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Developing Scratch-Based Ethnomathematics Game to Foster Students' Mathematical Problem-Solving Skills

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ABSTRACT Learning 5.0 requires digital learning environments that are interactive, meaningful, and culturally responsive. However, studies integrating Scratch with Baduy ethnomathematics to support students' mathematical problem-solving skills in number patterns remain limited. This study aimed to develop and evaluate a Scratch-based Baduy ethnomathematics game for Grade VII students. The study employed a research and development approach using the ADDIE model. A panel of three experts evaluated the product, six students participated in a small-group trial, and 25 students participated in a one-group pretest–posttest field test. Data were collected using expert validation sheets, student response questionnaires, and five open-ended problem-solving items. Material validation reached 100% in the final revision round, media validation reached 85%, and the overall S-CVI/Ave was 0.93. In the field test, the students' mean score increased from 62.40 on the pretest to 81.20 on the posttest, with a statistically significant difference, $t(24) = -9.52$, $p < 0.001$. Furthermore, 21 students (84%) achieved the minimum mastery criterion. Student responses were very positive, with an overall percentage of 93.92%, while the cultural-context aspect received the highest rating of 96.16%. These findings provide preliminary evidence that the developed game can support mathematical problem-solving and culturally meaningful learning of number patterns. Its main contribution lies in integrating Scratch technology, Baduy ethnomathematical contexts, and Pólya-based problem-solving scaffolding into a single digital learning medium. Nevertheless, causal conclusions remain limited because the study did not include a control group.

Keywords: baduy ethnomathematics; digital game-based learning; mathematical problem-solving; number patterns; scratch.

INTRODUCTION

Instructional approaches that prioritize one-way content transmission tend to hinder deep conceptual understanding, particularly for subjects that are abstract, dynamic, and heavily dependent on visual representation. Consequently, students often exhibit

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low learning motivation, and the development of crucial 21st-century competencies such as critical thinking, creativity, problem-solving, and digital literacy remains insufficient, even though these skills are vital for navigating global challenges in the digital transformation era (Costan et al., 2021; Koul & Nayar, 2021; Yulianto et al., 2025). As an alternative solution aligned with the principles of Learning 5.0, Scratch, a block-based visual programming platform, offers strong potential to support active, constructivist, and learner-centered learning (Ming et al., 2025). Scratch enables learners to express ideas and concepts through animations, simulations, and interactive games, shifting the focus of learning beyond final outcomes toward processes of thinking, exploration, and reflection (Ming et al., 2025). Its intuitive visual interface, which minimizes syntactic programming barriers, supports more concrete and meaningful comprehension of abstract concepts, logical structures, and cause-and-effect relationships. Consequently, integrating Scratch into learning activities enhances student engagement, deepens conceptual understanding, and fosters the development of computational thinking, creativity, and collaboration, positioning Scratch as an innovative learning solution that meets the demands of 21st-century education and internationally recognized scientific publication standards.

Learning 5.0 emphasizes the need for adaptive, personalized, and context-based pedagogical strategies, where technology serves as an enabler of meaningful, collaborative, and learner-centered experiences (González-Pérez & Ramírez-Montoya, 2022; Rusman et al., 2023). Despite ongoing efforts toward educational transformation, learning practices at various levels continue to face persistent pedagogical challenges, such as the dominance of teacher-centered instruction, low levels of student cognitive engagement, and the inadequate integration of technology into learning processes. At the same time, Education 5.0 is intended to equip graduates with the capacity to respond effectively to the evolving demands of the Fourth Industrial Revolution (4IR), an era characterized by rapid, complex, and unpredictable changes across multiple sectors, including both the opportunities and challenges posed by advances in artificial intelligence (Rymarczyk, 2020). The Education 5.0 agenda emphasizes adaptive, contextualized digital learning (Costan et al., 2021; Koul & Nayar, 2021; Yulianto et al., 2025). Integrating technology with local culture is therefore crucial: ethnomathematics enhances the relevance and meaning of mathematical concepts, while block-based visual programming such as Scratch cultivates computational thinking and problem-solving skills (Kabuye Batiibwe, 2024; Lidinillah et al., 2022; Pratama & Yelken, 2024). Consequently, a Scratch-based ethnomathematics game offers a timely, evidence-driven solution to post-pandemic educational challenges.

Scratch is a block-based visual programming environment designed for learners aged approximately 8–16 years. It enables students to create interactive graphics, animations, and audio without requiring mastery of complex programming syntax, thereby

lowering technical barriers and facilitating the modeling and exploration of mathematical concepts (Hu et al., 2021; Liao, 2023). Its visual, drag-and-drop interface allows students to focus on logical reasoning and conceptual understanding rather than technical coding procedures. When tasks are scaffolded with targeted questions and feedback, Scratch can enhance 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. Diagnostic tests at SMPN 1 Leuwidamar, Banten, showed most students failed to validate solutions, underscoring a persistent weakness. Evidence indicates that integrating Scratch-based activities with computational thinking strengthens structured reasoning and problem-solving (Fagerlund et al., 2021; Molina-Ayuso et al., 2022). Embedding mathematics in local cultural contexts through ethnomathematics further enhances relevance and engagement, supporting reflective "looking back" practices (Kabuye Batiibwe, 2024; Lidinillah et al., 2022). A nationwide study has mapped cultural practices and artifacts across Indonesia's 34 provinces, revealing mathematical concepts from basic arithmetic to advanced calculus (Kusuma et al., 2024). This urgency is reinforced by Indonesia's low PISA 2022 performance, with only 18% of students reaching Level 2 or higher (OECD, 2023a), highlighting the need for integrated strategies that strengthen problem-solving (Pólya), embed mathematics in culture, and leverage digital media.

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., 2024).

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 et al., 2021; 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., 2024; 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.

Baduy culture represents a form of local wisdom enriched with values of sustainability, harmony with nature, simplicity, and ethical living, making it a valuable source of authentic learning for fostering students' conceptual understanding and character development. Integrating Baduy culture into the learning process enables the contextualization of instructional content that is closely connected to students' socio-cultural realities, thereby enhancing the meaningfulness of learning while promoting cultural preservation, appreciative attitudes, and multicultural awareness. Within the Learning 5.0 framework, Baduy culture can be synergistically integrated with technology through a human-centered approach to holistically develop cognitive competencies, digital literacy, and humanitarian values alongside cultural identity. This study thus designs, develops, and evaluates a Scratch-based ethnomathematics game grounded in Baduy cultural practices to enhance students' problem-solving competence.

RESEARCH METHOD

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 a small-group trial guided the iterative revision of the product before field testing, thereby supporting its validity, usability, 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.

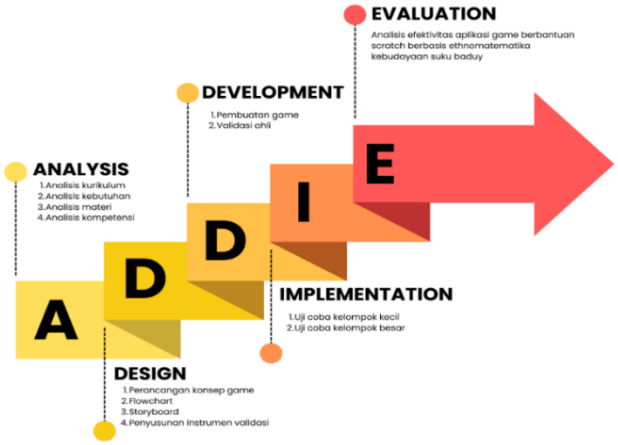


Figure 1. ADDIE Model
Source: https://waterbearlearning.com

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, five open-ended pretest and posttest items on number patterns, and response questionnaires were produced and revised based on expert feedback. The rubric assessed Pólya's four stages of understanding the problem, devising a plan, carrying out the plan, and looking back with emphasis on reflection. (4) Implement: a small-group trial ($n \approx 6$) refined technical-pedagogical aspects, followed by a field test ($n \approx 25$) 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 three 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. Product effectiveness was evaluated using descriptive statistics and a paired-samples t-test to examine differences between students' pretest and posttest problem-solving scores. Student responses were analyzed descriptively to evaluate the usability, engagement, learning support, cultural relevance, and Pólya-based scaffolding of the developed game.

The research instruments included: (1) expert validation sheets for content and media (feasibility questionnaires); (2) pretest and posttest items on number patterns, 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 expert panels, with I-CVI and S-CVI indices calculated (Arif et al., 2025).

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 (number-pattern) with the curriculum and the integration of ethnomathematics.	5-point Likert questionnaire (1 = strongly disagree, 5 = strongly agree)	A panel of three experts in mathematics content, learning media, and ethnomathematics.	Content Validity Index (I-CVI & S-CVI), descriptive analysis	I-CVI ≥ 0.78; S-CVI/Ave ≥ 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	A panel of three experts in mathematics content, learning media, and ethnomathematics.	Content Validity Index (I-CVI & S-CVI), descriptive analysis	I-CVI ≥ 0.78; Cronbach's α ≥ 0.70 (Ishak et al., 2023)
Essay Test	Measure students' mathematical problem-solving skills in number patterns	Five open-ended items scored using a Pólya-based analytic rubric	Three experts for content validation and 25 Grade VII students in the field test	Mean, standard deviation, minimum and maximum scores, mastery percentage, and paired samples t-test	Significant pretest–posttest difference at $p < 0.05$ and achievement of the minimum mastery criterion
Student Response Questionnaire	Capture students' perceptions of the practicality and acceptability of the Scratch-based game.	5-point Likert questionnaire	6 students in the small-group trial and 25 students in the field test	Descriptive analysis (mean, percentage)	≥ 75% positive responses → feasible for use
Teacher Response Questionnaire	Gather practical input on classroom implementation.	5-point Likert questionnaire and open-ended questions	Mathematics teacher at the research site	Descriptive and qualitative content analysis (feedback)	

Material validation assessed the accuracy, curricular alignment, presentation, and cultural appropriateness of the number-pattern content. Media validation assessed readability, visual design, navigation, interactivity, response handling, automated feedback, and documentation. Ethnomathematics validation focused on the accuracy and appropriateness of the Baduy cultural contexts embedded in the learning activities. The experts evaluated five key aspects: readability, presentation quality, ease of use, answer

processing, and documentation. Media validation applied similar evaluation criteria, with particular attention to the clarity of language, accuracy of mathematical terminology, instructional comprehensibility, visual appearance, navigation, feedback mechanisms, alignment with learning objectives, and documentation quality. In addition, a mathematics learning media specialist assessed two overarching dimensions, namely content feasibility covering conceptual accuracy and relevance to the curriculum and presentation feasibility, which included interface design, readability, interactivity, answer processing, and documentation. The validation process utilized a Likert-scale questionnaire as the assessment instrument.

Students' mathematical problem-solving skills were assessed using essay-based pretest and posttest items on number patterns. The analytic scoring rubric was based on Pólya's four stages: (1) understanding the problem, including identifying known and unknown information; (2) devising a plan, including selecting an appropriate strategy; (3) carrying out the plan, including applying the strategy accurately; and (4) looking back, including checking and interpreting the solution. 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.

Validity was determined using percentage criteria: 0–25% = highly invalid (complete revision), 26–50% = invalid (revision), 51–75% = valid (trial-ready), and 76–100% = highly valid (implementation-ready) (Maleki et al., 2025). A product was considered valid at ≥ 51%, with lower scores revised and re-evaluated (see Table 2), following formative evaluation principles to ensure alignment with learning goals (Maleki et al., 2025). 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 et al., 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 Grade VII students from SMPN 1 Leuwidamar, Lebak Regency, Banten. Six students participated in the small-group trial to identify usability and technical issues, while 25 students participated in the field test to evaluate the practicality and preliminary effectiveness of the developed game. The participating Baduy Indigenous students were characterized by strong adherence to traditional values, a simple lifestyle, and close harmony with nature, which shaped their experience-based and contextual learning tendencies. Therefore, culturally responsive, concrete, and visually supported learning approaches were particularly appropriate for supporting their cognitive development and emerging digital literacy. Participants were purposively selected based on three criteria: (1) current study of number patterns, (2) access to digital devices, and (3) willingness to participate. The study adopted a one-group pretest–posttest design without a control group, consistent with the early R&D stage emphasizing product feasibility in a limited context.

Data Collection and Analysis

Data were collected across the Develop, Implement, and Evaluate stages. Expert validation data were obtained during product development, small-group response data were collected from six students, and field-test data were obtained from 25 students through pretest and posttest assessments and student response questionnaires. The expert validation data were analyzed using percentages, I-CVI, and S-CVI/Ave to determine the feasibility of the developed game. Students' pretest and posttest scores were analyzed descriptively using means, standard deviations, minimum scores, and maximum scores, followed by a paired-samples t-test to examine the statistical significance of the score difference. Student responses were analyzed using mean scores and percentages. The developed game was considered feasible when the final expert validation scores met the valid or highly valid criteria. Preliminary effectiveness was indicated by a statistically significant difference between pretest and posttest scores at $p < 0.05$ and by the proportion of students achieving the minimum mastery criterion. Student acceptance was determined from the mean response scores and percentage categories.

RESULTS AND DISCUSSION

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 students' learning needs in number patterns and evaluated their alignment with the mathematics curriculum. Classroom observations and teacher interviews revealed limited use of interactive digital media and students' difficulties in recognizing numerical regularities, determining subsequent terms, formulating general rules, and reviewing their problem-solving processes. A review of the Merdeka Curriculum also indicated a gap between the expected competencies and classroom practices, particularly in providing contextual and culturally relevant mathematical problems. These findings suggested the need for an ethnomathematics-based learning approach that could make abstract number-pattern concepts more meaningful to students.

Table 3. Needs Analysis

Aspect	Findings & Gaps	Game Development Implications
Student Needs	Difficulties in recognizing numerical regularities, determining subsequent terms, formulating general rules, and applying problem-solving strategies to number-pattern problems; limited use of interactive digital media.	The Scratch-based ethnomathematics game provides interactive visualization, culturally contextualized problems, and systematic 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.

Previous studies have confirmed that integrating local culture into mathematics learning can increase instructional relevance, student engagement, and mathematical literacy (Kabuye Batiibwe, 2024; Kusuma et al., 2024; Pratama & Yelken, 2024). In the present study, Baduy cultural contexts were considered relevant for connecting number patterns with students' everyday and socio-cultural experiences. Meanwhile, Scratch-based learning media have been shown to support computational thinking and mathematical problem-solving through interactive visualization, exploration, and immediate feedback (Batni et al., 2024; Fagerlund et al., 2021; Y.-S. Su et al., 2022). Therefore, the results of the analysis provided the basis for developing a Scratch-based Baduy ethnomathematics game that integrates number-pattern content, interactive visual activities, and systematic problem-solving processes.

Design

The design stage translated the findings of the needs analysis into instructional and technical specifications for the Scratch-based Baduy ethnomathematics game. This

stage involved reviewing the number-pattern content, preparing the learning scenario, developing the game storyboard and navigation flow, and designing the research instruments. The content focused consistently on number patterns and was contextualized through Baduy cultural practices, including numerical sequences represented in harvest activities, traditional weaving patterns, and the structural arrangement of traditional houses. These cultural contexts were selected to connect abstract mathematical concepts with meaningful situations familiar to students. Previous studies have shown that integrating local culture into mathematics learning can strengthen contextual understanding, student engagement, and mathematical literacy (Kabuye Batiibwe, 2024; Kusuma et al., 2024; Pratama & Yelken, 2024).

The learning activities were organized according to Pólya's four problem-solving stages: understanding the problem, devising a plan, carrying out the plan, and looking back. The apperception and contextual problem menus were designed to help students identify known and unknown information in number-pattern problems. Guided questions supported students in formulating appropriate solution strategies, while interactive animations, visual pattern manipulation, and practice exercises facilitated the implementation of those strategies. Reflection prompts, fill-in activities, and automated feedback were incorporated to encourage students to review their procedures and verify their answers. This design is consistent with previous findings that Scratch-based learning can support structured reasoning, computational thinking, and mathematical problem-solving through interactive visualization and immediate feedback (Batni et al., 2024; Fagerlund et al., 2021; Y.-S. Su et al., 2022).

The design outputs included the game storyboard, navigation flow, main interface, contextual learning materials, interactive exercises, discussion activities, problem-solving rubric, and reflection features. The main interface consisted of a welcome page, an apperception menu, a learning menu containing number-pattern materials, an interactive quiz, a discussion menu, and reflection activities. Audio-visual elements and automated feedback were designed to increase interactivity and guide students through the problem-solving process. Validation and assessment instruments were also prepared during this stage, as described in the Research Method section. The overall design was reviewed by material, media, and ethnomathematics experts, to ensure mathematical accuracy, curricular alignment, usability, and cultural appropriateness before the prototype proceeded to the development stage.

Develop

The development stage produced Prototype I of the Scratch-based Baduy ethnomathematics game focusing on number patterns. The prototype consisted of a welcome page, an apperception menu, contextual learning materials, interactive number-pattern activities, exercises, a discussion menu, reflection prompts, and automated feedback. The initial prototype was developed based on the storyboard, navigation flow, instructional

specifications, and Pólya-based problem-solving activities established during the design stage.

Prototype I was subsequently reviewed by material, media, and ethnomathematics experts. The expert feedback primarily concerned the consistency of the visual design, clarity of instructional content, ease of navigation, completeness of documentation, and explicit integration of Pólya's problem-solving stages. The reviewers also recommended strengthening the connection between the number-pattern content and Baduy cultural contexts. Based on this feedback, several revisions were made, including improving menu navigation, clarifying instructions, reorganizing the presentation of number-pattern materials, refining the visual elements, adding automated feedback, and strengthening reflection prompts to support the looking-back stage. These revisions resulted in Prototype II, which provided more systematic, interactive, and culturally contextualized learning activities. 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. Results of Material Validation Across Revision Rounds

No	Aspect	Stage 1	Stage 2	Stage 3
1	Content	9	11	12
2	Presentation	12	14	16
	Total	21	25	28
	Score (%)	75%	89.29%	100%
	Criteria	Valid	Highly Valid	Highly Valid

Table 5. Results of Media Validation Across Revision Rounds

No	Aspect	Stage 1	Stage 2
1	Readability	4	7
2	Display	5	6
3	Ease of Use	5	7
4	Response Handling	7	10
5	Documentation	4	4
	Total	25	34
	Score (%)	62.50%	85%
	Criteria	Valid	Highly Valid

The material expert validation (Table 4) showed steady improvement from stage 1 (75%) to stage 3 (100%) 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 (2023) finding that layered CVI validation ensures strong feasibility for practical implementation.

Table 6. Final CVI Results of Expert Assessment

Aspect	I-CVI Min	I-CVI Max	S-CVI/Ave	Criteria
Content and presentation	0.83	1.00	0.94	Highly valid
Media usability, design, and interactivity	0.78	0.89	0.85	Valid
Baduy ethnomathematics context	1.00	1.00	1.00	Highly valid
Overall	–	–	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.

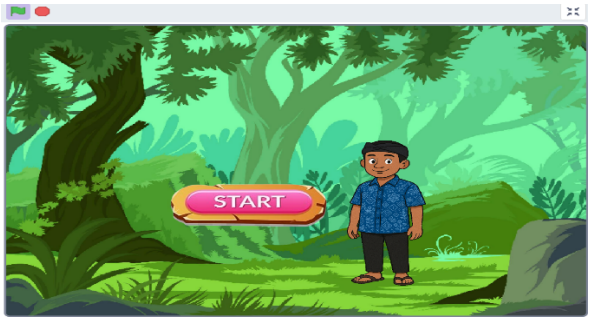


Figure 2. Home Page Interface



Figure 3. Learning Menu Interface



Figure 4. Quiz Interface



Figure 5. Apperception Interface



Figure 6. Competency Standards (KD) Menu

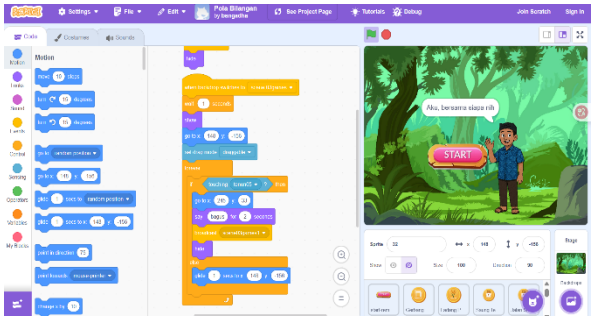


Figure 7. Discussion Menu

The developed learning medium 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 learning medium is systematic, interactive, and contextual: the content is pedagogically valid, the design is feasible for classroom use, and the features enhance engagement and motivation.

As presented in Table 7, 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 7. Student Responses in the Small-Group Trial

Usability	Engagement/ Motivation	Learning	Cultural Context	Pólya's Scaffolding	Overall Average
4.1 (Good)	4.3 (Very Good)	4.2 (Good)	4.4 (Very Good)	4.0 (Good)	4.2 (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 learning 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 et al. (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 25 Grade VII students at SMPN 1 Leuwidamar, Banten, using a one-group pretest–posttest design. Students completed five open-ended pretest and posttest items focusing on number patterns. The items were scored using an analytic rubric based on Pólya's problem-solving stages, including understanding the problem, devising a plan, carrying out the plan, and looking back. During the implementation, students used the Scratch-based Baduy ethnomathematics game to explore numerical regularities, solve culturally contextualized problems, receive automated feedback, and review their solutions.

Table 8. Field-Test Pretest and Posttest Results

Statistic	N	Mean	Standard Deviation	Minimum Score	Maximum Score
Pretest	25	62.40	8.15	48	75
Posttest	25	81.20	7.45	65	100

The descriptive results of the field test are presented in Table 8. The mean score increased from 62.40 in the pretest to 81.20 in the posttest. The posttest standard deviation was slightly lower than the pretest standard deviation, indicating that the distribution of posttest scores was somewhat less dispersed. The increase in the mean score provides initial evidence that students performed better after using the developed game. The interactive visualization and step-by-step activities in Scratch may have helped students recognize number-pattern relationships, select appropriate strategies, and carry out their solutions more systematically. This interpretation is consistent with previous studies indicating that Scratch-based activities can support structured reasoning and mathematical problem-solving when accompanied by appropriate pedagogical guidance (Batni et al., 2024; Fagerlund et al., 2021).

Table 9. Distribution of Students' Posttest Results

Score Category	Number of Students	Percentage	Description
= 100 (Perfect)	8	32%	Excellent mastery
70–99 (≥ Passing Grade)	13	52%	Achieved the mastery criterion
< 70 (Below Passing Grade)	4	16%	Did not achieve the mastery criterion
Total	25	100%	-

Table 9 presents the distribution of students' posttest scores. A total of 21 of the 25 students (84%) met or exceeded the minimum mastery criterion. Eight students (32%) achieved a score of 100, 13 students (52%) obtained scores between 70 and 99, and four students (16%) remained below the mastery criterion. These results indicate that most students were able to solve the number-pattern problems after participating in the learning activities. Nevertheless, the four students who did not achieve the mastery criterion demonstrate that the developed game cannot entirely replace teacher guidance, particularly when students experience difficulties interpreting contextual information or selecting an appropriate solution strategy.

The mastery results may also be related to the use of Baduy cultural contexts, which connected abstract number-pattern concepts with more meaningful visual and contextual situations. Ethnomathematical contexts can help students recognize the relevance of mathematical ideas to everyday and cultural practices, thereby supporting engagement and contextual understanding (Kabuye Batiibwe, 2024; Pratama & Yelken, 2024). However, because the study did not separately test the effect of the cultural component, these findings should be interpreted as evidence of contextual relevance rather than proof that Baduy ethnomathematics alone caused the improvement in students' scores.

Table 10. Paired-Samples t-test Results

Variable	Mean Difference	t-value	p-value	df	Conclusion
Pretest–Posttest	-18.80	-9.52	< 0.001	24	Significant

The paired-samples t-test results presented in Table 10 indicated a statistically significant difference between the pretest and posttest scores, $t(24) = -9.52$, $p < 0.001$. This finding provides preliminary evidence that students' mathematical problem-solving scores improved following the implementation of the Scratch-based Baduy ethnomathematics game. The result is consistent with previous research showing that Scratch-based interactive activities can facilitate mathematical exploration, visualization, and systematic problem-solving (Batni et al., 2024; Fagerlund et al., 2021). Nevertheless, because this study used a one-group pretest–posttest design without

a control group, the observed improvement cannot be attributed exclusively to the developed game.

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 Hu, Chen, and Su's (2020) meta-analysis on block-based programming effectiveness. Collectively, these results confirm strong student acceptance and validate the Scratch-based ethnomathematics medium as a relevant and effective tool for 21st-century education.

Table 11. Student Responses to the Scratch-Based Ethnomathematics Media

Domain	Mean Score	Percentage (%)	Category
Usability	4.61	92.17	Very Positive
Engagement/Motivation	4.71	94.23	Very Positive
Learning	4.71	94.11	Very Positive
Cultural Context	4.81	96.16	Very Positive
Pólya's Scaffolding	4.51	90.21	Very Positive
Overall Average	4.70	93.92	Very Positive

Discussion

The findings indicate that students perceived the developed game as usable, engaging, and culturally relevant. The combination of interactive visualization, automated feedback, and contextual number-pattern problems may have contributed to these positive responses. 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 et al., 2021). Integrating ethnomathematics further strengthens cultural relevance and deepens student engagement (Kabuye Batiibwe, 2024; Pratama & Yelken, 2024).

The improvement across the validation rounds shows that expert feedback contributed to clearer content organization, better navigation, stronger cultural integration, and more explicit problem-solving scaffolding.

This study advances prior work by integrating Baduy cultural contexts into a Scratch-based ethnomathematics game, enhancing procedural skills, motivation, and engagement. This aligns with evidence that ethnomathematics fosters mathematical literacy and contextual relevance (Abadi et al., 2024; Kabuye Batiibwe, 2024; Kusuma et al., 2024; Lidinillah et al., 2022). Unlike earlier studies that emphasized gamification without cultural grounding, this research demonstrates added value through cultural integration. Unlike previous studies that primarily employed Scratch for general gamification or computational thinking, this study combined Scratch technology, Baduy ethnomathematical contexts, and Pólya-based scaffolding in a single number-pattern learning game.

Student responses showed particularly positive perceptions of the cultural context and engagement components. 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. The Baduy cultural contexts may have made number-pattern problems more meaningful by connecting numerical regularities with harvest activities, weaving patterns, and traditional house structures. Nevertheless, the questionnaire results represent students' perceptions and cannot establish that the cultural component independently caused the improvement in test scores.

The Scratch-based learning medium provided preliminary evidence that it was both feasible and effective in enhancing problem-solving skills among students at SMPN 1 Leuwidamar, Lebak, Banten. The fact that 21 of 25 students achieved the mastery criterion suggests that most students were able to apply problem-solving strategies to number-pattern tasks. However, the four students who remained below the criterion indicate that digital media cannot completely replace teacher guidance. 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 exceeding the minimum mastery criterion (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 field-test sample (n = 25) 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 et al., 2021) and across varied socio-cultural contexts is recommended to validate and extend these findings on ethnomathematics-based Scratch learning media.

Practically, the developed Scratch-based game provides mathematics teachers with an interactive, culturally grounded tool for contextualizing abstract number-pattern concepts, complementing traditional instruction, and balancing procedural fluency with conceptual understanding.

CONCLUSION AND RECOMMENDATION

This study successfully developed a Scratch-based Baduy ethnomathematics game for teaching number patterns to Grade VII students. The developed product integrates interactive visualization, culturally meaningful Baduy contexts, automated feedback, and Pólya's problem-solving stages within a coherent digital learning environment. Expert validation indicated that the content, media design, and cultural components met the required feasibility criteria, while the small-group and field-test responses showed that students perceived the game as usable, engaging, and culturally relevant. The field-test results also provided preliminary evidence of improvement in students' mathematical problem-solving skills after using the game. The main contribution of this study lies in combining Scratch technology, Baduy ethnomathematics, and structured problem-solving scaffolding in a single learning medium. This integration offers mathematics teachers a practical alternative for contextualizing abstract number-pattern concepts and encouraging active exploration. Nevertheless, the findings should be interpreted within the limited one-group research context, and teacher guidance remains important for supporting conceptual understanding and reflective problem-solving.

Recommendations

The study is limited by its small sample size and one-group design, making the results preliminary. Future research should employ quasi-experimental or randomized controlled designs with larger, more diverse samples across socio-cultural contexts. The weak performance in understanding highlights the need for complementary approaches such as guided inquiry and scaffolding to balance procedural and conceptual mastery. Teachers also require TPACK-based training to ensure digital media

use supports reflective practices like looking back. Expanding ethnomathematical integration beyond Baduy culture could further enrich insights and inform policies that align local wisdom with the Education 5.0 agenda.

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