

# From culture to code: Integrating ethnomathematics into Scratch-based games to enhance students' mathematical problem-solving

Astari<sup>1\*</sup>, Rahmat Nurcahyo<sup>2</sup>, Muhadi Hariyanto<sup>3</sup>, Dwi Yulianto<sup>4</sup>

<sup>1</sup>Latansa Mashiro Islamic Religious High School (STAI), Banten, Indonesia

<sup>2,4</sup>Latansa Mashiro University, Banten, Indonesia

<sup>3</sup>Bina Sarana Informatika University, West Java, Indonesia

\*Correspondence: [astari@unilam.ac.id](mailto:astari@unilam.ac.id)

Received: 16 September 2025 / Accepted: 05 June 2026 / Published Online: 30 June 2026

© The Author(s) 2026

## Abstract

The COVID-19 pandemic has widened gaps in mathematics achievement, underscoring the need for adaptive digital learning strategies. A preliminary diagnostic assessment conducted at SMPN 1 Leuwidamar, Banten, revealed significant weaknesses in students' problem-solving skills, particularly in the looking-back stage of Pólya's model. This study aimed to develop and evaluate a Scratch-based learning medium integrated with Baduy ethnomathematics to enhance students' mathematical problem-solving abilities. Employing a Research and Development (R&D) approach based on the ADDIE model, the study involved 31 seventh-grade students. Data were collected through problem-solving tests, student and teacher questionnaires, and expert validation forms. The validation results indicated that the learning medium was highly feasible (mean = 0.93). Effectiveness testing revealed a significant improvement in problem-solving scores, increasing from an average of 62.40 to 81.20 ( $p < 0.001$ ), with 84% of students meeting the mastery criterion and 32% achieving perfect scores. The greatest improvement was observed in strategy implementation (moderate-to-high category), whereas improvement in the initial understanding stage was relatively modest. Student responses were highly positive (mean = 93.92%), particularly regarding cultural relevance and learning motivation. These findings confirm that integrating Baduy ethnomathematics into Scratch-based learning media effectively enhances mathematical problem-solving skills while reinforcing cultural relevance in the learning process.

**Keywords:** Digital learning media, Ethnomathematics, Mathematical problem-solving skills, Scratch-based game

**How to Cite:** Astari, A., Nurcahyo, R., Hariyanto, M., & Yulianto, D. (2026). From culture to code: Integrating ethnomathematics into Scratch-based games to enhance students' mathematical problem-solving. *AXIOM : Jurnal Pendidikan dan Matematika*, 15(1), 88-111. <https://doi.org/10.30821/axiom.v15i1.26012>

## Introduction

Persistent weaknesses in students' mathematical problem-solving remain a critical global concern in post-pandemic education, as evidenced by Programme for International Student Assessment (PISA) 2022 showing that only about 18% of Indonesian students reach Level 2 proficiency, indicating that beyond pandemic-related learning loss, deeper structural issues such as limited reflective practice, poor contextualization of mathematics, and superficial



digital integration persist amid Education 4.0 demands for computational thinking, adaptive reasoning, and culturally meaningful engagement, thereby necessitating innovative instructional designs that integrate digital interactivity, cultural relevance, and explicit problem-solving scaffolds (Pokhrel & Chhetri, 2021). At the same time, contemporary educational transformation is no longer confined to the Education 4.0 framework, but is increasingly aligned with the human-centered paradigm of Society 5.0, which emphasizes the integration of advanced digital technologies with social values, cultural identity, and sustainable development. In this context, digital learning must not merely enhance technological proficiency but also foster meaningful, contextually grounded learning experiences that connect students with their cultural environment (Costan et al., 2021; Koul & Nayar, 2021; Yulianto et al., 2025).

Against this backdrop, mathematics classrooms continue to struggle with fostering structured and reflective problem-solving. Although problem-solving is widely recognized as the core of mathematics learning, instructional practices frequently emphasize procedural execution rather than metacognitive evaluation. The four-stage model proposed by Pólya, understanding the problem, devising a plan, carrying out the plan, and looking back, remains theoretically robust; however, the reflective “looking back” stage is often underemphasized in practice. Preliminary diagnostic findings at SMPN 1 Leuwidamar, Banten, revealed that while many students attempted solutions, only a limited proportion systematically verified or refined their answers, indicating weaknesses in reflective reasoning and self-regulation. These instructional limitations are further compounded by the superficial integration of digital tools. In many cases, technology functions merely as a substitution for traditional worksheets rather than as a transformative medium that supports exploration, feedback, and iterative reasoning. Such conditions reflect gaps in teachers’ Technological Pedagogical Content Knowledge (TPACK), which constrain the pedagogical potential of digital environments to foster higher-order and structured problem-solving processes (Nuangchalerm, 2020; Sarumaha, 2020).

Accordingly, there is a need for instructional designs that explicitly scaffold problem-solving stages, promote reflective practice, and leverage interactive digital environments in culturally meaningful ways. Block-based visual programming environments offer one such possibility, as they lower technical barriers while enabling dynamic modeling and immediate feedback. When pedagogically structured, these environments can support computational thinking, iterative reasoning, and systematic problem-solving. Nevertheless, digital interactivity alone does not guarantee meaningful engagement if mathematical tasks remain culturally detached. Ethnomathematics addresses this gap by situating mathematical concepts within local cultural practices, thereby strengthening contextual understanding and learner identity. In the Indonesian context, Baduy cultural artifacts and practices present authentic representations of number patterns and proportional reasoning that can be meaningfully transformed into interactive learning scenarios. Despite evidence supporting digital programming environments and ethnomathematics independently, studies integrating both within a coherent game-based design to explicitly strengthen secondary students’ problem-solving processes remain limited. Therefore, this study develops and evaluates a Scratch-based ethnomathematics game grounded in Baduy cultural contexts to enhance students’ mathematical problem-solving competence (Hu & Dong, 2020; Liao, 2023).

When tasks are scaffolded with targeted questions and feedback, Scratch enhances engagement, computational thinking, and mathematical problem-solving (Batni et al., 2024; Hsiao & Su, 2021). Mathematics learning inherently relies on systematic problem-solving; Pólya's four-step model, understanding, planning, executing, and reviewing, remains central, yet classroom practice often omits the fourth step. This national concern is reflected locally. Diagnostic tests at SMPN 1 Leuwidamar, Banten, showed most students failed to validate solutions, underscoring a persistent weakness in Pólya's "looking back" stage. Although many students could initiate and execute solutions (22 formulated strategies; 16 calculated correctly), only 11 reviewed their answers, indicating limited metacognitive regulation. These findings suggest that instruction remains largely procedural, with insufficient scaffolding for reflective validation and limited meaningful technology integration. Technology is often used as a substitute rather than as a cognitive tool to strengthen structured reasoning and problem-solving (Nuangchalerm, 2020; Sarumaha, 2020). Evidence indicates that integrating Scratch-based activities with computational thinking enhances structured reasoning and problem-solving (Fagerlund et al., 2021; Molina-Ayuso et al., 2022). Moreover, embedding mathematics in local cultural contexts through ethnomathematics increases relevance and engagement, supporting reflective "looking back" practices (Kabuye Batiibwe, 2024; Lidinillah et al., 2022). A nationwide study mapping cultural practices across Indonesia's 34 provinces identified mathematical concepts ranging from basic arithmetic to advanced calculus (Kusuma et al., 2024b). This urgency is reinforced by Indonesia's low PISA 2022 performance, with only approximately 18% of students reaching Level 2 or higher (PISA, 2022), highlighting the need for integrated strategies that strengthen problem-solving (Polya), embed mathematics in culture, and leverage digital media. Addressing this gap requires an instructional design that integrates structured scaffolding aligned with Pólya's stages, interactive digital media to foster computational thinking, and culturally meaningful contexts to support engagement and reflective practice.

An analysis of number pattern tests at SMPN 1 Leuwidamar, Rangkasbitung, showed Grade VII students' weak problem-solving skills: only 22 formulated solutions, 16 calculated accurately, and 11 reviewed their answers, highlighting deficiencies in Pólya's "looking back" stage. These weaknesses were linked to minimal teacher-led reflection, low literacy in interpreting contexts, and fatigue from traditional methods lacking digital integration, which reduced motivation and problem-solving capacity (Yulianto et al., 2024). Such disengagement often stems from teachers' limited interactive pedagogy (Budirahayu & Saud, 2023) and insufficient mastery of TPACK, reducing technology to mere substitution rather than a means of fostering cognitive engagement and structured problem-solving (Nuangchalerm, 2020; Sarumaha, 2020). Consequently, Scratch's potential to strengthen problem-solving through Pólya's stages remains underutilized (Pérez-Jorge & Martínez-Murciano, 2022; Szabo et al., 2020). Evidence shows digital learning is most effective when paired with explicit pedagogical design and teacher training; thus, interventions should enhance teachers' TPACK (Sarumaha, 2020), integrate reflection and problem-posing (Yulianto et al., 2024), and embed ethnomathematics to sustain engagement (Kusuma et al., 2024b).

Previous studies demonstrate the effectiveness of Scratch-based media in enhancing mathematics learning outcomes and 21st-century skills (Fagerlund et al., 2021; Molina-Ayuso et al., 2022; Pérez-Jorge & Martínez-Murciano, 2022). Evidence further shows that block-

based visual programming such as Scratch fosters computational thinking and structured problem-solving when supported by appropriate pedagogy (Batni et al., 2024; Hu & Dong, 2020; J. Su et al., 2022). Likewise, ethnomathematics research highlights its role in promoting student engagement and mathematical literacy through culturally relevant contexts (Kusuma et al., 2024b; Lidinillah et al., 2022; Pratama & Yelken, 2024). Yet, few studies integrate Scratch with local ethnomathematics, particularly Baduy culture, to strengthen secondary students' problem-solving in number patterns. The selection of the Baduy culture is based on pedagogical and contextual relevance. As a community located in Lebak–Banten, it provides a culturally proximate and authentic context for students at SMPN 1 Leuwidamar, supporting culturally responsive learning and increasing cognitive accessibility and intrinsic motivation. Baduy cultural practices inherently embody mathematical structures such as number patterns, proportional reasoning, symmetry, spatial organization, and cyclical systems reflected in weaving motifs, house layouts, agricultural calendars, and spatial zoning. These structures align with Grade VII competencies and facilitate students' transition from contextual reasoning to symbolic generalization.

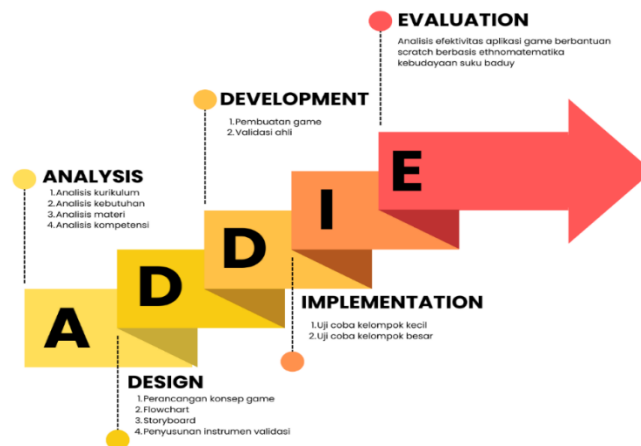
Integrating Baduy ethnomathematics also strengthens reflective reasoning aligned with Polya's "looking back" stage, as cultural contexts require students to validate solutions against real-world coherence. This reinforces metacognitive awareness and solution verification, the weakest stage identified in the preliminary diagnostic. Furthermore, the integration operationalizes the TPACK framework by combining Scratch-based technological design, structured problem-solving pedagogy, and culturally grounded mathematical content. Rather than functioning as mere substitution, Scratch serves as a cognitive simulation space for modeling and refining culturally contextualized patterns. From a research perspective, Baduy ethnomathematics remains underexplored in digital game-based learning. This study bridges computational thinking, ethnomathematics, and structured mathematical problem-solving, advancing a culturally situated computational problem-solving framework in which ethnomathematics functions as a cognitive scaffold within digital environments.

## Methods

This study systematically developed and evaluated a Baduy ethnomathematics-based mathematics learning game, ensuring reproducibility and providing empirical evidence of its effectiveness.

## Research Design

This study employed a Research and Development (R&D) approach with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to create a Baduy ethnomathematics-based mathematics learning game. Expert validation and small-group trials guided iterative revisions before large-scale implementation, ensuring both validity and practicality. The ADDIE model, widely applied in digital learning media development, was selected for its systematic, cyclical structure that integrates needs analysis, objective alignment, Scratch-based game design, and formative evaluation at each stage, thereby minimizing weaknesses and reinforcing instructional validity.



**Figure 1.** The ADDIE instructional design model was applied in this study .

As illustrated in Figure 1, each ADDIE phase informed the subsequent stage through iterative refinement, enabling continuous improvement of the Scratch-based ethnomathematics game based on expert feedback, pilot testing, and field implementation.

### Development Procedure

The development process followed the ADDIE model (Analyze–Design–Develop–Implement–Evaluate) (Branch, 2009). (1) Analyze: needs analysis through observations and interviews with principals and mathematics teachers identified learning objectives, target problem-solving competencies, and the Baduy ethnomathematics context. Cultural elements were derived from community consultations and literature, then validated by ethnomathematics experts for contextual accuracy and integration into Scratch game mechanics. (2) Design: learning specifications, game storyboards, problem-solving rubrics, and validation instruments were prepared. (3) Develop: a Scratch-based prototype, expert validation sheets, geometry test items (triangles–quadrilaterals), and response questionnaires were produced and revised based on expert feedback. The rubric assessed Pólya’s four stages of understanding, planning, executing, and reflecting, with emphasis on reflection. (4) Implement: a pilot test ( $n \approx 6$ ) refined technical-pedagogical aspects, followed by a larger trial ( $n \approx 25$ ) at SMPN 1 Leuwidamar, Banten. Teachers received scaffolding guides aligned with Pólya’s method, reflection prompts, and brief training to integrate Baduy cultural elements into Scratch. (5) Evaluate: final validation by two content and two media experts, supported by pretest–posttest measures, examined problem-solving gains. Integrated cultural elements (e.g., weaving patterns, house structures, village layouts) were revalidated by ethnomathematics experts. Effectiveness was analyzed through descriptive and inferential statistics (paired t-test) on problem-solving, motivation, and the link between cultural integration and performance.

The research instruments included: (1) expert validation sheets for content and media (feasibility questionnaires); (2) essay tests on triangles and quadrilaterals, scored with an analytic rubric; and (3) student and teacher response questionnaires (5-point Likert scale) assessing feasibility, practicality, and acceptance. All questionnaires were content-validated by an expert panel using the Content Validity Index (CVI) method, which includes the Item-level Content Validity Index (I-CVI) and the Scale-level Content Validity Index (S-CVI) to quantify

expert agreement regarding item relevance and clarity. The I-CVI represents the proportion of experts rating each item as relevant, while the S-CVI reflects the overall content validity across all items in the instrument (Arif et al., 2025). Instrument reliability was confirmed through a pilot study using Cronbach's  $\alpha$  (Ishak et al., 2023). Essay tests were evaluated with a standardized rubric, and inter-rater reliability was assessed using Cohen's kappa or ICC (Al-Hassan et al., 2025). Quantitative data were analyzed descriptively (means, percentages) and inferentially (pretest–posttest paired t-test, effect sizes) to determine feasibility and effectiveness. To ensure systematic data collection and rigorous evaluation of the Scratch-based ethnomathematics game developed, multiple research instruments were employed. These included expert validation sheets to assess the product's content and media feasibility, essay-based tests to measure students' mathematical problem-solving skills, and response questionnaires to capture students' and teachers' perceptions of the game's practicality and usability. Each instrument was designed with specific analytical procedures and validity criteria to ensure methodological rigor. A summary of the research instruments, purposes, validators, analytical techniques, and validity criteria is presented in Table 1.

**Table 1.** Research Instruments, Analysis Techniques, and Evaluation Criteria

Instrument	Purpose	Format & Scale	Validator	Analysis Technique	Validity Criteria
Content Validation Sheet	Assess the alignment of mathematics content (triangles and quadrilaterals) with the curriculum and the integration of ethnomathematics.	5-point Likert questionnaire (1 = strongly disagree, 5 = strongly agree)	3 subject-matter experts (secondary mathematics lecturers)	Content Validity Index (I-CVI & S-CVI), descriptive analysis	I-CVI $\geq$ 0.78; S-CVI/Ave $\geq$ 0.90 considered valid (Arif et al., 2025)
Media Validation Sheet	Evaluate the design, interface, interactivity, and usability of the Scratch-based game.	5-point Likert questionnaire	3 experts in mathematics learning media	Content Validity Index (I-CVI & S-CVI), descriptive analysis	I-CVI $\geq$ 0.78; Cronbach's $\alpha \geq$ 0.70 (Ishak et al., 2023)
Essay Test	Measure students' mathematical problem-solving skills (number patterns).	5 open-ended items with analytic rubric (0–4 per indicator)	The study involved 31 students, consisting of 6 students in the pilot test and 25 students in the field trial.	Mean score analysis; inter-rater reliability (Cohen's kappa/ICC)	Kappa/ICC $\geq$ 0.75 (Ibrahim et al., 2025)
Student Response Questionnaire	Capture students' perceptions of the practicality and acceptability of the Scratch-based game.	5-point Likert questionnaire	31 Grade VII students	Descriptive analysis (mean, percentage)	$\geq$ 75% positive responses $\rightarrow$ feasible for use
Teacher Response Questionnaire	Gather practical input on classroom implementation.	5-point Likert questionnaire + open-ended questions	Mathematics teacher at the research site	Descriptive and qualitative content analysis (feedback)	

As shown in Table 1, each instrument served a distinct evaluative function within the ADDIE framework. Expert validation sheets were used to determine content and media validity, while

essay-based tests measured students' mathematical problem-solving skills. Response questionnaires collected user feedback to assess the practicality and acceptance of the developed Scratch-based ethnomathematics game.

Material validation was conducted by three subject-matter experts in mathematics education specializing in number patterns. Each expert evaluated the developed learning materials using a structured validation instrument covering five aspects: readability, clarity of presentation, usability, answer-processing accuracy, and documentation quality. Media validation was carried out by three experts in mathematics learning media, who assessed the Scratch-based game using a Likert-type validation questionnaire. The evaluation focused on language clarity, accuracy of mathematical terminology, instructional comprehensibility, interface design, navigation, visual quality, interactivity, feedback mechanisms, alignment with learning objectives, and documentation. In addition, the media experts evaluated two broader dimensions: content feasibility (conceptual accuracy and curricular relevance) and presentation feasibility (interface design, readability, interactivity, answer processing, and documentation). All validation data were analyzed using the Content Validity Index (I-CVI and S-CVI/Ave) to determine the validity of the developed product.

Students' mathematical problem-solving ability was assessed using five open-ended essay questions on number patterns. The items were constructed based on Pólya's four-stage problem-solving framework, consisting of (1) understanding the problem, where students identify known and unknown information; (2) devising a plan, which involves selecting appropriate strategies or mathematical relationships; (3) carrying out the plan, referring to the correct implementation of procedures and calculations; and (4) looking back, where students verify and reflect on the reasonableness of their solutions. Students' responses were evaluated using an analytic scoring rubric with a 0–4 scale for each stage, allowing the researchers to capture the completeness and quality of students' reasoning processes. Each item was structured to elicit evidence of all four stages, ensuring consistency between the theoretical framework discussed in the introduction and the operational indicators used in the assessment instrument. The test was validated by subject-matter experts to ensure consistency with competencies, cognitive levels, and learning objectives. A student response questionnaire evaluated perceptions of the Scratch-based ethnomathematics game in terms of (1) usability, (2) visual appeal and interactivity, (3) content relevance, and (4) contribution to motivation and understanding, with expert validators confirming item clarity and contextual appropriateness. A teacher response questionnaire further examined practicality and acceptance, focusing on (1) curricular alignment, (2) classroom integration, (3) effectiveness in achieving objectives, and (4) sustainability, also validated by experts for relevance and accuracy.

Product validity was interpreted using percentage-based feasibility criteria commonly employed in educational product development studies. These criteria were adapted from established evaluation frameworks in instructional design and learning media assessment (Akbar, 2013; Riduwan, 2010; Sugiyono, 2019). Validation scores were converted into percentage categories to determine product feasibility: 0–25% = highly invalid (complete revision required), 26–50% = invalid (major revision required), 51–75% = valid (trial-ready with minor revisions), and 76–100% = highly valid (ready for implementation). A prototype was considered sufficiently valid when the validation score reached at least 51%, indicating that the product met the minimum feasibility requirements for field testing (Maleki et al., 2025).

Scores below this threshold required revision and re-evaluation before implementation. This interpretation was applied during the formative evaluation stage to guide iterative improvements, consistent with instructional design principles emphasizing continuous refinement of educational products (Branch, 2009). Effectiveness was measured through content mastery, problem-solving, and student responses. The product was deemed effective if mean scores across these aspects were in the high category, as summarized in Table 2 (Hu & Dong, 2020).

**Table 2.** Criteria for Effectiveness and Student Responses to the Product

Percentage Score	Mastery & Problem-Solving Effectiveness	Student Response to the Product
85–100%	Very High	Very Positive
70–84%	High	Positive
50–69%	Low	Negative
< 50%	Very Low	Very Negative

Through this systematic validation and effectiveness assessment, the study demonstrates that the Scratch-based game prototype is not only valid in terms of content and media but also effective in enhancing students' mathematical problem-solving skills within the context of Baduy ethnomathematics.

## Research Sample

The study involved 31 seventh-grade students from SMPN 1 Leuwidamar, Lebak Regency, Banten Province, Indonesia, aged 12–13 years, who were studying basic number patterns according to the national curriculum. The sample consisted of 16 female and 15 male students with relatively balanced gender distribution and heterogeneous mathematical abilities, as indicated by a diagnostic test conducted before the intervention that classified students into high-, medium-, and low-achievement groups. Most students possessed basic digital literacy and experience using smartphones or school computers, although none had prior experience with Scratch programming. The school is located in a semi-rural area near the Baduy cultural region, where students are familiar with local cultural practices such as traditional weaving patterns, house structures, and village layouts, which were integrated into the ethnomathematics-based game design. The sample size was considered adequate for an initial development study aimed at evaluating product validity, practicality, and preliminary effectiveness. The development process included a pilot test with six students to identify technical issues and revise the Scratch-based prototype, followed by a field trial with 25 students to assess practicality and effectiveness. Participants were purposively selected based on three criteria: currently studying the targeted mathematical topics, having access to digital devices required to run the game, and voluntarily agreeing to participate. The study employed a one-group pretest–posttest design without a control group, commonly used in early Research and Development studies to evaluate feasibility and preliminary effectiveness within a limited educational context; most students came from families engaged in agriculture or small-scale local trade, reflecting the socio-cultural characteristics of rural communities in Lebak Regency.

A control group was not used because the primary objective of this study was to develop and conduct a formative evaluation of a Scratch-based ethnomathematics learning game rather than to compare instructional approaches. In early-stage Research and Development (R&D) studies, limited trials using a one-group pretest–posttest design are commonly employed to

assess product validity, practicality, and preliminary effectiveness before conducting larger-scale experimental studies. Therefore, the focus of this study was on testing the feasibility and refinement of the developed prototype in a real classroom context. Future research will employ quasi-experimental or controlled designs with larger samples to examine the comparative effectiveness of the Scratch-based ethnomathematics game.

## Data Collection and Analysis

Data were collected in the Evaluation phase (E of ADDIE) using three instruments: (1) essay-based post-tests on triangles and quadrilaterals to assess mathematical problem-solving; (2) Likert-scale questionnaires to measure feasibility and practicality as rated by content experts, media experts, teachers, and students; and (3) observation notes and written feedback for qualitative insights. Content validity was tested using I-CVI, S-CVI/Ave, and Aiken's V (Table 1), while construct validity was examined through exploratory factor analysis (EFA) when sample size permitted. Quantitative data (validation scores, questionnaires, test results) were analyzed descriptively (means, SDs, percentages) and inferentially (paired t-test) to evaluate feasibility and effectiveness. Qualitative data (expert reviews, observations, teacher–student feedback) were thematically analyzed to iteratively refine the prototype until it achieved high validity, reliability, and effectiveness, consistent with instructional design literature.

## Results

The Scratch-based learning media were developed using the ADDIE model (Analyze, Design, Develop, Implement, Evaluate), consistent with the study's aim of creating culturally grounded media to strengthen students' problem-solving, particularly in strategy planning and solution implementation.

### Analyze

The analysis identified Grade VII learning needs on number patterns and evaluated curriculum alignment. Observations and teacher interviews revealed limited digital media use and students' difficulties in recognizing regularities, identifying patterns, and generalizing rules. A review of the Merdeka curriculum showed gaps between intended competencies and practice, suggesting the potential of an ethnomathematics approach. The findings of the needs analysis are summarized in Table 3. Prior studies confirm that integrating local culture enhances instructional relevance and mathematical literacy (Kabuye Batiibwe, 2024; Kusuma et al., 2024b; Pratama & Yelken, 2024). Meanwhile, Scratch-based media effectively foster computational thinking and problem-solving in mathematics (Batni et al., 2024; Fagerlund et al., 2021; Y.-S. Su et al., 2022). These insights underpin the development of a Scratch-based ethnomathematics game to improve problem-solving through interactive, contextual, and visual experiences linking number patterns with local culture.

**Table 3.** Needs Analysis

Aspect	Findings & Gaps	Game Development Implications
Student Needs	Difficulties in identifying types of triangles/quadrilaterals, distinguishing formulas, and applying problem-solving; limited use of digital media	The Scratch game provides interactive visualization and accessible problem-solving practice.
Curriculum & Lesson Plans	Basic competencies are aligned, but lack connections between mathematical concepts and real-life contexts (ethnomathematics).	The game integrates mathematics with local culture to enhance relevance and learning motivation.
Development Justification	The gap between curriculum and classroom practices, coupled with limited digital learning media.	Scratch-based ethnomathematics game strengthens problem-solving skills through interactive and contextual learning experiences.

## Design

The design stage involved material review, instrument development, and a prototype of Scratch-based media integrating Baduy ethnomathematics to strengthen students' problem-solving skills. Instructional content emphasized number patterns contextualized through local culture, such as arithmetic and geometric sequences reflected in harvest yields and traditional Baduy house structures, thereby linking abstract concepts to real-life experiences and enhancing both understanding and cultural relevance. Learning materials were structured around Polya's problem-solving steps: understanding, strategizing, executing, and reviewing through exploration, visual manipulation, and reflection, fostering critical thinking, knowledge transfer, and active engagement.

The design stage also produced detailed storyboards, game flow structures, a problem-solving rubric, and validation instruments. The game incorporated several key features: (a) a structured interface consisting of the opening page, introduction, main menu, sub-materials, and exercises; (b) audio-visual interactivity with automated feedback to support immediate learning responses; and (c) reflection prompts and fill-in tasks designed to reinforce the "looking back" phase of Pólya's problem-solving model. Evidence of these design features can be observed in the prototype interfaces presented in Figures 2–7, which illustrate the home page, learning menu, quiz interface, apperception page, competency standards menu, and discussion menu. The research instruments consisted of (1) product validation sheets, (2) mathematical problem-solving tests, and (3) student response questionnaires. Product validation was conducted to ensure content accuracy, instructional clarity, presentation quality, and curriculum alignment. The validation process involved three subject-matter experts in mathematics education, two experts in mathematics learning media, and one ethnomathematics expert to ensure the appropriateness of both mathematical content and cultural integration.

## Develop

The design stage produced Prototype I of the Scratch-based ethnomathematics learning media, comprising the main interface, opening menu, learning modules, and practice exercises. Developed through a user-centered design approach, it emphasized readability, navigation, interactivity, and visual appeal to foster student motivation. Prototype I was validated by experts in content, media, and ethnomathematics, whose feedback informed systematic revisions to enhance design consistency, instructional clarity, and the integration of Pólya's

problem-solving rubric. The revised Prototype II, documented in Figures 2–7 and Tables 4–5, included a welcome page, main menu, subtopics, exercises, reflective questions, audio, animations, and automated feedback. These refinements ensured visual engagement, content validity, and pedagogical relevance, making the media suitable for pilot testing.

**Table 4.** Material Validation Results

Aspect	Mean Score	Percentage (%)	Category
Content Accuracy	3.75	93.7	Highly Valid
Presentation Quality	3.80	95.0	Highly Valid
Overall Mean	3.77	94.3	Highly Valid

**Table 5.** Media Expert Validation Results

Aspect	Stage 1	Stage 2	Percentage (%)	Criteria
Readability	4	7	87.5	Highly Valid
Visual Design	5	6	75.0	Valid
Ease of Use	5	7	87.5	Highly Valid
Response Handling	7	10	100	Highly Valid
Documentation	4	4	50.0	Needs Revision
<b>Total Score</b>	<b>25</b>	<b>34</b>	<b>73.7%</b>	<b>Valid</b>

The material expert validation (Table 4) showed steady improvement from stage 1 (75%) to stage 3 (100%), with an overall mean of 88.06%, classified as highly valid. This confirms Branch's (2009) view that iterative refinement is central to the ADDIE model in ensuring clarity and curricular alignment. Media expert validation (Table 5) also improved, from 62.5% at stage 1 to 85% at stage 2, averaging 73.7% and deemed valid with minor revisions in documentation. To strengthen validity, expert judgments were analyzed using the Content Validity Index (CVI), a widely recognized approach for ensuring inter-rater reliability in instrument development (Arif et al., 2025; Ibrahim & Mohd Matore, 2025; Maleki et al., 2025). Results (Table 6) indicated that material (content and presentation) achieved an S-CVI/Ave of 0.94 (highly valid), media 0.85 (valid), and ethnomathematics (Baduy cultural context) a perfect 1.00 (highly valid). The overall CVI mean was 0.93, categorized as highly valid, supporting Ishak et al.'s (2017) finding that layered CVI validation ensures strong feasibility for practical implementation.

**Table 6.** Expert Validation Results

Aspect	I-CVI Min	I-CVI Max	S-CVI/Ave	Criteria
Content (accuracy & presentation)	0.83	1.00	0.94	Highly valid
Media (usability, design, interactivity)	0.78	0.89	0.85	Valid
Ethnomathematics (Baduy cultural context)	1.00	1.00	1.00	Highly valid
Overall average	–	–	0.93	Highly valid

The findings confirm that the research instrument meets validity standards, particularly in content and cultural integration. Only the media component requires minor refinement in navigation and documentation to optimize learning use. This validation is consistent with recent studies emphasizing the role of content validity, reliability, and consistency testing using CVI and Cohen's kappa to ensure instrument feasibility (Arif et al., 2025; Ibrahim & Mohd Matore, 2025; Ishak et al., 2023; Maleki et al., 2025). Accordingly, comprehensive validation is essential to guarantee the instrument's effective application in culturally responsive and digitally supported mathematics learning.

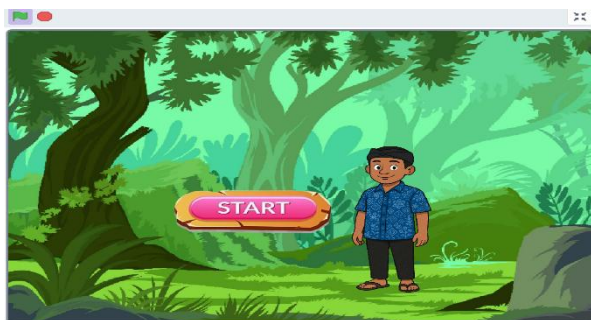


Figure 2. Home Page Interface



Figure 3. Learning Menu Interface

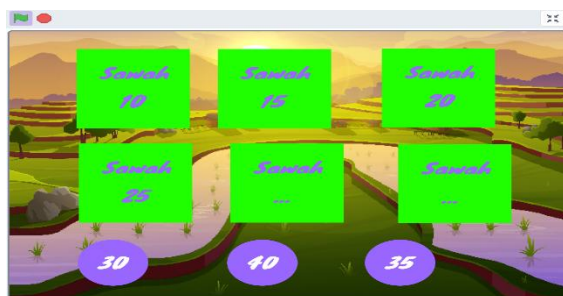


Figure 4. Quiz Interface



Figure 5. Apperception Interface

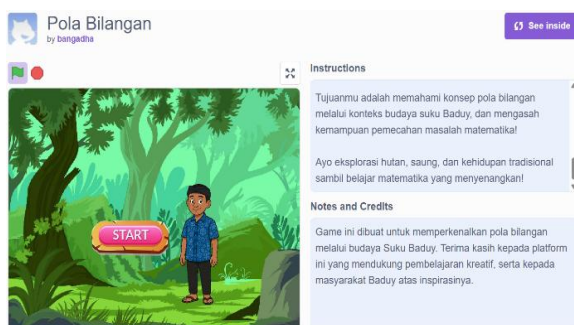


Figure 6. Competency Standards (KD) Menu

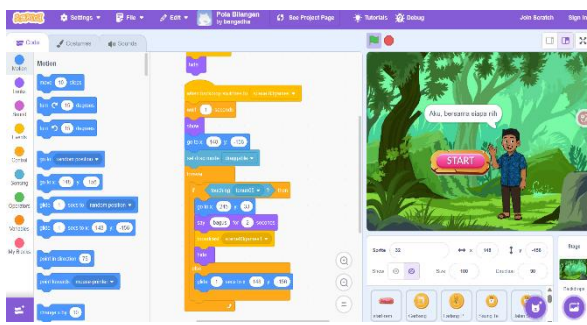


Figure 7. Discussion Menu

The developed learning media integrates several main menus. Figure 2 presents the home page, designed as a simple yet engaging gateway to all features. Figure 3 illustrates the learning menu, containing core ethnomathematics-based content with clear navigation. Figure 4 shows the interactive quiz page, which assesses conceptual understanding and fosters critical thinking. Figure 5 depicts the apperception page, linking prior knowledge to new topics for contextualized learning. Figure 6 displays the Basic Competencies (KD) menu, aligning content with the curriculum and clarifying objectives. Figure 7 introduces the discussion menu, providing space for idea exchange, collaborative problem-solving, and peer interaction. Overall, the media is systematic, interactive, and contextual: the content is pedagogically valid, the design is feasible for classroom use, and the features enhance engagement and motivation. A pilot test with six students at SMPN 1 Leuwidamar confirmed improved problem-solving skills, as shown by pre- and post-test results. A preliminary pilot test involving six students at SMPN 1 Leuwidamar was conducted to evaluate the initial effectiveness of the Scratch-based ethnomathematics game. The results indicated a substantial improvement in students' mathematical problem-solving performance, as reflected in the pre- and post-test scores presented in Table 7.

**Table 7.** Pilot Study Results: Pre–Post Test on Problem-Solving Skills

Statistic	Pre-Test	Post-Test	Gain
Mean Score	55.2	76.8	+21.6
Standard Deviation	9.4	8.1	–
N	30	30	–
Paired t-test	–	$t = 7.42, p < 0.001$	–
Cohen's d	–	1.15 (large effect)	–

The results indicate that the Scratch-based ethnomathematics game significantly improved students' mathematical problem-solving performance ( $t = 7.42, p < 0.001$ ). The calculated effect size (Cohen's  $d = 1.15$ ) indicates a large effect according to Cohen's (1988) conventional criteria, suggesting that the intervention produced a substantial educational impact. These findings confirm that the Scratch-ethnomathematics game significantly improves students' problem-solving skills with a large effect size. In addition to pre–posttest outcomes, students' perceptions were assessed using a 25-item, 5-point Likert questionnaire, which showed high reliability (Cronbach's  $\alpha = 0.89$ ), consistent with established standards of instrument validation emphasizing internal consistency (Arif et al., 2025; Ibrahim & Mohd Matore, 2025; Maleki et al., 2025). As presented in Table 8, student responses rated the media from good to very good across all domains, supporting recent evidence on the positive effects of Scratch-based learning for motivation, engagement, and problem-solving (Batni et al., 2024; Fagerlund et al., 2021; Molina-Ayuso et al., 2022; J. Su et al., 2022).

**Table 8.** Results of the Pilot Study: Student Response Questionnaire

Usability	Engagement/ Motivation	Learning	Cultural Context	Pólya's Scaffolding	Mean Category
4.1 (Good)	4.3 (Very Good)	4.2 (Very Good)	4.4 (Very Good)	4.0 (Good)	Overall: Good–Very Good

Score Categories: 1.00–1.80 = Very Poor; 1.81–2.60 = Poor; 2.61–3.40 = Fair; 3.41–4.20 = Good; 4.21–5.00 = Very Good.

Most students found the medium engaging, easy to use, and culturally relevant, while also supporting systematic mathematical problem-solving. The medium was therefore valid, effective, and positively received, especially in cultural and motivational aspects. These results align with Batni et al. (2024), who emphasize Scratch-based programming's potential to enhance engagement, and Hu & Dong (2020), who confirm the effectiveness of block-based visual programming in fostering structured learning. Integrating local culture through ethnomathematics further increased relevance and motivation, as noted by Pratama and Yelken (2024) and Kabuye Batiibwe (2024). However, improvements in scaffolding remain necessary, consistent with Budirahayu and Saud (2023), who argue that pedagogical innovations require collaborative teacher strategies to ensure reflective and sustainable learning.

## Implement

The field test involved 26 seventh-grade students at SMPN 1 Leuwidamar, Banten, using a one-group pretest–posttest design. An essay test on quadrilaterals and triangles was analyzed with Pólya's four problem-solving indicators: understanding, planning, executing, and reflecting. The results showed a significant improvement in students' mathematical problem-solving skills after using the Scratch-based ethnomathematics media.

**Table 9.** Field Test Results: Pretest and Posttest

Statistic	Mean	Standard Deviation	Minimum Score	Maximum Score
Pretest	62.40	8.15	48	75
Posttest	81.20	7.45	65	100

Table 9 presents the descriptive statistics of students' problem-solving performance before and after the implementation of the Scratch-based ethnomathematics game. The mean score increased substantially from 62.40 in the pretest to 81.20 in the posttest, indicating a gain of 18.80 points. This increase shows that most students moved from below the minimum mastery criterion ( $KKM = 70$ ) to a level exceeding the expected competency standard. The relatively small standard deviations in both measurements ( $SD_{pre} = 8.15$ ;  $SD_{post} = 7.45$ ) indicate that the improvement was not limited to a small subgroup of students but was relatively consistent across the entire class, suggesting that the intervention benefited learners with different initial ability levels. Such patterns of improvement are commonly interpreted as evidence of equitable learning gains in technology-supported environments (Fagerlund et al., 2021; Hu & Dong, 2020).

From a pedagogical perspective, the increase in scores can be explained by the interactive and visual characteristics of Scratch, which enable students to model mathematical ideas dynamically and explore problem-solving processes through iterative experimentation. Previous studies have shown that block-based programming environments support structured reasoning, computational thinking, and mathematical problem-solving, particularly when learning tasks are scaffolded through guided inquiry and reflection (Batni et al., 2024; Molina-Ayuso et al., 2022). Furthermore, the integration of ethnomathematics contexts derived from Baduy cultural practices provides meaningful real-world representations that help students interpret mathematical patterns and structures more concretely. According to the ethnomathematics theory, contextualizing mathematics within cultural practices enhances conceptual accessibility and learning motivation, thereby improving students' engagement in problem-solving activities (Kabuye Batiibwe, 2024; Kusuma et al., 2024). Consequently, the descriptive results in Table 9 represent not only statistical improvement but also pedagogical evidence that culturally contextualized digital learning environments can support the development of mathematical problem-solving skills. This aligns with Hu & Dong (2020), who found that visual programming environments like Scratch enhance cognitive outcomes and promote equitable learning, and with Fagerlund et al. (2020), who showed that Scratch fosters consistency in problem-solving through systematic computational approaches. Overall, these results support prior findings that digital technology interventions improve average performance while reducing achievement disparities.

**Table 10.** Distribution of Students' Posttest Results

Score Category	Number of Students	Percentage	Description
$\geq 100$ (Perfect)	8	32%	Excellent mastery
70–99 ( $\geq$ Passing Grade)	14	52%	Satisfactory, achieved
$< 70$ (Below Passing Grade)	4	16%	Not achieved

Note: The mastery threshold follows the Minimum Mastery Criterion ( $KKM = 70$ ) applied in Indonesian secondary education.

The distribution of posttest scores in Table 10 shows that 84% of students achieved or exceeded the minimum mastery criterion ( $\geq 70$ ), indicating that most students successfully attained the expected learning outcomes after using the Scratch-based ethnomathematics game.

Specifically, 32% obtained a perfect score (100), reflecting high conceptual and procedural mastery, while 52% reached satisfactory mastery (70–99), and only 16% remained below the mastery threshold (Kabuye Batiibwe, 2024; Pratama & Yelken, 2024). The mastery benchmark follows the Minimum Mastery Criterion (KKM) applied in Indonesian secondary education and aligns with mastery learning theory (Bloom, 1976; Gustey, 2010). This distribution indicates that the intervention not only improved overall achievement but also reduced the proportion of low-performing students (Kabuye Batiibwe, 2024; Pratama & Yelken, 2024). These findings suggest that integrating Scratch-based visual programming with ethnomathematical contexts supports meaningful learning, enhances engagement, and strengthens students' ability to solve mathematical problems systematically in line with Pólya's problem-solving framework (Budirahayu & Saud, 2023).

**Table 11.** Average Scores and N-Gain by Pólya's Indicators

Pólya's Indicator	Pretest	Posttest	Improvement	N-Gain	Effectiveness Category
Understanding	65.2	74.6	+9.4	0.27	Low
Planning	61.8	80.4	+18.6	0.48	Moderate
Executing	60.4	83.2	+22.8	0.58	Moderate–High
Looking Back	62.1	76.5	+14.4	0.38	Moderate

Analysis of the four indicators of Pólya's problem-solving framework reveals differentiated improvement patterns across cognitive stages (Table 11). The executing stage recorded the highest gain (+22.8; N-Gain = 0.58, moderate–high), followed by planning (+18.6; N-Gain = 0.48, moderate). This pattern suggests that the Scratch-based ethnomathematics game particularly strengthens procedural reasoning and strategy implementation. Such findings are consistent with research indicating that block-based visual programming environments enhance algorithmic thinking and procedural problem-solving through interactive and step-by-step representations. In the Scratch environment, students interact with visual blocks, animations, and immediate feedback mechanisms, which function as computational representations that guide learners in structuring solution steps and testing strategies systematically. The planning stage also demonstrated substantial improvement, indicating that the game-based tasks supported students in formulating strategies before executing solutions. This improvement may be explained by the game's scaffolded design, which embeds contextual ethnomathematical scenarios derived from Baduy cultural practices. According to constructivist learning theory, contextualized representations help learners transform abstract mathematical problems into meaningful cognitive structures (Pratama & Yelken, 2024; Shadilly, 1990) By presenting number patterns through culturally familiar contexts such as weaving motifs and traditional house structures, the Scratch game provides visual and contextual representations that facilitate strategic reasoning.

Moderate improvement was observed in the looking back stage (+14.4; N-Gain = 0.38), which reflects partial strengthening of reflective thinking. This outcome indicates that the reflective prompts embedded in the Scratch game encouraged students to re-evaluate their solutions, although reflective problem-solving habits generally require sustained pedagogical reinforcement. Previous studies emphasize that reflective evaluation is often the most neglected component of Pólya's model in classroom practice, as students tend to focus on obtaining answers rather than verifying them (Hsiao & Su, 2021; Pérez-Jorge & Martínez-Murciano, 2022) In contrast, the understanding stage exhibited the lowest improvement (+9.4; N-Gain =

0.27, low). This suggests that while Scratch effectively supports procedural and strategic phases of problem-solving, its influence on initial conceptual comprehension is relatively limited. Conceptual understanding typically depends on prior mathematical knowledge and conceptual instruction rather than interactive execution alone (Hu & Dong, 2020; Molina-Ayuso et al., 2022). Consequently, although visual programming environments can facilitate problem-solving processes through representational and procedural support, deeper conceptual comprehension may require additional scaffolding, such as guided inquiry or explicit conceptual explanations. Overall, these findings indicate that Scratch-based ethnomathematics learning primarily enhances higher-order procedural and strategic dimensions of mathematical problem-solving, particularly in the planning and executing stages. The integration of cultural contexts further strengthens students' engagement and cognitive representation of mathematical ideas, supporting the argument that culturally responsive digital learning environments can effectively bridge abstract mathematical reasoning with meaningful real-world contexts.

**Table 12.** Results of the Paired Sample t-test

Variable	Mean Difference	t-value	p-value	Conclusion
Pretest–Posttest	-18.80	-9.52	< 0.001	Significant

The paired-sample t-test results presented in Table 12 indicate a statistically significant improvement in students' mathematical problem-solving skills after the implementation of the Scratch-based ethnomathematics learning media. The analysis yielded a mean difference of  $-18.80$ , reflecting a substantial increase in posttest scores compared with pretest scores. The t-value of  $-9.52$  with  $p < 0.001$  confirms that the improvement is statistically significant at the conventional  $\alpha = 0.05$  level, indicating that the observed learning gains are highly unlikely to occur by chance and demonstrating the effectiveness of the developed learning media in enhancing students' problem-solving performance. Statistically, the large magnitude of the t-value represents a strong separation between pretest and posttest score distributions, demonstrating that students consistently performed better after the intervention. The negative sign of the t-value simply reflects the order of subtraction (pretest minus posttest) rather than a negative learning outcome; instead, it indicates that posttest scores were substantially higher than pretest scores.

These findings align with previous studies demonstrating that Scratch-based learning environments can significantly enhance students' computational thinking and mathematical problem-solving abilities when supported by structured pedagogical scaffolding (Fagerlund et al., 2020; Hu & Dong, 2020; Pérez-Jorge & Martínez-Murciano, 2022). Furthermore, the integration of ethnomathematical contexts contributes to strengthening students' engagement, cultural relevance, and mathematical literacy, which in turn supports improved problem-solving performance (Abadi et al., 2024; Kusuma et al., 2024). From a pedagogical perspective, the significant improvement suggests that combining interactive digital programming environments such as Scratch with culturally grounded ethnomathematical contexts promotes deeper cognitive engagement during the problem-solving process. This integration enables students to visualize mathematical structures, experiment with strategies dynamically, and reflect on solutions, thereby reinforcing the procedural stages of Pólya's problem-solving model, particularly in the planning and execution phases. Overall, the

statistical evidence supports the conclusion that the Scratch-based ethnomathematics game constitutes an effective instructional intervention for improving students' mathematical problem-solving abilities in secondary education contexts.

## Evaluate

The evaluation, conducted through student response questionnaires, yielded an average score of 93.92% in the "very positive" category, indicating high enthusiasm, motivation, and optimal media use. This finding aligns with evidence that game-based interactive media fosters engagement, motivation, and digital literacy. Further, Scratch-based learning has been shown to enhance computational thinking, creativity, and problem-solving when pedagogically structured (Batni et al., 2024; Fagerlund et al., 2021; J. Su et al., 2022). Supporting this, Pérez-Jorge and Martínez-Murciano (2022) found that Scratch gamification significantly boosts engagement, consistent with Chang in (Hafid, 2022) meta-analysis on block-based programming effectiveness. Collectively, these results confirm strong student acceptance and validate Scratch-ethnomathematics media as a relevant and effective tool for 21st-century education.

**Table 13.** Student Responses to the Scratch-Based Ethnomathematics Media

Domain	Mean Score	Percentage (%)	Category
Usability	4.6	92.17	Very Positive
Engagement/Motivation	4.7	94.23	Very Positive
Learning	4.7	94.11	Very Positive
Cultural Context	4.8	96.16	Very Positive
Pólya's Scaffolding	4.5	90.21	Very Positive
<b>Overall Average</b>	<b>4.7</b>	<b>93.92</b>	<b>Very Positive</b>

The evaluation results presented in Table 13 indicate that students demonstrated very positive perceptions toward the Scratch-based ethnomathematics learning media across all evaluated domains. The overall mean score reached 4.7 out of 5 (93.92%), which falls within the *very positive* category according to the Likert-scale interpretation criteria commonly applied in educational media evaluation (Arif et al., 2025; Ishak et al., 2023). This high score indicates that the developed game was perceived as usable, engaging, culturally meaningful, and pedagogically supportive for mathematical learning. A closer examination of each domain reveals important insights into how students interacted with the learning media. The cultural context dimension obtained the highest score (96.16%), suggesting that the integration of Baduy ethnomathematical elements successfully enhanced the contextual relevance of mathematical concepts. This finding aligns with ethnomathematics research emphasizing that embedding cultural knowledge in mathematics learning increases students' sense of familiarity and meaningful engagement with abstract concepts (Kabuye Batiibwe, 2024; Pratama & Yelken, 2024) By linking number patterns with traditional Baduy cultural practices such as weaving motifs and architectural structures, the game allowed students to connect mathematical reasoning with real-life cultural experiences.

Similarly, the engagement and motivation dimension (94.23%) indicates that the Scratch-based interactive environment effectively stimulated students' interest and active participation. This supports prior studies demonstrating that block-based visual programming platforms, such as Scratch, enhance learner engagement through interactive animations, gamification features,

and immediate feedback mechanisms (Batni et al., 2024; Fagerlund et al., 2020; Pérez-Jorge & Martínez-Murciano, 2022). The visual and game-based design of the media, therefore, contributed to creating an enjoyable and motivating learning atmosphere. The learning dimension (94.11%) further suggests that students perceived the game as beneficial for understanding mathematical concepts and practicing problem-solving. Interactive tasks and structured activities within the game supported students in exploring patterns, testing strategies, and verifying solutions, which are essential elements of mathematical reasoning. These findings are consistent with research indicating that Scratch-based environments support conceptual exploration and computational thinking when integrated with appropriate pedagogical scaffolding (Hu & Dong, 2020; Molina-Ayuso et al., 2022).

In addition, the usability dimension (92.17%) demonstrates that students found the interface intuitive and easy to navigate. Clear menus, visual instructions, and interactive elements allowed students to interact with the game without significant technical difficulties. Usability is a critical factor in digital learning media because user-friendly interfaces reduce cognitive load and allow students to focus on learning tasks rather than technical operations (Batni et al., 2024).

Finally, Pólya's scaffolding dimension (90.21%), although slightly lower than other domains, still falls within the very positive category. This indicates that the game successfully guided students through the stages of mathematical problem-solving, including understanding problems, planning strategies, executing solutions, and reflecting on answers. However, the relatively lower score compared to other domains suggests that additional scaffolding mechanisms, such as more explicit reflection prompts or guided hints, could further strengthen students' engagement in the "looking back" stage of Pólya's model. Overall, these results confirm that the Scratch-based ethnomathematics game not only provides an engaging digital learning experience but also supports culturally contextualized mathematical problem-solving. The strong positive responses across usability, engagement, cultural relevance, and learning effectiveness indicate that the developed media is well accepted by students and pedagogically suitable for classroom implementation.

## Discussion

The findings demonstrate that the Scratch-based ethnomathematics medium is user-friendly and enhances engagement, motivation, and cultural relevance, while providing scaffolding aligned with Pólya's problem-solving steps. This supports evidence that game-based interactive media fosters enthusiasm, motivation, and digital literacy (Batni et al., 2024; Fagerlund et al., 2021; Pérez-Jorge & Martínez-Murciano, 2022). Meta-analyses also confirm that block-based programming, such as Scratch, effectively develops computational thinking and structured problem-solving (Hu & Dong, 2020). Integrating ethnomathematics further strengthens cultural relevance and deepens student engagement (Kabuye Batiibwe, 2024; Pratama & Yelken, 2024). Developed through the ADDIE model (Branch, 2009), the medium achieved its objectives and was validated by experts: content validation scored 88.06% ("very valid"), confirming feasibility for classroom trials, while media validation reached 73.7% ("valid"), requiring minor improvements (Arif et al., 2025; Maleki et al., 2025). Effectiveness testing showed significant gains in problem-solving, with the highest improvements in

executing (+22.8; N-Gain = 0.58, moderate–high) and planning (+18.6; N-Gain = 0.48, moderate). These results align with prior studies confirming that interactive, visual programming media strengthen procedural fluency and higher-order thinking skills (Batni et al., 2024; Fagerlund et al., 2021; Hu & Dong, 2020).

Previous studies have demonstrated that Scratch-based learning environments can improve computational thinking, engagement, and students' mathematical problem-solving skills through interactive and visual programming activities (Batni et al., 2024; Fagerlund et al., 2020; Pérez-Jorge & Martínez-Murciano, 2022). However, most of these studies primarily focus on technological affordances and gamification elements without incorporating culturally meaningful contexts that connect mathematical concepts with students' socio-cultural experiences. Likewise, research on ethnomathematics highlights the importance of embedding local cultural practices into mathematics instruction to enhance relevance, identity, and mathematical literacy (Kabuye Batiibwe, 2024; Lidinillah et al., 2022; Pérez-Jorge & Martínez-Murciano, 2022). Nevertheless, these studies typically rely on conventional teaching approaches or contextual tasks and rarely integrate ethnomathematical contexts into interactive digital environments such as Scratch-based games. Addressing this gap, the present study extends prior research by integrating Baduy cultural contexts into a Scratch-based ethnomathematics game designed to foster students' mathematical problem-solving skills. Unlike previous studies that examined either Scratch-based programming or ethnomathematics separately, this study combines both approaches within a structured instructional framework based on Pólya's problem-solving stages. Through this integration, the game not only promotes procedural problem-solving skills but also strengthens cultural relevance, engagement, and reflective learning processes. This contribution demonstrates how culturally grounded digital game-based learning can bridge the gap between technological innovation and culturally responsive mathematics education. This aligns with evidence that ethnomathematics fosters mathematical literacy and contextual relevance (Abadi et al., 2024; Kabuye Batiibwe, 2024; Kusuma et al., 2024b; Lidinillah et al., 2022). Unlike earlier studies that emphasized gamification without cultural grounding, this research demonstrates added value through cultural integration. However, gains in conceptual understanding remained modest (+9.4; N-Gain = 0.27; low category), indicating the need for reinforcement through scaffolding or guided inquiry (Budirahayu & Saud, 2023) to balance procedural and conceptual learning across Pólya's problem-solving stages.

The cultural dimension significantly strengthened engagement and motivation, with questionnaire scores reaching 96.16% (cultural context) and 94.23% (engagement/motivation). These findings echo Pratama and Yelken (2024), who showed how ethnomathematics contextualizes abstract concepts, such as arithmetic sequences and numerical patterns, through woven motifs, textile ornaments, and traditional architecture. Thus, students not only acquire procedural understanding via interactive visualization but also connect mathematics to daily life. Compared with prior studies emphasizing general gamification benefits (Batni et al., 2024; Pérez-Jorge & Martínez-Murciano, 2022), This study highlights the unique added value of embedding local culture into digital game-based learning. Nonetheless, cultural integration proved more effective for motivation and problem-solving strategies than for conceptual mastery, reinforcing the need for teacher scaffolding (Budirahayu & Saud, 2023).

Scratch-based learning media proved both feasible and effective in enhancing problem-solving skills among students at SMPN 1 Leuwidamar, Lebak, Banten. In the number pattern test designed with Pólya's steps, 22 of 26 students (84%) exceeded the minimum mastery criterion (KKM). This demonstrates that Scratch supports both problem posing and problem-solving, aligning with Hu et al.'s (2020) meta-analysis on block-based programming, Batiibwe's (2024) insights on ethnomathematics and mathematical literacy, and Molina-Ayuso et al.'s (2022) evidence of Scratch as an effective tool for contextual mathematics teacher training. Student surveys further confirmed positive responses, with pretest–posttest analysis showing significant gains ( $t = -9.52$ ;  $p < 0.001$ ) and 84% achieving or surpassing the KKM. Despite these promising outcomes, methodological limitations must be noted. The one-group pretest–posttest design without a control group introduces threats to internal validity (e.g., testing effects, external influences) (Arif et al., 2025; Maleki et al., 2025), and the small sample ( $n = 26$ ) constrains generalizability (Ibrahim & Mohd Matore, 2025). Short intervention duration, potential teacher bias, and external factors such as student motivation and family support (Budirahayu & Saud, 2023) may also have influenced results. Accordingly, replication through quasi-experimental or randomized controlled trial (RCT) designs with larger, more diverse samples (Batni et al., 2024; Hu & Dong, 2020) and across varied socio-cultural contexts is recommended to validate and extend these findings on ethnomathematics-based Scratch learning media.

Theoretically, these findings extend Pólya's problem-solving framework by integrating ethnomathematics to enhance student engagement. Practically, Scratch-based media rooted in local culture provides an innovative tool for teaching secondary school mathematics, particularly geometry, enabling teachers to complement traditional instruction while balancing procedural fluency and conceptual understanding. The results of the study are presented in the form of graphs, tables, or descriptive text. Analysis and interpretation of these results are necessary before discussion. For experimental research, the order of presentation of the results should align with the research hypothesis, while for qualitative research, it should align with the research questions.

## Conclusion

This study developed and evaluated a Scratch-based ethnomathematics learning game incorporating Baduy cultural contexts to enhance junior high school students' mathematical problem-solving skills. Following the ADDIE development model, the media was validated by experts and implemented with Grade VII students. The validation results demonstrated high content validity (88.06%) and acceptable media validity (73.7%), indicating that the developed media is suitable for classroom use. Effectiveness testing using a one-group pretest–posttest design revealed a significant improvement in students' problem-solving performance ( $p < 0.001$ ), with mean scores increasing from 62.40 to 81.20. Improvements were most prominent in the planning and executing stages of Pólya's problem-solving model, while gains in understanding were relatively limited. These findings indicate that integrating Scratch-based digital games with ethnomathematical contexts can effectively support students' procedural problem-solving processes while enhancing engagement through culturally meaningful learning experiences. However, the small sample size and absence of a control group limit the

generalizability of the results. Future studies should employ more rigorous experimental designs with larger samples and explore instructional scaffolding strategies to strengthen conceptual understanding within interactive digital learning environments aligned with the Society 5.0 education landscape.

## Declarations

Author Contribution : AA: Conceptualization, Writing – Original Draft, Editing, and Visualization.  
RN: Validation and Supervision.  
MH: Resources, Investigation, and Data Curation.  
DY: Writing – Review & Editing, Formal Analysis, Validation, Supervision and Methodology.

Conflict of Interest : The authors declare no conflict of interest.

Additional Information : Additional information is available for this paper.

## References

- Abadi, A. K., Dewi, I. S., Islam, S., Pratama, O. P. A., Kristiono, A. A., & Wijaya, M. B. (2024). Desarrollo de medios interactivos de aprendizaje en la ciudad de Purwokerto: aspectos cognitivos del baloncesto escolar (Interactive learning media development in Purwokerto city: cognitive aspects of school basketball). *Retos*, 58, 891–902. <https://doi.org/https://doi.org/10.47197/retos.v58.106613>
- Akbar, S. (2013). *Instrumen perangkat pembelajaran*. Remaja Rosdakarya.
- Al-Hassan, O. M., Alhasan, L. M., AlAli, R. M., Al-Barakat, A. A., Al-Saud, K. M., & Ibrahim, N. A. (2025). Enhancing early childhood mathematics skills learning through digital Game-Based Learning. *International Journal of Learning, Teaching and Educational Research*, 24(2), 186–205. <https://doi.org/10.26803/ijlter.24.2.10>
- Arif, M., Sajjad, M., Khan, R. A., & Ehsan, H. R. ul. (2025). Development and validation of a tool to measure telehealth educational environment (THEEM). *BMC Medical Education*, 25(1), 136. <https://doi.org/10.1186/s12909-025-06751-5>
- Batni, B., Junaini, S. N., Sidi, J., Mustafa, W. A., & Awang Ismail, Z. I. (2024). Current research trends of scratch block based programming for K-12: A Systematic Review. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 51(2), 138–152. <https://doi.org/10.37934/araset.51.2.138152>
- Bloom, B. S. (1976). *Human characteristics and school learning*. McGraw-Hill. <https://books.google.co.id/books?id=bkUmAQAIAAJ>
- Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Springer US. <https://doi.org/10.1007/978-0-387-09506-6>
- Budirahayu, T., & Saud, M. (2023). Pedagogical innovation and teacher collaborations in supporting student learning success in Indonesia. *Cogent Education*, 10(2). <https://doi.org/10.1080/2331186X.2023.2271713>
- Cohen, J. (1988). *Statistical power analysis for the Behavioral Sciences* (2nd ed.). Lawrence Erlbaum Associate.
- Costan, E., Gonzales, G., Gonzales, R., Enriquez, L., Costan, F., Suladay, D., Atibing, N. M., Aro, J. L., Evangelista, S. S., Maturan, F., Selerio, E., & Ocampo, L. (2021). Education

- 4.0 in developing economies: a systematic literature review of implementation barriers and future research agenda. *Sustainability*, 13(22), 12763. <https://doi.org/10.3390/su132212763>
- Fagerlund, J., Häkkinen, P., Vesisenaho, M., & Viiri, J. (2020). Computational thinking in programming with Scratch in primary schools: A systematic review. *Computer Applications in Engineering Education*. <https://doi.org/10.1002/cae.22255>
- Fagerlund, J., Häkkinen, P., Vesisenaho, M., & Viiri, J. (2021). Computational thinking in programming with Scratch in primary schools: A systematic review. *Computer Applications in Engineering Education*, 29(1), 12–28. <https://doi.org/10.1002/cae.22255>
- Gustey. (2010). Lessons of mastery learning. *Educational Leadership: Journal of the Department of Supervision and Curriculum Development*, 68, 52–57. <https://eric.ed.gov/?id=EJ913779>
- Hafid, M. (2022). Islamisasi ilmu pengetahuan. *HAKAM: Jurnal Kajian Hukum Islam Dan Hukum Ekonomi Islam*, 5(2). <https://doi.org/10.33650/jhi.v5i2.3501>
- Hsiao, P.-W., & Su, C.-H. (2021). A study on the impact of steam education for sustainable development courses and its effects on student motivation and learning. *Sustainability (Switzerland)*, 13(7). <https://doi.org/10.3390/su13073772>
- Hu, X., & Dong, G. (2020). Study-related burnout of college students in China during online education period. *Proceedings - 2020 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology, WI-IAT 2020*, 746–751. <https://doi.org/10.1109/WIIAT50758.2020.00115>
- Ibrahim, S. N. A., & Mohd Matore, M. E. E. (2025). The validity of the malaysian teachers' global competency level instrument using Cohen Kappa, content validity ratio and content validity index analyses. *Journal of Applied Science, Engineering, Technology, and Education*, 7(1), 82–93. <https://doi.org/10.35877/454RI.asci3848>
- Ishak, S. A., Hasran, U. A., & Din, R. (2023). Media education through digital games: A review on design and factors influencing learning performance. *Education Sciences*, 13(2), 102. <https://doi.org/10.3390/educsci13020102>
- Ishaq. (2017). *Metode penelitian hukum dan penulisan skripsi, tesis, serta disertasi*. Alfabeta.
- Kabuye Batiibwe, M. S. (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>
- Koul, S., & Nayar, B. (2021). The holistic learning educational ecosystem: A classroom 4.0 perspective. *Higher Education Quarterly*, 75(1), 98–112. <https://doi.org/10.1111/hequ.12271>
- Kusuma, A. B., Hanum, F., Abadi, A. M., & Ahmad. (2024a). Exploration of ethnomathematics research in Indonesia 2010-2023. *Infinity Journal*, 13(2), 393–412. <https://doi.org/10.22460/infinity.v13i2.p393-412>
- Kusuma, A. B., Hanum, F., Abadi, A. M., & Ahmad, A. (2024b). Exploration of ethnomathematics research in Indonesia 2010-2023. *Infinity Journal*, 13(2), 393–412. <https://doi.org/10.22460/infinity.v13i2.p393-412>
- Liao, S.-M. (2023). Scratch to R: Toward an inclusive pedagogy in teaching coding. *Journal of Statistics and Data Science Education*, 31(1), 45–56. <https://doi.org/10.1080/26939169.2022.2090467>

- Lidinillah, D. A. M., Rahman, R., Wahyudin, W., & Aryanto, S. (2022). Integrating sundanese ethnomathematics into mathematics curriculum and teaching: a systematic review from 2013 to 2020. *Infinity Journal*, *11*(1), 33. <https://doi.org/10.22460/infinity.v11i1.p33-54>
- Maleki, A., Khodabakhshzadeh, H., Zeraatpish, M., & Baghaei, P. (2025). Development and validation of the online formative assessment validity scale (OFAVS) in EFL contexts. *Discover Sustainability*, *6*(1), 471. <https://doi.org/10.1007/s43621-025-01336-0>
- Molina-Ayuso, Á., Adamuz-Povedano, N., Bracho-López, R., & Torralbo-Rodríguez, M. (2022). Introduction to computational thinking with scratch for teacher training for spanish primary school teachers in mathematics. *Education Sciences*, *12*(12), 899. <https://doi.org/10.3390/educsci12120899>
- Nuangchalerm, P. (2020). TPACK in ASEAN perspectives: Case study on Thai pre-service teacher. *International Journal of Evaluation and Research in Education (IJERE)*, *9*(4), 993. <https://doi.org/10.11591/ijere.v9i4.20700>
- Pérez-Jorge, D., & Martínez-Murciano, M. C. (2022). Gamification with Scratch or App Inventor in Higher Education: A Systematic Review. *Future Internet*, *14*(12), 374. <https://doi.org/10.3390/fi14120374>
- PISA. (2022). *Innovating education and educating for innovation*. OECD Publishing. <https://doi.org/10.1787/9789264265097-en>
- Pokhrel, S., & Chhetri, R. (2021). A literature review on impact of covid-19 pandemic on teaching and learning. *higher education for the future*, *8*(1), 133–141. <https://doi.org/10.1177/2347631120983481>
- Pratama, R. A., & Yelken, T. Y. (2024). Effectiveness of ethnomathematics-based learning on students' mathematical literacy: a meta-analysis study. *Discover Education*, *3*(1), 202. <https://doi.org/10.1007/s44217-024-00309-1>
- Putri, Y. S., & Arsanti, M. (2022). Kurikulum Merdeka sebagai upaya pemulihan pembelajaran. *Prosiding Seminar Nasional Sultan Agung*, (November), 21–26. <https://ditsmp.kemdikbud.go.id/kurikulum-merdeka-sebagai-upaya-pemulihan-pembelajaran/%0A>
- Riduwan. (2010). *Skala pengukuran variabel-variabel penelitian*. Alfabeta.
- Sarumaha, Y. A. (2020). Introduction of TPACK in Mathematics Education Realm. *Intersections*, *5*(2), 48–58. <https://doi.org/10.47200/intersections.v5i2.606>
- Shadilly, H. (1990). *Eksiklopedi Indonesia*. Ichitar Baru- Van Hoeve. [http://opac.kaltimprov.go.id/ucs/index.php?p=show\\_detail&id=1293](http://opac.kaltimprov.go.id/ucs/index.php?p=show_detail&id=1293)
- Su, J., Zhong, Y., & Ng, D. T. K. (2022). A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region. *Computers and Education: Artificial Intelligence*, *3*, 100065. <https://doi.org/https://doi.org/10.1016/j.caeai.2022.100065>
- Su, Y.-S., Shao, M., & Zhao, L. (2022). Effect of mind mapping on creative thinking of children in scratch visual programming education. *Journal of Educational Computing Research*, *60*(4), 906–929. <https://doi.org/10.1177/07356331211053383>
- Sugiyono. (2019). *Metode penelitian pendidikan (kuantitatif, kualitatif, kombinasi, R&D dan penelitian pendidikan)*. Alfabeta.

- Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability*, *12*(23), 10113. <https://doi.org/10.3390/su122310113>
- Yulianto, D., Umami, M., Junaedi, Y., Anwar, S., Juniawan, E., & Sanjaya, T. (2025). Empowering early math education: the role of web 2.0 tools in improving counting skills in early learners. *international journal of education in mathematics, science and technology*, *13*(4), 872–894. <https://doi.org/10.46328/ijemst.4887>
- Yulianto, D., Umami, M. R., & Mony, R. S. (2024). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. <https://doi.org/10.30738/union.v12i1.16900>