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Integrating Ethnomathematics into Guided Inquiry Learning: Designing Culturally Responsive Mathematics Instruction to Support Students' Mathematical Reasoning, Connections, and Appreciation

Dhoriva Urwatul Wutsqa, Hery Nugroho *, Septi Yana Wulandari

Mathematics Education Department, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

* Correspondence: herynugroho.2023@student.uny.ac.id

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Abstract

Although numerous studies have developed guided inquiry-based instructional materials for mathematics education, most have relied on generic problem contexts and have given limited attention to the integration of ethnomathematics as a meaningful cultural resource for learning. Furthermore, prior research has focused primarily on cognitive outcomes, leaving the combined influence of inquiry-based instruction on students' mathematical reasoning, mathematical connections, and mathematical appreciation underexplored. To address this gap, this study aimed to describe the design process and evaluate the implementation of Ethnomathematics-Integrated Guided Inquiry Teaching Devices (GITD-E). Employing a Research and Development (R&D) approach based on the ADDIE framework, the study involved Grade VII students at a junior high school in Yogyakarta, Indonesia. Data were collected through expert validation, practicality questionnaires, classroom observations, and post-test assessments, while implementation outcomes were examined using a one-shot case study design. The findings indicate that the developed GITD-E met established criteria of validity and practicality and yielded positive learning outcomes. In addition, integrating local cultural contexts appeared to enhance students' engagement and support more meaningful mathematics learning experiences. Theoretically, this study extends guided inquiry learning by positioning ethnomathematics as a contextual dimension within inquiry-based mathematics instruction. Practically, it offers insights for designing culturally responsive, contextually relevant, and student-centered mathematics learning environments.

Keywords: Ethnomathematics; Guided inquiry; Mathematical Reasoning; Mathematical Connection; Mathematical Appreciation; Teaching Devices

Introduction

Mathematics education in secondary schools continues to face persistent challenges related to students' conceptual understanding and meaningful engagement with mathematical ideas. Although many students are able to solve routine procedural tasks, a substantial body of research indicates that they often experience difficulties when confronted with problems requiring reasoning, the coordination of multiple mathematical concepts, and an understanding of the meaning and purpose of mathematics itself (Kablan & Uğur, 2021; Özreçberoğlu & Çağanağa, 2018; Öztürk et al., 2020; Thanheiser & Melhuish, 2023). Such findings suggest that mathematics instruction has not yet fully realized its potential to cultivate higher-order forms of mathematical thinking. One manifestation of this challenge is students' limited mathematical reasoning. Rather than constructing and justifying mathematical ideas, students frequently rely on procedural execution without understanding the underlying rationale of the methods they employ (Kania et al., 2025; Quarfoot & Rabin, 2022; Sigus & Mädamürk, 2024). Consequently, many students encounter difficulties in formulating mathematical arguments, drawing valid conclusions, and generating mathematical generalizations.

Beyond reasoning, students' ability to establish mathematical connections remains a significant concern. Research has shown that many learners perceive mathematics as a collection of isolated topics rather than a coherent and interconnected body of knowledge, making it difficult for them to relate mathematical ideas across topics, connect mathematics with other disciplines, or recognize its relevance in everyday contexts (Loka Son, 2022; Wedman & Bennet, 2025). Equally important is students' appreciation of mathematics. Mathematics is frequently perceived as abstract (Nugroho, Desti, et al., 2025; Nugroho et al., 2024; Nugroho, Sugiman, et al., 2025; Nugroho & Septianisha, 2025), rigid (Jiang et al., 2021; Rebollo et al., 2022), and detached from social and cultural realities (Ernest, 1991, 2015). As a result, mathematics learning often fails to support students' development not only in cognitive domains but also in affective dimensions that shape their engagement with mathematical activity. These challenges highlight the need for instructional approaches that actively engage students in exploration, reasoning, and reflection while fostering meaningful relationships between mathematics and their lived experiences.

Guided inquiry learning offers one such approach. Its central premise is that knowledge is constructed through the investigation of meaningful problems, enabling students to develop conceptual understanding through active engagement with mathematical ideas (Chen & Chen, 2025; de Jong et al., 2023). Through processes of questioning, exploration, conjecturing, and justification, students are encouraged to construct mathematical knowledge rather than passively receive it. Such experiences have the potential to support the development of both mathematical reasoning and mathematical connections. However, inquiry processes are likely to become more meaningful when the problems investigated emerge from contexts that are familiar and relevant to students' everyday lives. Contextually meaningful situations can simultaneously stimulate cognitive engagement and affective involvement, thereby enhancing the quality of learning experiences (Prahmana et al., 2025; Rubel & McCloskey, 2021). Consistent with this perspective, D'Ambrosio (2003) argued that real-world and culturally grounded problems can promote students' interest in and understanding of mathematics through an ethnomathematical approach.

Ethnomathematics conceptualizes mathematics as a human activity embedded within social and cultural practices (D'Ambrosio, 1985, 2007, 2016). From this perspective, mathematical knowledge cannot be separated from the cultural contexts in which it is generated, interpreted, and applied (Bishop, 1988; Khasanah et al., 2023; Mellawaty et al., 2023). Ethnomathematics therefore extends mathematics learning beyond the acquisition of formal structures by enabling students to recognize how mathematical ideas are manifested in everyday activities, traditions, and cultural artefacts (D'Ambrosio & Rosa, 2016; Nur et al., 2020; Rosa & Orey, 2011). As a result, ethnomathematics provides a rich source of authentic and meaningful contexts through which students can explore mathematical concepts, develop reasoning, establish conceptual connections, and cultivate a deeper appreciation of mathematics. To realize this potential, however, cultural contexts need to be systematically incorporated into instructional design rather than functioning merely as supplementary examples.

Instructional materials play a central role in mediating this integration because they guide both teachers' pedagogical decisions and students' learning experiences (Putri et al., 2019; Yerizon et al., 2022). Within inquiry-oriented environments, instructional materials structure the process of problem formulation, investigation, concept construction, and conclusion drawing. Integrating ethnomathematics into guided inquiry-based instructional materials therefore creates opportunities for students to engage with mathematical investigations situated in culturally meaningful contexts. Such integration enables learners to connect formal mathematical concepts with familiar cultural practices, thereby supporting more meaningful conceptual construction. Moreover, positioning culture as an integral component of inquiry-based learning may simultaneously strengthen students' cognitive engagement through reasoning and conceptual exploration and their affective engagement through increased relevance, identity affirmation, and appreciation of mathematics as a culturally situated human endeavor.

Several studies have developed guided inquiry-based instructional materials for mathematics learning (Asnidar et al., 2018; Eshetu et al., 2022; Istikomah et al., 2022; Miftahul Jannah et al., 2020; Nunaki et al., 2019; Ogunjimi & Gbadeyanka, 2022; Opticia et al., 2022). However, these studies have generally employed broad or context-neutral problem situations and have rarely incorporated ethnomathematical perspectives into the design of instructional materials. Furthermore, previous research has primarily examined learning outcomes (Asnidar et al., 2018; Miftahul Jannah et al., 2020; Nunaki et al., 2019), conceptual understanding (Eshetu et al., 2022; Istikomah et al., 2022), critical thinking, and academic achievement (Ogunjimi & Gbadeyanka, 2022). Although guided inquiry has been widely implemented, its systematic integration with ethnomathematics within instructional materials, particularly in geometry learning, remains underexplored. Moreover, few studies have simultaneously examined mathematical reasoning, mathematical connections, and appreciation of mathematics, despite the importance of these dimensions in fostering meaningful mathematics learning experiences.

Addressing these gaps, this study introduces Ethnomathematics-Integrated Guided Inquiry Teaching Devices (GITD-E) and examines both their development process and implementation. Theoretically, the study contributes to the literature on guided inquiry learning by positioning ethnomathematics as a contextual and cultural component that supports mathematical reasoning, mathematical connections, and students' appreciation of mathematics. Practically, the resulting instructional materials provide a reference for teachers seeking to design culturally responsive and meaningful mathematics learning experiences and offer insights for curriculum developers and policymakers interested in strengthening the integration of local cultural knowledge within mathematics education.

Accordingly, this study is guided by the following research questions: (1) How are GITD-E designed? and (2) How does the implementation of GITD-E support students' mathematical reasoning, mathematical connections, and appreciation of mathematics? Therefore, the study aims to describe the design process of GITD-E and examine its implementation in supporting these dimensions of students' mathematical learning.

Methods

This study employed a Research and Development (R&D) methodology to design, validate, and evaluate GITD-E for mathematics learning. R&D is particularly appropriate for studies that aim not only to generate educational products but also to examine their quality and implementation within authentic educational settings (Gall et al., 1989). The development process was guided by the ADDIE framework, which consists of five interrelated phases: Analysis, Design, Development, Implementation, and Evaluation (Molenda, 2002). The ADDIE model was selected because it provides a systematic structure for designing instructional products while ensuring alignment among learning needs, instructional objectives, implementation processes, and evaluation procedures.

The primary products developed in this study were lesson plans and student worksheets integrating guided inquiry learning with ethnomathematical contexts. Beyond producing pedagogically feasible instructional materials, the study also examined how the implementation of GITD-E supported students' mathematical reasoning, mathematical connections, and appreciation of mathematics. Accordingly, the study combined product development objectives with an examination of learning outcomes associated with the use of the developed instructional materials.

Analysis

The analysis phase was conducted to establish the conceptual and contextual foundations of the instructional design. This phase comprised three complementary activities: needs analysis, learner analysis, and curriculum analysis. The needs analysis was conducted through classroom observations and interviews with mathematics teachers to identify challenges encountered in mathematics instruction, particularly those related to students' mathematical reasoning, mathematical connections, and appreciation of mathematics. Learner analysis focused on students' cognitive characteristics, participation patterns during learning, and familiarity with local cultural practices that could serve as meaningful contexts for ethnomathematical integration. Curriculum analysis examined the alignment of the selected mathematical content with the Indonesian 2013 Curriculum, including core competencies, basic competencies, and learning objectives. The findings from these analyses informed the development of instructional materials that were pedagogically relevant, culturally responsive, and contextually appropriate.

Design

The design phase aimed to translate the findings of the analysis phase into an initial instructional framework. Two forms of design were produced during this stage: instructional product design and research instrument design. The instructional product design focused on the development of lesson plans and student worksheets integrating guided inquiry principles with ethnomathematical contexts. Learning activities were structured to support students' inquiry processes through problem identification, concept exploration, collaborative discussion, justification of findings, and conclusion drawing. Ethnomathematical contexts were embedded throughout these activities to provide meaningful situations through which students could investigate mathematical concepts.

The research instrument design involved the development of instruments intended to assess students' mathematical reasoning, mathematical connections, and appreciation of mathematics. The mathematical reasoning test was developed based on the framework proposed by Goos et al. (2020) and consisted of four open-ended items measuring students' abilities to formulate mathematical conjectures, identify patterns, draw logical conclusions, and evaluate the validity of mathematical statements. The blueprint of the mathematical reasoning instrument is presented in Table 1.

Table 1. Blueprint of Mathematical Reasoning Instrument

Aspect	Indicator	Item Number
Formulating conjectures	Students are able to formulate conjectures related to the properties of triangles and quadrilaterals based on contextual problems	1
Identifying patterns	Students are able to identify patterns and relationships among the angles, sides, perimeter, or area of triangles and quadrilaterals	2
Drawing conclusions	Students are able to draw logical conclusions from problems involving triangles and quadrilaterals in cultural contexts	3
Evaluating mathematical statements	Students are able to evaluate the correctness of mathematical arguments related to triangles and quadrilaterals	4

The mathematical connection test comprised three open-ended items adapted from the mathematical connection standards proposed by the National Council of Teachers of Mathematics (NCTM, 2000). The instrument assessed students' abilities to establish connections among mathematical topics, connect mathematics with other disciplines, and relate mathematical concepts to real-life situations. The blueprint of the mathematical connection instrument is presented in Table 2.

Table 2. Blueprint of Mathematical Connection Instrument

Aspect	Indicator	Item Number
Connections among mathematical topics	Students are able to connect concepts of perimeter, area, and properties of triangles and quadrilaterals	1
Connections between mathematics and other disciplines	Students are able to relate geometric concepts in triangles and quadrilaterals to cultural artefacts and daily activities	2
Connections between mathematics and daily life	Students are able to apply concepts of triangles and quadrilaterals to solve contextual problems in everyday life	3

To assess students' appreciation of mathematics, a 22-item questionnaire was developed based on Aiken's (1974) framework. The questionnaire measured three dimensions: interest in mathematics, enjoyment of mathematics and mathematics-related activities, and perceived usefulness of mathematics. The instrument blueprint is presented in Table 3.

Table 3. Blueprint of Mathematics Appreciation Questionnaire

Aspect	Indicator	Item Number
Interest	Showing interest in mathematics	2, 7, 11, 18
Enjoyment	Showing enjoyment toward mathematics	1, 9, 14, 20
	Enjoying activities related to mathematics	4, 10, 16, 22
Usefulness	Recognizing the usefulness of mathematics in daily life	3, 8, 13, 19
	Recognizing the role of mathematics in developing ways of thinking	5, 6, 12, 15, 17, 21

Development

The development phase focused on transforming the initial design into a complete instructional product and establishing its validity and practicality. Following the recommendations of Nugroho et al. (2024), this phase consisted of three major activities: (1) product development, (2) internal validation, and (3) external validation.

The GITD-E materials were developed by transforming the instructional storyboard produced during the design phase into complete lesson plans and student worksheets using Microsoft Word and Canva. Product development was conducted iteratively through continuous consultation with academic supervisors to ensure the quality of the instructional content, visual presentation, and integration of key learning components, including competencies, learning objectives, instructional materials, inquiry activities, and assessment tasks.

Internal validity was evaluated by two mathematics education experts from public universities in Yogyakarta using a five-point Likert-type validation instrument ranging from 1 (strongly disagree) to 5 (strongly agree). Quantitative analysis involved examining inter-rater agreement using Cohen's Kappa as an indicator of content validation consistency (McHugh, 2012), while content validity was evaluated using Aiken's V coefficient (Aiken, 1985). Qualitative feedback from experts was used to revise and refine the instructional materials. Validation scores were converted into feasibility percentages and interpreted according to the criteria proposed by Arikunto (2013), ranging from very poor to very good.

The validity percentage was calculated using the following formula:

$$P = \frac{\Sigma n_i}{N} \times 100\%$$

Note:

P = percentage of assessment score

Σn_i = score obtained

N = maximum score

The research instruments were subsequently examined for content and construct validity. Content validity was established through expert review, whereas construct validity was assessed through Confirmatory Factor Analysis (CFA) using data obtained from 100 junior high school students in Yogyakarta. Internal consistency reliability was examined using Cronbach's alpha coefficient.

External validation focused on practicality and involved one mathematics teacher and 31 students. The practicality evaluation examined the content, presentation, language, and graphical aspects of the developed materials illustrated in Table 4. Findings from this stage informed subsequent revisions until the instructional materials met the established practicality criteria and were deemed suitable for classroom implementation.

Table 4. GITD-E Practicality Level

Lesson Plan	Student Worksheet Interval Score	Category
$X > 29.4$	$X > 37.8$	Very good
$23.8 < X \leq 29.4$	$30.6 < X \leq 37.8$	Good
$18.2 < X \leq 23.8$	$23.4 < X \leq 30.6$	Sufficient
$12.6 < X \leq 18.2$	$16.2 < X \leq 23.4$	Bad
$X \leq 12.6$	$X \leq 16.2$	Very bad

Implementation

The implementation phase examined the use of GITD-E in an authentic classroom setting. Participants consisted of 32 Grade VII students aged 12–13 years enrolled in a public junior high school in Yogyakarta, Indonesia. The study employed a one-shot case study design conducted across seven instructional meetings.

The participating class was selected purposively based on accessibility, the school's willingness to implement ethnomathematics-based learning, and the mathematics teacher's assessment that the class represented typical Grade VII learning characteristics and achievement levels. Throughout the implementation, all learning activities were conducted according to the guided inquiry model integrated with ethnomathematical contexts.

Classroom observations were conducted to monitor the fidelity of implementation and students' engagement during learning. The implementation of GITD-E was considered practical when the percentage of learning implementation exceeded 80%. Data collected during this phase were used to evaluate the outcomes associated with the developed instructional materials.

Evaluation

The evaluation phase consisted of a summative assessment designed to examine how the implementation of GITD-E supported students' mathematical reasoning, mathematical connections, and appreciation of mathematics. Students' mathematical reasoning and mathematical connection scores were interpreted using the school's Minimum Mastery Criterion known as KKM of 75. Students' appreciation of mathematics was evaluated using the established questionnaire category intervals, with an average score of at least 74.8 indicating a high level of appreciation. Prior to inferential analysis, data normality was assessed using the One-Sample Kolmogorov–Smirnov test. Subsequently, One-Sample t-tests were conducted at a significance level of .05 to determine whether students' mean scores significantly exceeded the predetermined performance criteria. These analyses were used to evaluate the extent to which the implementation of GITD-E supported the targeted cognitive and affective learning outcomes.

Results and Discussion

This section presents the findings obtained from each phase of the ADDIE model and discusses how the development and implementation of GITD-E supported students' mathematical reasoning, mathematical connections, and appreciation of mathematics.

Analysis

The analysis phase provided the foundation for the development of GITD-E through an examination of instructional needs, learner characteristics, curriculum requirements, and local cultural resources. Classroom observations and teacher interviews revealed that mathematics instruction remained predominantly teacher-centered and relied heavily on conventional textbooks. Such instructional practices appeared to limit students' opportunities to actively construct mathematical understanding, thereby contributing to difficulties in reasoning, establishing conceptual connections, and relating mathematical ideas to meaningful contexts.

Analysis of learner characteristics indicated that Grade VII students were transitioning toward formal operational thinking. Consequently, instructional activities were designed to emphasize exploration, guided discovery, and engagement with concrete situations closely related to students' experiences. Curriculum analysis further identified triangles and quadrilaterals as challenging topics for students. These difficulties were largely associated with procedural learning practices in which students memorized formulas without understanding the conceptual relationships and decomposition processes underlying geometric formulas. As a result, students often struggled to apply geometric concepts in unfamiliar or contextual situations.

To address these challenges, ethnomathematical contexts derived from Yogyakarta culture were identified and incorporated into the instructional design. These contexts included architectural features surrounding the Yogyakarta Palace, Batik *Tambal* motifs, *Joglo* house roofs, *besek* used in *kenduri* traditions, *bas-basan* and *gobak sodor* games, *wajik* cutting activities, and traditional kite designs. These cultural artefacts provided authentic contexts through which geometric concepts related to triangles and quadrilaterals could be explored meaningfully. Several examples of the identified cultural contexts are presented in Figure 1.

Figure 1. Results of Local Cultural Identification

Design

The design phase focused on translating the findings of the analysis phase into a coherent instructional framework that integrated guided inquiry learning with ethnomathematical contexts. The learning design was structured around six stages of guided inquiry: observing contextual problems, formulating hypotheses, collecting and processing data, testing hypotheses, drawing conclusions, and applying concepts through discussion and advanced problem-solving activities. Within this framework, local cultural contexts functioned as authentic entry points for mathematical inquiry, enabling students to engage with mathematical ideas through situations that were familiar and meaningful to their everyday experiences. The integration of cultural contexts was intended not only to enhance students' engagement but also to facilitate connections between formal mathematical concepts and real-world phenomena. The overall design of the local culture-based guided inquiry learning activities is presented in Table 5.

Table 5. Design of a Local Culture-Based Guided Inquiry Method in Learning Activities

Guided Inquiry Stage	Brief Design
Observing the Problem	Students observe culture-based contextual problems provided by the teacher to formulate the problem.
Formulating Hypotheses	Students propose possible solutions with teacher guidance through leading questions.
Collecting Data	Students carry out activities in the worksheet to obtain data and discover the required concepts.
Testing Hypotheses	Students solve the initial problem using information obtained from the worksheet activities.
Drawing Conclusions	Students formulate conclusions about the new concepts learned during the activities.
Application and Follow-Up	Students present their work results and complete application problems.

The lesson plans were developed to ensure alignment with curriculum requirements and inquiry-oriented learning principles. Each lesson plan incorporated essential instructional components, including learning identity, core competencies, basic competencies, achievement indicators, learning objectives, instructional materials related to triangles and quadrilaterals, guided inquiry learning procedures, learning resources, and assessment activities. Particular attention was given to structuring learning experiences that encouraged students to investigate mathematical relationships, construct explanations, and justify conclusions through guided exploration of culturally situated problems.

Student worksheets were designed as the primary medium through which guided inquiry activities were operationalized. The worksheets were aligned with both the lesson plans and the inquiry learning sequence and consisted of several units addressing the properties, perimeter, and area of triangles and quadrilaterals. To support meaningful mathematical exploration, the worksheets incorporated local cultural contexts, exploratory tasks, prediction activities, investigation procedures, and reflective components. These elements were intentionally designed to encourage students to formulate conjectures, identify mathematical patterns, establish conceptual connections, and reflect on the role of mathematics within cultural practices and everyday life.

More specifically, each worksheet component was aligned with particular learning objectives and targeted mathematical competencies. The Brief Information (Sekilas Info) section introduced students to mathematical ideas embedded in local cultural practices and was intended to foster interest and appreciation of mathematics. Contextual cultural problems presented in the Problem (Masalah) section encouraged students to connect mathematics with authentic situations and cultural artefacts. The Prediction Column (Kolom Perkiraan Jawaban) provided opportunities for students to formulate initial conjectures based on prior knowledge, thereby supporting mathematical reasoning and conceptual connections.

Subsequent sections guided students through the inquiry process. The Recall Section (Ingat Kembali) activated previously learned concepts relevant to the investigation, while the Activities (Aktivitas) section facilitated the exploration of patterns, relationships, and emerging mathematical ideas. During the Testing Hypotheses stage, students evaluated and refined their initial conjectures through the Solution Column (Kolom Penyelesaian), encouraging them to justify their reasoning based on evidence obtained during the investigation. The Conclusion Column (Kolom Kesimpulan) then required students to synthesize and articulate the mathematical concepts developed throughout the learning activities.

Finally, the Challenge (Tantangan) and Brain Exercise! (Ayo Mengasah Otak!) sections extended students' learning by providing opportunities to apply mathematical concepts in new situations and establish connections across different contexts. These activities were designed to strengthen mathematical connections and promote flexible problem-solving. The detailed alignment between the guided inquiry stages, worksheet components, targeted competencies, and instructional purposes is presented in Table 6.

Table 6. Design of a Local Culture-Based Guided Inquiry in Student Worksheets

Guided Inquiry Step	**Worksheet Content**	**Targeted Skills**	**Brief Design**
Observing the Problem	Brief Information (*Sekilas Info*)	Appreciation of Mathematics	Local culture-based mathematical information to increase students' interest and appreciation of mathematics in daily life.
	Problem (*Masalah*)	Mathematical Appreciation & Connection	Contextual cultural problems that encourage students to connect mathematics with real-life situations.

Guided Inquiry Step	Worksheet Content	Targeted Skills	Brief Design
Formulating Hypotheses	Prediction Column (*Kolom Perkiraan Jawaban*)	Reasoning & Mathematical Connection	Students predict possible solutions by relating prior knowledge to the problem.
Collecting Data	Recall Section (*Ingat Kembali*)	Reasoning & Mathematical Connection	Review of previously learned material that supports problem solving.
	Activities (*Aktivitas*)	Reasoning & Mathematical Connection	Activities guiding students to identify patterns, relationships, and new concepts.
Testing Hypotheses	Solution Column (*Kolom Penyelesaian*)	Reasoning Ability	Students evaluate and verify their initial hypotheses using collected information.
Drawing Conclusions	Conclusion Column (*Kolom Kesimpulan*)	Reasoning Ability	Students write conclusions based on the completed activities.
Application & Follow-Up	Challenge (*Tantangan*)	Mathematical Connection	Application problems requiring students to connect mathematics with other contexts.
	Brain Exercise! (*Ayo Mengasah Otak!*)	Mathematical Connection	Additional exercises to strengthen understanding and problem-solving skills.

In addition to the instructional materials, assessment instruments were developed to align with the objectives of the study. Open-ended test items were designed to assess students' mathematical reasoning and mathematical connections, whereas a questionnaire was developed to examine students' appreciation of mathematics. Collectively, these instruments were intended to capture both the cognitive and affective dimensions of learning targeted by the GITD-E design.

Development

The development phase focused on transforming the instructional design into a complete set of GITD-E and establishing their validity, practicality, and measurement quality. The resulting products consisted of lesson plans and student worksheets that systematically integrated guided inquiry learning with local cultural contexts from Yogyakarta. The development process was iterative, involving expert review and revision to ensure alignment between curriculum objectives, inquiry-oriented learning activities, ethnomathematical contexts, and the targeted learning outcomes of mathematical reasoning, mathematical connections, and appreciation of mathematics.

The lesson plans were designed to align curriculum competencies with guided inquiry activities situated within meaningful cultural contexts. As illustrated in Table 7, the instructional objectives were derived from Basic Competency 3.11, which emphasizes understanding the relationships among the properties, perimeter, and area formulas of triangles and quadrilaterals. These competencies were operationalized through learning indicators requiring students to identify and classify triangles and determine their interior and exterior angles. To support conceptual understanding, learning activities were initiated through contextual problems derived from cultural artefacts surrounding the Yogyakarta Palace, allowing students to explore geometric ideas through observation, investigation, and discussion.

Table 7. Some Important Parts of a Lesson Plan

<table>
<tr><th colspan="2">Lesson Plan</th></tr>
<tr>
<td>B. Kompetensi Dasar dan Indikator
<table>
<tr><th>Kompetensi dasar</th><th>Indikator Pencapaian</th></tr>
<tr><td>3.11 Mengaitkan rumus keliling dan luas untuk berbagai jenis segiempat (persegi, persegipanjang, belah ketupat, jajargenjang, trapesium, dan layang-layang) dan segitiga.</td><td>3.11.1 Mengidentifikasi sifat-sifat segitiga
3.11.2 Mengelompokkan segitiga berdasarkan besar sudut
3.11.3 Mengelompokkan segitiga berdasarkan panjang sisi
3.11.4 Menentukan besar sudut segitiga
3.11.5 Menentukan besar sudut dalam segitiga</td></tr>
</table>
</td>
<td>B. Basic Competence and Indicators
<table>
<tr><th>Basic Competence</th><th>Achievement Indicators</th></tr>
<tr><td>3.11 Relate the formulas for perimeter and area for various types of quadrilaterals (square, rectangle, rhombus, parallelogram, trapezoid, and kite) and triangles.</td><td>3.11.1 Identify the properties of triangles
3.11.2 Classify triangles based on their angle measures
3.11.3 Classify triangles based on their side lengths
3.11.4 Determine the interior angles of a triangle
3.11.5 Determine the exterior angles of a triangle</td></tr>
</table>
</td>
</tr>
<tr>
<td>C. Tujuan Pembelajaran
Melalui proses pembelajaran guided inquiry berbasis budaya lokal yang diawali dengan mengamati masalah yang berkaitan dengan bangunan di sekitar kraton Yogyakarta diharapkan siswa mampu :
1. Mengidentifikasi sifat-sifat segitiga
2. Mengelompokkan segitiga berdasarkan besar sudut
3. Mengelompokkan segitiga berdasarkan panjang sisi
4. Menentukan besar sudut dalam segitiga
5. Menentukan besar sudut luar segitiga</td>
<td>C. Learning Objectives
Through a guided inquiry learning process based on local culture, beginning with observing problems related to buildings around the Yogyakarta Palace, students are expected to be able to:
1. Identify the properties of triangles
2. Classify triangles based on their angle measures
3. Classify triangles based on their side lengths
4. Determine the interior angles of a triangle
5. Determine the exterior angles of a triangle</td>
</tr>
</table>

Similarly, the student worksheets were developed as the primary medium for inquiry-based learning. The worksheets incorporated ethnomathematical contexts through cultural narratives, visual representations, exploratory tasks, and reflective activities. One example is presented in Table 8, where the Quick Info! section introduces students to the architectural characteristics of the Joglo house. Rather than functioning merely as contextual enrichment, the cultural information was intentionally connected to geometric concepts, enabling students to identify and analyze quadrilateral structures embedded within traditional architecture. Through this approach, students were encouraged to recognize mathematics as a meaningful component of cultural practices and everyday life.

Table 8. Some Important Parts of a Student Worksheet

Student Worksheets	
	**Triangles & Trapezoids** **Quick Info!** Did you know about the traditional houses of the Special Region of Yogyakarta? The traditional house of Yogyakarta is called a *Joglo*. The *Joglo* design is considered by the Javanese people as the most perfect form of a Javanese house. Today, the *Joglo* shape can be found in cafes, restaurants, art galleries, and hangout spots with a classic style. However, in the past, the *Joglo* house was only used by nobles or people with high economic status. This house design has three main components: *pendapa* (meeting hall), *pringgitan* (central room), and *dalem* (family room). In general, *Joglo* houses are shaped like quadrilaterals. Over time, *Joglo* architecture has been classified into 12 types: *Joglo Kepuhan Limasan, Kepuhan Lawakan, Jempongan, Pengrawit, Ceblokan, Apitan, Lambangsari, Trajumas, Semar Tinandu, Hageng, Mangkurat, and Wantah Apitan*

The validity of GITD-E was established through expert evaluation. Inter-rater reliability analysis using Cohen's Kappa yielded a coefficient of 1.00, indicating perfect agreement between the two validators and demonstrating a very high level of consistency in the evaluation process. Content validity analysis using Aiken's V produced coefficients of .93 for the lesson plans and .91 for the student worksheets, indicating that both products achieved a very high level of content validity. These findings suggest that the instructional materials were judged to be conceptually appropriate, pedagogically coherent, and consistent with the intended integration of guided inquiry and ethnomathematics.

Further evidence of product quality was obtained from the feasibility assessment. The lesson plans achieved an overall feasibility score of 85.73% as summarized in Table 9, while the student worksheets obtained a score of 85.86% as shown in Table 10, both of which were classified within the "very good" category. As shown in the lesson-plan evaluation results, particularly high ratings were obtained for instructional identity, learning objectives, learning resources, and language use. Similarly, the student worksheets received favorable evaluations across content, presentation, and language dimensions. These results indicate that the developed materials met established standards for instructional quality and classroom readiness.

Table 9. Lesson Plan Eligibility Results

Aspects	Assessment Score		Average
	Validator 1	Validator 2	
Identity	100%	100%	100%
Formulation of learning objectives and indicators	100%	80%	90%
Material selection	80%	86.67%	83.34%
Selection of learning models	80%	80%	80%
Planning of learning activities	72.5%	72.5%	72.5%
Selection of learning resources	80%	100%	90%
Preparation of assessments	80%	80%	80%
Language use	80%	100%	90%
Total			85.73%

The practicality of GITD-E was subsequently examined through external validation involving both teachers and students. Teacher evaluations classified the lesson plans as "very good" and the student worksheets as "good," indicating that the materials were considered feasible and manageable for classroom implementation. Student responses further supported the practicality of the worksheets, with 23% of students rating them as "very good," 74% as "good," and 3% as "fair." Notably, no negative responses were reported. These findings suggest that the instructional materials were positively received by learners and were capable of supporting active engagement in inquiry-oriented learning activities.

Table 10. Student Worksheet Eligibility Results

Aspects	Assessment Score		Average
	Validator 1	Validator 2	
Material/content eligibility	80%	81.82%	80.91%
Display	96.67%	86.67%	91.67
Language compatibility	80%	90%	85%
Total			85.86%

In addition to evaluating the instructional materials, the quality of the research instruments was also examined. Construct validity was assessed using CFA. The results indicated that the data were suitable for factor analysis, as demonstrated by a Kaiser–Meyer–Olkin (KMO) value of .888 and a significant Bartlett's Test of Sphericity ($p < .05$). The analysis supported a five-factor structure with eigenvalues greater than 1, explaining 63.49% of the total variance. These findings provide evidence of satisfactory construct validity and indicate that the instruments adequately represented the intended measurement dimensions.

Reliability analysis further demonstrated acceptable to excellent internal consistency. Cronbach's alpha coefficients were .797 for the mathematical reasoning instrument, .788 for the mathematical connection instrument, and .921 for the mathematics appreciation questionnaire. These coefficients exceeded commonly accepted thresholds for educational research and indicate that the instruments generated consistent and dependable measurements. Collectively, the validity and reliability findings provide evidence that the instruments were appropriate for examining the cognitive and affective outcomes targeted by the implementation of GITD-E.

Finally, the development phase demonstrated that GITD-E satisfied established criteria of validity and practicality and was supported by psychometrically sound research instruments. The combination of guided inquiry activities and ethnomathematical contexts resulted in instructional materials that were pedagogically coherent, culturally relevant, and suitable for implementation in mathematics classrooms.

Implementation

The implementation phase was conducted over six instructional meetings, followed by one additional meeting for the administration of the post-test instruments. Throughout the implementation, students engaged progressively with concepts related to triangles and quadrilaterals, including their properties, perimeter, and area, through learning activities structured according to the guided inquiry framework and supported by ethnomathematical contexts derived from Yogyakarta culture.

The implementation process was monitored through classroom observation sheets completed by observers during each instructional meeting. Observations focused on both teacher and student activities to evaluate the extent to which the designed learning procedures were enacted in practice. The results indicated a high level of implementation fidelity, with an average implementation score of 92.53% for teacher activities and 90.80% for student activities. These findings suggest that the instructional procedures embedded within GITD-E were implemented consistently and that students actively participated in the planned learning activities. Based on the predetermined criteria, GITD-E was therefore categorized as practical and feasible for classroom implementation.

Despite the high level of implementation, classroom observations revealed several important dynamics. During the initial stages of learning, some students experienced difficulties formulating hypotheses and independently exploring contextual problems. This challenge appeared to be related to students' previous experiences with teacher-centered instruction, in which mathematical procedures were typically demonstrated before problem-solving activities began. Consequently, several groups initially waited for explicit procedural guidance from the teacher before engaging with the inquiry tasks.

As the implementation progressed, however, students gradually became more active in discussing ideas, identifying mathematical patterns, proposing explanations, and presenting conclusions. This observation suggests that participation in inquiry-oriented learning requires an adaptation process, particularly for students who are more familiar with conventional instructional approaches. The gradual increase in student participation indicates that guided inquiry learning may support the development of more active forms of mathematical engagement when students are provided with sufficient opportunities to explore, discuss, and justify mathematical ideas.

The implementation also revealed that inquiry-based activities situated within cultural contexts required more instructional time than conventional learning approaches. Discussions involving cultural artefacts, such as Joglo architecture and batik motifs, appeared to increase student engagement and curiosity. Nevertheless, some students initially focused more on the cultural narratives than on the mathematical concepts embedded within those contexts. Consequently, teacher scaffolding and questioning strategies played a critical role in directing students' attention toward relevant mathematical relationships and maintaining the focus of classroom discussions. These observations highlight the importance of pedagogical mediation in ethnomathematics-based learning environments.

Evaluation

The outcomes of GITD-E implementation were examined through students' mathematical reasoning, mathematical connections, and appreciation of mathematics. The results were interpreted using predetermined benchmark criteria, namely a minimum score of 75 for mathematical reasoning and mathematical connections and a minimum score of 74.8 for appreciation of mathematics.

Descriptive analysis indicated that students achieved a mean score of 83.18 in mathematical reasoning, 85.22 in mathematical connections, and 81.03 in appreciation of mathematics. All average scores exceeded the established benchmark values. Prior to inferential analysis, the assumptions of normality were examined using the Kolmogorov–Smirnov test. The results indicated that all datasets were normally distributed ($p > .05$), supporting the use of parametric statistical procedures. Subsequent One-Sample t-tests demonstrated that the mean scores for mathematical reasoning ($t = 5.331$), mathematical connections ($t = 4.889$), and appreciation of mathematics ($t = 3.718$) were significantly higher than the predetermined criteria ($p < .05$). These findings indicate that students who participated in learning using GITD-E achieved performance levels that exceeded the expected minimum standards across all three dimensions examined in this study.

Discussion

The findings suggest that the systematic development and implementation of GITD-E through the ADDIE framework resulted in instructional materials that were both feasible for classroom use and associated with positive learning outcomes. Across the analysis, design, development, implementation, and evaluation phases, the ADDIE model provided a structured process through which instructional objectives, cultural contexts, inquiry activities, and assessment procedures could be aligned. This finding is consistent with previous studies highlighting the effectiveness of ADDIE in producing valid, practical, and pedagogically coherent instructional products (Nugroho et al., 2024; Nurmala Sari Agustina et al., 2021; Shahidayanti et al., 2024).

The findings concerning mathematical reasoning may be interpreted in relation to the characteristics of guided inquiry learning. Throughout the learning process, students were required to observe contextual situations, formulate conjectures, identify relationships, evaluate evidence, and construct conclusions. These activities correspond closely to core aspects of mathematical reasoning and provide opportunities for students to engage in mathematical sense-making rather than procedural imitation. The observed outcomes therefore support previous findings that inquiry-oriented learning environments can facilitate students' development of mathematical reasoning through active engagement in problem-solving processes (Eshetu et al., 2022; Pujiastuti & Haryadi, 2023).

Similarly, the findings related to mathematical connections may be understood through the role of ethnomathematical contexts in supporting conceptual integration. Cultural artefacts such as batik motifs, Joglo architecture, and traditional games provided meaningful contexts through which students could connect geometric concepts with familiar experiences and broader cultural knowledge. Such contexts may have enabled students to recognize relationships among mathematical ideas, connect mathematics with other domains, and apply mathematical knowledge beyond classroom settings. This interpretation aligns with previous studies indicating that culturally situated learning environments can strengthen students' conceptual connections and support knowledge transfer (Indriani et al., 2024; Nugroho et al., 2024; Nur et al., 2020; Rahayu et al., 2025).

Students' appreciation of mathematics also appeared to benefit from learning experiences that situated mathematics within meaningful cultural practices. Rather than encountering mathematics solely as an abstract and formal discipline, students were exposed to examples illustrating how mathematical ideas are embedded in everyday life and cultural traditions. Such experiences may have contributed to students' perceptions of mathematics as relevant, useful, and socially meaningful. This interpretation is consistent with studies suggesting that culturally responsive mathematics instruction can enhance students' interest, enjoyment, and appreciation of mathematics (Herawaty et al., 2019; Modesta & Anthony, 2021; Nugroho et al., 2024; Nursyahidah et al., 2025a, 2025b).

However, the findings should be interpreted cautiously. The positive outcomes observed in this study cannot be attributed solely to the integration of guided inquiry and ethnomathematics. Classroom observations demonstrated that teacher facilitation played a substantial role in supporting students' participation and mathematical thinking. Several students continued to require scaffolding when formulating hypotheses, interpreting contextual problems, and constructing explanations. These observations suggest that learning outcomes were influenced not only by the instructional materials themselves but also by students' prior knowledge, learning readiness, and the quality of teacher support. This interpretation is consistent with research emphasizing the central role of teacher facilitation in inquiry-based learning environments (Dobber et al., 2017; Eshetu et al., 2022).

Furthermore, although cultural contexts appeared to increase student engagement, they did not automatically promote mathematical understanding. Some students initially focused more on cultural narratives and artefacts than on the mathematical relationships embedded within them. This finding reinforces arguments within ethnomathematics research that cultural contexts require careful pedagogical mediation to ensure that students engage with the mathematical meanings represented in cultural practices (Mellawaty et al., 2023; Nugroho et al., 2026; Shahidayanti et al., 2024).

Several limitations should also be acknowledged. First, the study involved a single classroom, limiting the transferability of the findings to broader educational contexts (Creswell, 2014). Second, the use of a one-shot case study design without a pretest or comparison group restricts the extent to which causal claims can be made regarding the influence of GITD-E on student outcomes (Shadish et al., 2002). Consequently, the findings should be interpreted as evidence of positive implementation outcomes rather than definitive proof of instructional effectiveness. Future studies may therefore benefit from employing quasi-experimental or experimental designs involving larger and more diverse samples.

Despite these limitations, the study contributes to the growing literature on culturally responsive mathematics education by demonstrating how ethnomathematics can be systematically integrated within guided inquiry-based instructional materials. The findings suggest that culturally grounded inquiry activities may support students' mathematical reasoning, mathematical connections, and appreciation of mathematics while simultaneously creating opportunities for meaningful engagement with local cultural knowledge. For teachers, the study highlights the importance of scaffolding and pedagogical guidance when implementing inquiry-oriented and culturally situated learning. For curriculum developers, it underscores the potential value of embedding local cultural contexts within instructional materials to promote more relevant, meaningful, and student-centered mathematics learning experiences.

Conclusion

This study achieved its objectives by describing the design process of GITD-E and examining their implementation in supporting students' mathematical reasoning, mathematical connections, and appreciation of mathematics. Developed through the ADDIE framework, GITD-E was found to satisfy established criteria of validity and practicality and was implemented with a high level of fidelity in classroom settings. The findings further indicated that students' performance in mathematical reasoning, mathematical connections, and appreciation of mathematics exceeded the predetermined benchmark criteria, suggesting positive learning outcomes associated with the use of the developed instructional materials.

Beyond the development of instructional products, this study contributes to mathematics education by demonstrating how ethnomathematical contexts can be systematically integrated within guided inquiry learning to create culturally meaningful opportunities for mathematical exploration. The findings suggest that local cultural practices and artefacts may function not merely as contextual illustrations but as resources that support students' engagement with mathematical ideas and facilitate connections between formal mathematics and everyday experiences. In this regard, the study extends existing work on guided inquiry learning by positioning ethnomathematics as a contextual and cultural dimension that can enrich inquiry-based mathematics instruction.

Nevertheless, the findings should be interpreted within the scope of the study design. Given the use of a one-shot case study design and a single classroom setting, the results provide evidence of positive implementation outcomes rather than definitive causal effects. Future research may therefore employ quasi-experimental or longitudinal designs involving larger and more diverse samples to further examine the relationship between ethnomathematics-integrated inquiry learning and students' mathematical development. Practically, the study highlights the potential of culturally responsive inquiry-based learning to support meaningful mathematics learning and underscores the importance of teacher scaffolding in facilitating students' engagement with both cultural contexts and mathematical ideas.

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Conflicts of Interest

The authors declare that they have no competing interests.

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