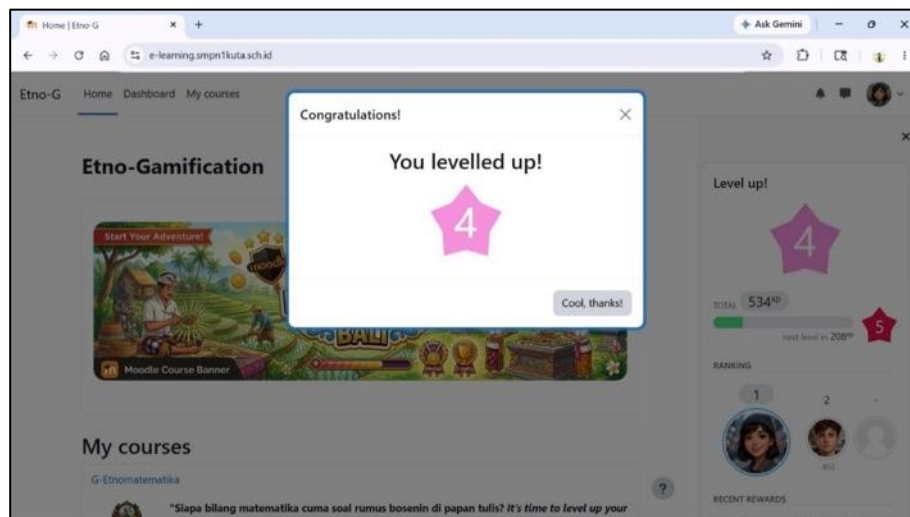


Figure 6. Form that Shows Students' Level

3.1.4. Initial Testing Stage Results

The initial trial phase was conducted by several respondents, including education experts, informatics experts, teachers, and junior high school students in Bali. The details of the number of respondents include: two informatics experts, two education experts, eight IT education evaluators, 30 teachers, and 70 junior high school students from public schools in Bali (specifically Southern Bali). The initial trial results of the ethno-gamification platform for mathematics learning based on challenges of local Balinese wisdom can be seen in Table 5.

Table 5. Initial Testing Results

Respondents	Items-													Σ	Percentage of Effectiveness (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13		
Informatics Expert-1	5	4	4	5	4	4	4	4	4	4	4	5	5	56	86.15
Informatics Expert-2	5	4	5	4	5	4	4	5	4	5	4	4	4	57	87.69
Educational Expert-1	4	5	4	4	4	5	4	4	5	5	5	5	4	58	89.23
Educational Expert-2	4	5	4	5	4	5	4	4	4	5	4	4	5	57	87.69
Evaluator-1	5	5	5	4	5	4	4	5	4	4	5	4	4	58	89.23
Evaluator-2	4	4	4	5	4	5	5	4	4	5	4	4	5	57	87.69
Evaluator-3	4	4	4	4	4	4	4	4	4	4	4	5	4	53	81.54
Evaluator-4	5	4	5	4	4	4	4	5	4	4	5	5	5	58	89.23
Evaluator-5	5	4	4	4	5	5	4	4	5	5	4	4	4	57	87.69
Evaluator-6	4	4	5	5	4	4	4	5	5	4	4	4	4	56	86.15
Evaluator-7	4	5	5	4	4	4	4	4	4	4	4	4	4	54	83.08
Evaluator-8	5	4	5	4	5	4	5	4	5	4	5	4	4	58	89.23
Teacher-1	4	5	4	4	4	4	5	4	4	4	5	4	4	55	84.62
Teacher-2	4	5	4	5	4	4	5	4	5	4	5	4	4	57	87.69
Teacher-3	5	5	4	5	4	5	5	5	4	5	4	4	5	60	92.31
Teacher-4	4	4	4	5	4	5	4	4	4	5	4	4	4	55	84.62
Teacher-5	4	4	5	5	4	5	4	5	4	5	4	4	4	57	87.69
Teacher-6	5	4	4	4	5	5	5	4	5	4	4	5	5	59	90.77
Teacher-7	5	4	4	4	4	4	5	4	4	4	5	4	4	55	84.62
Teacher-8	4	4	5	4	4	4	5	4	5	4	5	4	4	56	86.15
Teacher-9	4	5	4	4	4	5	5	5	4	5	4	4	5	58	89.23
Teacher-10	4	5	4	5	4	4	4	4	5	4	5	5	4	57	87.69
Teacher-11	5	5	5	4	5	4	4	4	4	4	4	4	4	56	86.15
Teacher-12	4	4	4	5	4	5	4	5	4	4	4	4	5	56	86.15
Teacher-13	4	4	4	4	4	4	5	4	4	4	5	4	4	54	83.08
Teacher-14	4	5	4	4	4	5	4	4	5	4	4	4	4	55	84.62
Teacher-15	4	5	4	5	4	5	4	4	5	4	4	4	5	57	87.69
Teacher-16	5	5	5	4	5	4	4	5	4	4	5	5	4	59	90.77
Teacher-17	4	4	4	5	4	5	5	4	5	5	4	4	4	57	87.69
Teacher-18	4	4	4	4	4	4	4	4	4	4	4	4	5	53	81.54
Teacher-19	5	4	5	4	4	4	5	4	4	4	5	4	4	56	86.15
Teacher-20	5	4	5	4	5	4	5	4	4	4	4	4	5	57	87.69
Teacher-21	4	5	5	5	4	4	5	4	4	4	5	4	4	57	87.69
Teacher-22	5	4	4	4	4	4	5	4	5	4	5	4	4	56	86.15
Teacher-23	5	4	4	4	4	5	5	5	4	5	4	4	5	58	89.23
Teacher-24	4	5	4	4	4	5	4	4	5	4	5	5	4	57	87.69
Teacher-25	4	5	4	5	4	5	4	4	4	4	4	4	4	55	84.62
Teacher-26	5	5	5	4	5	4	4	5	4	4	4	4	5	58	89.23
Teacher-27	4	4	4	5	4	5	5	4	4	5	5	4	4	57	87.69
Teacher-28	4	4	4	4	4	5	4	5	4	4	4	4	4	54	83.08
Teacher-29	5	4	5	4	4	4	4	5	4	4	4	5	4	56	86.15
Teacher-30	5	4	4	4	5	4	4	5	4	5	4	5	4	57	87.69
Student-1	4	4	5	5	4	4	5	5	5	4	5	4	4	58	89.23
Student-2	5	4	5	4	4	4	4	4	4	5	4	5	5	57	87.69
Student-3	4	4	5	4	4	4	5	4	4	4	4	4	4	54	83.08
Student-4	4	4	5	4	5	4	5	4	4	4	4	4	4	55	84.62
Student-5	4	5	5	5	4	4	5	4	4	4	5	4	5	58	89.23
Student-6	4	5	4	4	4	4	5	4	5	4	5	4	5	57	87.69
Student-7	4	5	4	4	4	5	5	5	4	5	4	4	4	57	87.69
Student-8	5	4	5	4	4	4	4	4	5	4	5	5	4	57	87.69
Student-9	4	4	5	4	4	4	5	4	4	4	4	4	5	55	84.62
Student-10	4	4	5	4	5	4	5	4	4	4	4	4	4	55	84.62
Student-11	4	5	5	5	4	5	4	5	4	4	4	4	4	57	87.69
Student-12	4	5	4	4	5	4	4	5	4	4	4	5	4	56	86.15
Student-13	4	5	4	4	4	4	4	5	4	5	4	5	4	56	86.15
Student-14	5	4	4	5	4	4	5	5	5	4	5	4	4	58	89.23
Student-15	4	4	4	5	4	5	5	4	4	5	4	5	5	58	89.23
Student-16	4	4	5	5	5	4	5	4	4	4	4	4	4	56	86.15
Student-17	4	4	4	4	4	5	4	4	5	4	4	4	4	54	83.08
Student-18	4	4	4	5	4	4	4	4	4	4	5	4	5	55	84.62
Student-19	4	5	4	5	4	4	4	4	4	5	5	5	4	57	87.69
Student-20	5	4	5	4	5	4	4	4	4	4	4	4	5	56	86.15
Student-21	4	5	4	4	5	4	4	4	4	4	5	4	4	55	84.62
Student-22	4	4	4	4	5	4	4	4	5	4	5	4	4	55	84.62
Student-23	4	4	4	5	4	5	4	5	4	5	4	5	4	57	87.69
Student-24	4	4	5	5	5	4	5	4	5	4	4	5	4	58	89.23
Student-25	4	4	4	4	4	5	4	5	4	4	4	5	4	55	84.62

Respondents	Items-													Σ	Percentage of Effectiveness (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13		
Student-26	4	4	4	5	4	4	4	4	4	4	5	4	4	54	83.08
Student-27	4	5	4	5	4	4	4	4	4	4	5	4	5	56	86.15
Student-28	5	4	5	4	5	4	5	4	4	5	5	5	4	59	90.77
Student-29	4	5	4	4	5	4	5	4	4	4	4	4	5	56	86.15
Student-30	4	4	4	4	5	4	5	4	4	4	5	4	4	55	84.62
Student-31	4	5	4	4	4	4	4	4	5	4	5	4	4	55	84.62
Student-32	4	5	4	4	4	4	4	5	5	5	4	5	4	57	87.69
Student-33	5	4	5	4	4	4	4	4	4	4	4	5	4	55	84.62
Student-34	4	4	5	4	4	4	4	4	5	4	4	5	4	55	84.62
Student-35	4	4	5	4	5	4	4	4	4	4	4	5	4	55	84.62
Student-36	4	5	4	4	5	4	4	4	4	4	5	5	5	57	87.69
Student-37	5	5	5	5	4	5	4	4	4	4	4	4	4	57	87.69
Student-38	4	4	4	4	4	5	4	4	4	4	4	5	4	54	83.08
Student-39	4	5	4	4	4	5	4	4	4	5	4	5	4	56	86.15
Student-40	4	5	4	4	4	4	4	4	5	4	5	4	5	56	86.15
Student-41	4	5	4	4	4	4	4	5	5	5	4	4	5	57	87.69
Student-42	5	4	5	4	4	4	4	4	4	4	4	4	5	55	84.62
Student-43	4	4	5	4	4	4	4	4	5	4	4	5	4	55	84.62
Student-44	4	4	5	4	5	4	4	4	4	4	4	5	4	55	84.62
Student-45	4	5	4	4	5	4	4	4	4	4	5	5	5	57	87.69
Student-46	5	5	5	5	4	5	4	4	4	4	4	4	4	57	87.69
Student-47	4	4	4	4	4	5	4	4	4	4	4	5	4	54	83.08
Student-48	4	5	4	4	4	5	4	4	4	5	4	5	4	56	86.15
Student-49	4	4	4	4	5	4	5	4	5	4	5	4	5	57	87.69
Student-50	4	4	4	5	5	5	4	5	4	5	4	4	5	58	89.23
Student-51	4	5	5	4	4	4	5	4	5	4	4	4	5	57	87.69
Student-52	5	4	4	4	5	4	4	4	4	4	4	5	4	55	84.62
Student-53	4	4	4	5	4	4	4	4	4	4	5	4	4	54	83.08
Student-54	4	5	4	4	4	4	4	4	5	4	5	5	4	56	86.15
Student-55	4	5	4	4	4	4	4	5	5	5	4	4	4	56	86.15
Student-56	5	4	5	4	4	4	4	4	4	4	5	4	5	56	86.15
Student-57	4	4	5	4	4	4	4	4	5	4	5	4	5	56	86.15
Student-58	4	4	5	4	4	4	5	4	5	4	4	5	5	57	87.69
Student-59	4	5	4	5	4	4	4	4	4	4	5	4	4	55	84.62
Student-60	5	5	4	4	5	4	4	4	4	4	4	5	4	56	86.15
Student-61	4	4	5	4	5	4	4	4	4	4	4	5	4	55	84.62
Student-62	4	5	4	4	5	4	4	4	4	4	4	5	4	55	84.62
Student-63	4	5	4	4	5	4	4	4	4	4	5	5	5	57	87.69
Student-64	4	4	4	5	4	5	4	4	4	4	4	4	4	54	83.08
Student-65	5	4	5	4	4	5	4	4	4	4	4	5	4	56	86.15
Student-66	4	5	4	4	4	5	4	4	4	5	4	5	4	56	86.15
Student-67	5	4	4	4	5	4	5	4	5	4	5	4	5	58	89.23
Student-68	4	5	5	5	5	5	4	5	4	5	4	4	5	60	92.31
Student-69	5	4	4	4	4	4	5	4	5	4	4	4	5	56	86.15
Student-70	4	5	4	4	5	4	4	4	4	4	4	5	4	55	84.62
Average														86.50	

3.1.5. Revision of Initial Testing Results

In addition to the quantitative test results shown in Table 5, there is also a table containing qualitative data. The qualitative data were obtained from suggestions given by respondents during the initial trial. The qualitative data in question can be seen in detail in Table 6.

Table 6. Respondents Suggestions

Respondents	Suggestions
Informatics Expert-1	Please add a feature to set the language used on the platform.
Educational Expert-2	It would be better to provide facilities to display the student leaderboard based on the levels they have achieved.
Evaluator-3	Provide a feature to view example expansions of the material for each game challenge.
Evaluator-7	Show the facility to view discussions conducted by students during the learning process through the platform.
Teacher-13	Show the student discussion activity log.
Teacher-28	Show the student leaderboard based on achievement levels.
Student-47	It is necessary to show the ranking of student scores.
Student-64	It would be advisable to include a feature for language settings.

Based on the suggestions shown in Table 6, revisions need to be made to the ethno-gamification platform for mathematics learning based on the challenges of local Balinese wisdom. The revision made to address the suggestion from informatics expert-1, student-64, is to create a language setting feature on the platform. The language setting feature in question can be seen in Figure 7. The revision made to address the suggestion from Educational Expert-2, Teacher-28, and Student-47 is to create a feature to display student score rankings. The ranking feature in question can be seen in Figure 8. The revision made to address the suggestion from Evaluator-7 and Teacher-13 is to create a feature to display student discussion activity logs on the platform. The feature displaying student discussion logs can be seen in Figure 9. The revision made to address the suggestion from evaluator-3 is to create a feature to show the expansion of material in each game challenge. The display of the expansion feature in question can be seen in Figure 10.

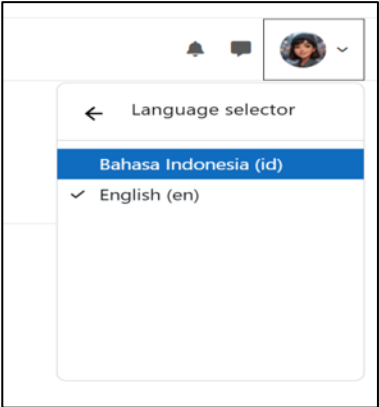


Figure 7. Language Selector Feature

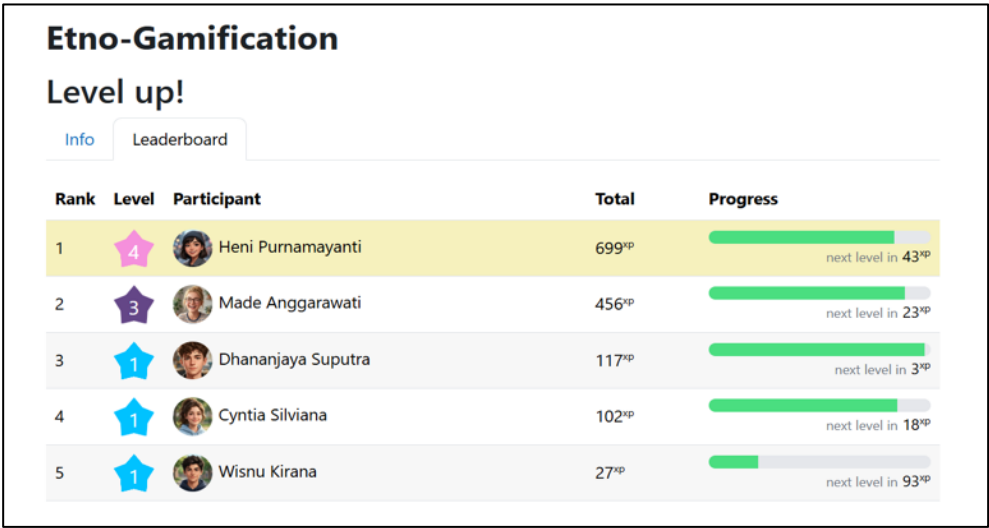


Figure 8. Feature to Show Students' Leaderboard

Discussion	Started by	Last post ↓	Replies	Subscribe
☆ Kalimat Tertutup dan Kalimat Terbuka	Heni Purnamaya... 21 May 2026	Heni Purnamaya... 21 May 2026	0	☒
☆ Ijin bertanya	Dhananjaya Sup... 20 May 2026	Heni Purnamaya... 20 May 2026	1	☒
☆ Tantangan contoh kalimat tertutup!	I Ketut Lokasanti 20 May 2026	Dhananjaya Sup... 20 May 2026	1	☐

Figure 9. Feature to Show Students Discussion Activity Log



Figure 10. Feature to Show the Expansion of Material in Each Game Challenge

3.2. Discussion

This research successfully designed instructional content on the Ethno-Gamification Platform by integrating junior high school mathematics material, specifically the topic of Linear Equations in One Variable, into the local Balinese cultural context. Based on the results of field data analysis, the classification of the subject matter into three levels of difficulty, namely *Nista* (Easy), *Madya* (Medium), and *Utama* (Difficult). This is not just a simple linguistic labelling but a form of philosophical internalisation of Balinese society into the cognitive structure of students. At the *Nista* level, the focus is directed towards identifying the truth of simple statements that are close to the students' daily lives, such as counting the number of colours on a Tridatu bracelet or the initial number of Canang Sari. Psychologically, the placement of highly familiar concrete contexts at this initial level serves to reduce the mathematical anxiety often experienced by middle school students when they first encounter the abstract concept of algebra.

Meanwhile, at the Intermediate level, students are challenged to compare quantitative statements or construct closed mathematical sentences from ceremony preparations, such as counting Pajegan components or modelling *janur*/ young coconut leaves for the Galungan holiday. This context effectively facilitates the cognitive transition of early adolescents from concrete operational thinking to formal operational thinking. At its peak, at the Primary level, the challenges presented demand higher-order thinking skills, where students must evaluate hidden variables such as the concept of debit and the fairness of water distribution in the Subak irrigation system. Through this highest level, students no longer memorise formulas but are able to use mathematics as a tool for solving real-world problems (perceived usefulness).

The integration of Balinese local wisdom into digital platforms has proven to provide significant contributions as cognitive scaffolding, as well as fostering cultural pride for students. Research by Ardana et al. (2024), Lokasanti et al. (2026), and Nandiwardhana et al. (2025) reinforces the integration of Balinese local wisdom into digital platforms, allowing real Balinese cultural objects such as Tridatu, Pajegan, Canang Sari, and the *Subak* system to be brought onto digital screens that are easily accessible to students. This makes learning no longer feel rigid or Westernised. Students are no longer forced to imagine abstract universal objects but are instead confronted with real visualisations of the environment where they grow up. Furthermore, this strategy goes beyond mere academic instructional boundaries as it successfully triggers an affective impact in the form of preserving local identity amidst the onslaught of globalisation. The digital native characteristics of middle school students, who are usually indifferent to conventional printed modules, become very interested in exploring their ancestral philosophical values because they are packaged in adaptive and interactive digital visualisations.

In addition to the factor of ethnomathematics, the application of game mechanics in this platform is directed towards creating the concept of meaningful gamification as a driver of students' intrinsic motivation. This is supported by the research findings of Gyedu et al. (2026), Malayao et al. (2026), and Sailer et al. (2017), which show similarities with this study in terms of the presence of point systems, badges, leaderboards, and immediate feedback features that change students' perspectives on the learning process. One of the impacts is the change in students' paradigm towards mistakes, where failure to answer questions is no longer seen as a daunting academic punishment, but rather as an immersive opportunity to try again in a game mission (Andryananda et al., 2026; Wright & Denisova, 2024). Although competitive elements like leaderboards sometimes risk putting pressure on some students, the integration of adventure storylines based on local wisdom can reduce these negative impacts. This game element successfully rides on the psychological tendencies of middle school students who enjoy challenges and visual recognition, thereby shifting the initial extrinsic motivation (pursuing scores) to intrinsic motivation driven by curiosity to solve math puzzles.

Based on the results of the initial trials and comprehensive feedback from experts and users, a series of important revisions have been implemented to optimise the usability and validity of this platform. In response

to suggestions from computer science experts and students regarding accessibility limitations, a language settings feature has been successfully added to ensure the platform remains inclusive for all users. Next, to accommodate input from education experts, teachers, and students regarding motivational aspects, the platform was enhanced by incorporating a student score ranking feature designed visually to stimulate healthy competition without causing cognitive frustration. Recommendations from evaluators and teachers regarding the importance of social interaction are also realised through the provision of a student discussion activity log feature, which is crucial in facilitating peer interaction in accordance with the psychological development phase of middle school adolescents. This is also in line with the research by Karapiperis et al. (2023) and Leem (2023), which fundamentally highlights the importance of providing a student discussion activity log feature in online learning. In order to maintain the depth of academic content behind the veneer of game elements, the material expansion feature in each challenge was successfully integrated based on the evaluator team's suggestions. Through this series of improvements, the ethno-gamification platform not only serves as an engaging entertainment medium but also transforms into a valid, effective, and widely implementable hybrid solution to enhance the numeracy literacy of junior high school students without uprooting them from their local cultural roots.

Furthermore, leaderboards that display student rankings transparently and in real time can foster an unhealthy atmosphere of hyper-competition in the classroom. For some students, public exposure to their academic performance can create high levels of social pressure. Instead of focusing on a deeper understanding of mathematical concepts, students risk shifting their attention solely to outperforming their peers to maintain social prestige within their group. The most significant risk of this ranking visualization is that it impacts students with low academic ability or math anxiety. When students consistently see their names at the bottom of the leaderboard, this can reinforce feelings of learned helplessness. This constant public exposure to failure leads to demotivation, lowers self-efficacy, and ultimately leads to students withdrawing from learning activities on the platform altogether.

The main novelty of this research lies in the development of a hybrid digital learning ecosystem that comprehensively integrates the philosophical and aesthetic values of Balinese local wisdom in ethnomathematics with the mechanics of a modern gamification framework (meaningful gamification) within a cohesive interactive platform. Based on previous literature reviews, most research on Balinese ethnomathematics tends to be limited to the level of scientific documentation, textual materials, or static printed modules that are less adaptive to the younger generation. On the other hand, commercial math gamification applications available in the global market are generally designed to be universal and lack contextual relevance and emotional closeness to local Indonesian culture. This Ethno-Gamification platform successfully fills that research gap not only by digitising local content but also by reconstructing the rich living laboratory of Balinese culture (such as *Asta Kosala Kosali* calculations, weaving symmetry, and the water flow of the *Subak* system) into a series of adaptive digital reality challenges.

Furthermore, the novelty of this platform is based on the classification of the cognitive scaffolding structure of mathematics, packaged using the Balinese emic difficulty levels, namely Nista (Easy), Madya (Medium), and Utama (Difficult). The level division based on local philosophy is specifically designed to bridge the cognitive transition of Junior High School students who are in the phase of transitioning from concrete to abstract thinking. Unlike conventional digital learning media, which tend to be one-way or merely transfer question banks to a digital format (digitised worksheets) without narrative engagement. This platform offers pedagogical innovation that balances the depth of formal mathematics curriculum content, game elements that foster intrinsic motivation (such as points, badges, leaderboards, and immediate feedback), and the mission of preserving cultural identity (cultural pride). The integration of three dimensions (gamification technology, Balinese ethnomathematics, and psychological facilitation for early adolescents) can make this research a pioneer in immersive local culture-based junior high school mathematics learning media in the digital era.

3.3. Implications

The development of this Ethno-Gamification Platform provides significant and multidimensional contributions to the mathematics education ecosystem, particularly at the Junior High School level. The main theoretical impact of this research is its success in providing a robust cognitive scaffolding structure to bridge the psychological transition phase of early adolescents, who are moving from a concrete operational mindset to an abstract formal operational one. By reconstructing pure mathematical formulas (such as the topic of Linear Equations in One Variable) into visualisations of local Balinese wisdom that are close to the students' daily lives, this platform empirically reduces mathematical anxiety. This pedagogical impact transforms the negative stigma of mathematics, which was initially considered frightening and rigid, into a meaningful, solution-oriented, and adaptive learning material for students' thinking dynamics. Socioculturally, the results of this research trigger a positive disruptive impact on the decolonisation of mathematics education in formal schools. By utilising the living laboratory of Balinese culture (such as dimensional counting in *Asta Kosala Kosali*, fractals in *mejeaitan*, and water flow modelling in the *Subak* system), this research provides strong scientific justification that mathematics is an integral part of the students' ancestral civilisation. The implementation of this technology successfully enhanced students' understanding of the real-world usefulness of mathematics (perceived

usefulness) while also revitalising cultural pride among the younger generation. This proves that the digitalisation of education does not have to undermine traditional values, but can instead become an effective tool for preserving local cultural heritage amidst the onslaught of globalisation. From a methodological and educational technology aspect, this hybrid platform successfully fills the research gap by synergising modern game mechanics and the depth of ethnomathematics into a cohesive digital ecosystem. The application of meaningful gamification strategies through a system of badges, points, real-world challenges, and instant feedback successfully harnessed the psychological characteristics of middle school students as digital natives to redirect them towards educational activities. The tangible impact of this mechanism is the transformation of students' learning motivation, from initially extrinsic (merely chasing scores) to intrinsic motivation (the emergence of curiosity and emotional attachment to solving math missions). Additionally, the presence of post-revision collaborative features (such as student activity discussion logs) impacts the creation of healthy peer interaction spaces in the digital learning environment. Ultimately, the practical impact and sustainability of this research are reflected in the high effectiveness scores (average effectiveness percentage > 80%) obtained from the initial trials involving IT experts, education experts, IT evaluators, teachers, and students. With this very high level of effectiveness, this ethno-gamification platform is ready to be widely implemented as a hybrid learning medium in schools. The long-term impact is the potential escalation of national numeracy literacy achievements at the early adolescent level through the use of entertaining (immersive) media, without detracting from the essence of the depth of formal mathematics curriculum academic material.

3.4. Limitations

Although this research has successfully developed a valid and responsive Ethno-Gamification Platform for junior high school mathematics learning, there are several limitations that need to be acknowledged. First, the focus of the mathematics material integrated into this platform is still very limited, as it only covers the material on Linear Equations in One Variable. This limitation in the scope of the material means that the platform cannot yet be used comprehensively to support the junior high school mathematics curriculum for a full semester, considering that other abstract materials, such as spatial geometry, quadratic functions, or statistics, require different visual modelling and integration of local wisdom. Second, the scope of local wisdom explored and integrated into this platform is still entirely centered on the physical culture and social systems of the Balinese community (such as *Tridatu*, *Canang Sari*, *Pajegan*, and the *Subak* system). This causes the implementation and contextual relevance of this platform to be very region-specific, so its cognitive effectiveness and emotional closeness may not be optimal if applied to middle school students outside the region or outside the Balinese cultural ecosystem. Third, from a methodological and testing aspect, this research is still at the stage of design development and initial trials to measure the effectiveness and functionality of the platform based on feedback from experts, teachers, and small groups of students. This research has not yet conducted large-scale experimental tests in real classrooms to measure the direct impact of the platform on improving learning outcomes, long-term memory retention, or its statistical effectiveness compared to conventional learning media. These limitations open up significant opportunities and serve as a foundation for future research recommendations to expand the scope of algebra material, adapt the platform to other Nusantara cultural contexts, and conduct large-scale field experiments.

4. Conclusion

This research successfully developed the Ethno-Gamification Platform as a valid, innovative, and responsive medium for teaching mathematics to junior high school students, catering to the psychological characteristics of digital native students. The integration of the material on Linear Equations in One Variable into three levels of difficulty based on Balinese philosophy (*Nista*, *Madya*, *Utama*) has proven to provide effective cognitive scaffolding in bridging the transition of students' mindsets from concrete to abstract. The research results have shown an effectiveness level of 86.50% for the Ethno-Gamification Platform for Mathematics Learning Based on Local Balinese Wisdom Challenges for Junior High School Students, categorising it as very effective and ready for implementation. The utilisation of local cultural objects such as *Tridatu*, *Canang Sari*, *Pajegan*, and the *Subak* system has successfully enhanced students' understanding of the real-world applications of mathematics while also fostering cultural pride. Additionally, the application of meaningful gamification mechanics has proven capable of changing the paradigm of student failure and shifting learning motivation from extrinsic to intrinsic. The initial trial results, which were later refined with the addition of language settings, leaderboards, peer discussion logs, and material expansion, indicate that this platform has met the optimum validity standards. Thus, this hybrid platform is ready to be widely implemented as a strategic solution to enhance the numeracy literacy of junior high school students without uprooting them from their local wisdom roots. To address the limitation related to the scope of mathematical material, which is currently limited to Linear Equations in One Variable, future research needs to massively expand the instructional content. Furthermore, to address the spatial and cultural limitations that are currently still fully centered on the Balinese cultural ecosystem, the recommended strategic solution is the development of a modular and adaptive platform architecture. Researchers can then design a content management system on the platform that allows teachers or developers from outside the region to upload their own local wisdom narratives without having to change the core game mechanics. Through this approach, aspects of meaningful gamification, such as point systems, badges, and adventures, are maintained, but the cultural context can be dynamically changed to adapt to other archipelagic cultures, such as Javanese, Sundanese, Dayak, or Papuan cultures. Finally, to address the

methodological limitations that have only reached the stage of functional testing and initial validity, the next research agenda should be directed towards large-scale field trials using real experimental methods. The concrete solution is to implement the Pretest-Posttest Control Group Design research method, involving several public junior high schools from various distinct regional characteristics.

Author Contributions

I Ketut Lokasanti, Dewa Gede Hendra Divayana: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. I Ketut Lokasanti, Dewa Gede Hendra Divayana, I Gde Wawan Sudatha, I Wayan Sukra Warpala: Investigation, Data curation, Software, Validation, Writing – review & editing. I Ketut Lokasanti, Dewa Gede Hendra Divayana: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

Funding

This work was supported by the Directorate of Research and Community Service, Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, which provided the opportunity and funding support for this research. This support is in the form of Operational Assistance for the Implementation of State University Research Programs to complete this research on time, based on Master Contract Number:107/C3/DT.05.00/PL-MULTITAHUN LANJUTAN/2026 and Derivative Contract Number: 143/UN48.16/PT.01.03/2026.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that artificial intelligence (AI) tools were used solely to assist in language refinement, grammar checking, and improving the clarity of writing in this manuscript. All ideas, research design, data collection, analysis, and interpretation of results are the original work of the author. The author takes full responsibility for the content and integrity of this study.

Acknowledgement

The authors would like to thank the Directorate of Research and Community Service, Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, which provided the opportunity and funding support for this research to complete this research on time. The authors also express their gratitude to the Chancellor and Head of the Institute for Research and Community Service, Universitas Pendidikan Ganesha, who have provided support and opportunities to the authors, so that the research can run smoothly.

References

- Afiah, N., Dayu, D. P. K., & Istiq'faraoh, N. (2025). Utilization of digital learning media in arts and culture education in Indonesian schools abroad. *Journal of Innovation and Research in Primary Education*, 4(2), 203–210. <https://doi.org/10.56916/jirpe.v4i2.1223>
- Almufarreh, A. (2026). Gamification in education and its impact on student academic performance: A conceptual model based on systematic literature review and PLS-SEM analysis. *Algorithms*, 19(2), 1–30. <https://doi.org/10.3390/a19020143>
- Andang, Sowanto, & Hadi, A. M. (2025). Integrating ethnomathematics into digital learning materials to enhance junior high school students' geometry problem solving skills. *Multidisciplinary Science Journal*, 8(5), 1–11. <https://doi.org/10.31893/multiscience.2026327>
- Andryananda, A. A. P. T. M., Hamid, H. W. R., Angeline, M. I., Wulandari, I., Marfuah, L., & Hamzah, A. K. I. (2026). Bringing numbers to life and reducing anxiety: An augmented reality and haptic feedback-based mathematics game for primary school students. *F1000Research*, 14, 1–25. <https://doi.org/10.12688/f1000research.170339.2>
- Ardana, I. M., Sugiarta, I. M., Sudatha, I. G. W., Andayani, M. S. L., & Divayana, D. G. H. (2024). Ethno-flipped learning of mathematics lessons based on internalizing data from tri mandala concept on Schoology platform. *Journal of Applied Data Sciences*, 5(3), 1343–1353. <https://doi.org/10.47738/jads.v5i3.361>
- Atmaja, I. M. D., Noviantari, P. S., Bria, M. K., & Sapitri, N. M. Y. (2024). Ethnomathematics concept for learning at high school in Bali. *GUYUB: Journal of Community Engagement*, 5(3), 634–655. <https://doi.org/10.33650/guyub.v5i3.9375>

- Batiibwe, M. S. K. (2024). The role of ethnomathematics in mathematics education: A literature review. *Asian Journal for Mathematics Education*, 3(4), 383–405. <https://doi.org/10.1177/27527263241300400>
- Cakir, F. S., & Adiguzel, Z. (2020). Analysis of leader effectiveness in organization and knowledge sharing behavior on employees and organization. *SAGE Open*, 10(1), 1–14. <https://doi.org/10.1177/2158244020914634>
- Darmayasa, J. B., Wahyudin, W., & Mulyana, T. (2019). Ethnomathematics: Operasi bilangan bulat pada aturan pertemuan masyarakat Bali. *Mathematics Education and Application Journal (META)*, 1(1), 1–7. <https://doi.org/10.35334/meta.v1i1.834>
- Ersozlu, Z. (2024). The role of technology in reducing mathematics anxiety in primary school students. *Contemporary Educational Technology*, 16(3), 1–11. <https://doi.org/10.30935/cedtech/14717>
- García-Pérez, M. A. (2024). Are the steps on Likert scales equidistant? Responses on visual analog scales allow estimating their distances. *Educational and Psychological Measurement*, 84(1), 91–122. <https://doi.org/10.1177/00131644231164316>
- Gyedu, F. O., Partey, P. A., Bofo, F. A., & Agbo, D. D. (2026). Gamification effect: Enhancing student learning outcomes in higher education: A meta-analysis and policy implications. *SAGE Open*, 16(1), 1–21. <https://doi.org/10.1177/21582440261421375>
- Iriandre, A. P. R., Maharani, S., Darmadi, D., & Romandoni, H. R. (2025). Exploring ethnomathematics in junior high schools: Indonesia's contribution and research clusters in enhancing 21st century skills. *Al-Ishlah: Jurnal Pendidikan*, 17(1), 1755–1765. <https://doi.org/10.35445/alishlah.v17i1.5549>
- Jun, M., & Lukas, T. (2025). Gamification elements and their impacts on education: A review. *Multidisciplinary Reviews*, 8(5), 1–7. <https://doi.org/10.31893/multirev.2025155>
- Karapiperis, D., Tzaflikou, K., Tsoni, R., Feretzakis, G., & Verykios, V. S. (2023). A probabilistic approach to modeling students' interactions in a learning management system for facilitating distance learning. *Information*, 14(8), 1–13. <https://doi.org/10.3390/info14080440>
- Koo, M., & Yang, S. W. (2025). Likert-type scale. *Encyclopedia*, 5(1), 1–11. <https://doi.org/10.3390/encyclopedia5010018>
- Leem, B. H. (2023). Impact of interactivity on learning outcome in online learning settings: Ordinal logit model. *International Journal of Engineering Business Management*, 15, 1–10. <https://doi.org/10.1177/18479790231203107>
- Lokasanti, I. K., Divayana, D. G. H., Sudatha, I. G. W., & Warpala, I. W. S. (2026). User interface design for gamification of ethnomathematics data/content based on challenges of local wisdom. *Journal of Applied Data Sciences*, 7(1), 165–182. <https://doi.org/10.47738/jads.v7i1.987>
- Malayao, S. J., Javellana, M., Bendoy, M., Pinar, F. I., & Acut, D. (2026). Gamifying academic achievement in mathematical physics through student feedback on leaderboard performance tracking. *Journal of Technology and Science Education*, 16(1), 3–27. <https://doi.org/10.3926/jotse.3321>
- McGowan, J. (2023). Quality and reporting of large-scale improvement programmes: A review of maternity initiatives in the English NHS, 2010–2023. *BMJ Quality & Safety*, 2023(1), 1–12. <https://doi.org/10.1136/bmjqs-2023-016606>
- Mendrofa, N. K. (2024). Computational thinking skills in 21st century mathematics learning. *JlIP: Jurnal Ilmiah Ilmu Pendidikan*, 7(1), 792–801. <https://doi.org/10.54371/jiip.v7i1.3780>
- Naibaho, L. (2021). Online learning evaluation during COVID-19 using CSE-UCLA evaluation model at English Education Department Universitas Kristen Indonesia. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, 4(2), 1987–1997. <https://doi.org/10.33258/birci.v4i2.1887>
- Nandiwardhana, I. K., Astawan, I. G., & Utami, K. H. D. (2025). Balinese local wisdom-based animation video to improve students' cultural literacy. *Jurnal Media dan Teknologi Pendidikan*, 5(3), 610–620. <https://doi.org/10.23887/jmt.v5i3.100192>
- Novita, R., & Herman, T. (2021). Digital technology in learning mathematical literacy, can it be helpful? *Journal of Physics: Conference Series*, 1776(1), 1–9. <https://doi.org/10.1088/1742-6596/1776/1/012027>
- Pandawana, I. D. G. A., & Sedhana, I. B. G. M. (2020). Pengenalan konsep Asta Kosala-Kosali pada bade di Bali berbasis multimedia interaktif. *Jurnal Sistem Informasi dan Komputer Terapan Indonesia (JSIKTI)*, 2(4), 21–30. <https://doi.org/10.33173/jsikti.85>
- Ragelienė, T. (2016). Links of adolescents identity development and relationship with peers: A systematic literature review. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, 25(2), 97–105. <https://pubmed.ncbi.nlm.nih.gov/27274745/>
- Riski, M., Jailani, J., & Fitriana, S. N. (2024). Ethnomathematics-inspired mathematics learning in Indonesia: A systematic literature review. *International Journal of Multicultural and Multireligious Understanding*, 11(9), 422–431. <https://doi.org/10.18415/ijmmu.v11i9.6169>
- Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69, 371–380. <https://doi.org/10.1016/j.chb.2016.12.033>
- Simanjuntak, S. D., Fauzi, K. M. A., Mukhtar, M., & Sitepu, I. (2024). Transformation of mathematics learning through a combination of gamification and ethnomathematics approach. *Electronic Journal of Education, Social Economics and Technology*, 5(2), 322–328. <https://doi.org/10.33122/ejeset.v5i2.165>

- Sitinjak, R. H. I., Wardani, L. K., & Nilasari, P. F. (2020). Traditional Balinese architecture: From cosmic to modern. *SHS Web of Conferences*, 76, 1–14. <https://doi.org/10.1051/shsconf/20207601047>
- Triantafyllou, S. A., Georgiadis, C., & Sapounidis, T. (2025). Gamification in education and training: A literature review. *International Review of Education*, 71, 483–517. <https://doi.org/10.1007/s11159-024-10111-8>
- Weinhandl, R., Baldinger, S., & Kapplmüller, M. (2025). Educational design characteristics of digital mathematics learning environments from a student perspective. *International Journal of Mathematical Education in Science and Technology*, 1–27. <https://doi.org/10.1080/0020739X.2025.2562275>
- Wijayanti, N. P. A. A., Sunardi, S., Tirta, I. M., Margaretha, P. M., & Wijaya, Y. Y. (2019). Ethnomathematics in Balinese culture as a learning material for logic and reasoning geometry. *IOP Conference Series: Earth and Environmental Science*, 243(1), 1–9. <https://doi.org/10.1088/1755-1315/243/1/012058>
- Wright, S., & Denisova, A. (2024). It's a terrible choice to make but also a necessary one: Exploring player experiences with moral decision making mechanics in video games. *Computers in Human Behavior*, 161, 1–21. <https://doi.org/10.1016/j.chb.2024.108424>