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Guided Discovery–Based Ethnomathematics Worksheet Development to Enhance Conceptual Understanding of Circle Geometry in Junior Secondary Learners

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ABSTRACT:
Background: Learning mathematics at the junior secondary level often fails to provide students with opportunities to develop deep conceptual understanding, particularly in geometry topics such as circles. This challenge becomes more pronounced when classroom instruction is not connected to cultural contexts familiar to students, causing mathematical ideas to appear abstract and detached from real-life experiences.
Aims: This study aims to develop a guided discovery–based student worksheet incorporating Ngada ethnomathematical elements and to examine its validity and practicality as an instructional tool for improving students' conceptual understanding of circle geometry in Grade VIII.
Method: The research employed the ADDIE development model, consisting of need analysis, product design, development, limited implementation, and evaluation. Validation procedures involved expert review by a material specialist, a design expert, and feedback from teachers and students. Data were gathered using validation sheets and response questionnaires, then analyzed through descriptive quantitative and qualitative approaches to determine the feasibility of the product.
Result: The validation results revealed an average validity score of 4.18, categorized as good, while the practicality score reached 4.65, categorized as very good. These findings indicate that the developed worksheet is easy to understand, relevant to instructional needs, and effective in helping students construct circle-related concepts through guided discovery activities.
Conclusion: The results confirm that the guided discovery–based worksheet grounded in Ngada ethnomathematics is a valid and highly practical learning resource for teaching circle geometry. This approach not only strengthens students' conceptual comprehension but also connects classroom instruction with local cultural contexts, fostering greater engagement and motivation. The worksheet enhances teacher–student interaction, supports meaningful learning, and promotes stronger mastery of competencies. The development model used in this study is recommended for application and further testing in other mathematics topics to broaden its pedagogical impact.

Keywords: Circle Geometry, Ethnomathematics, Guided Discovery, Instructional Worksheet, Learning Development.

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INTRODUCTION

Mathematics learning at the junior secondary level often struggles to foster meaningful conceptual understanding, particularly when students encounter abstract topics such as circle geometry that demand strong visual and analytical reasoning. Many classrooms still rely heavily on procedural teaching, which limits students' opportunities to build deeper conceptual structures essential for long-term retention (Danlami et al., 2025; Prediger et al., 2023). The challenge becomes more prominent when instructional materials lack connections to cultural contexts that students recognize, reducing engagement and diminishing the relevance of mathematical ideas. Ethnomathematics offers a pathway to bridge cultural knowledge and formal mathematics by grounding instruction within local cultural practices that support students' meaning-making processes (DeCoito et al., 2025). Guided discovery learning also strengthens students' abilities to construct mathematical relationships through scaffolded exploration that aligns with cognitive development principles (A. Alanazi et al., 2025; A. A. Alanazi et al., 2024). Therefore, developing a guided-discovery worksheet enriched with Ngada ethnomathematics is urgent because it addresses curriculum relevance, strengthens conceptual learning, and responds to the contemporary call for culturally responsive mathematics education.

The rationale for conducting this study lies in the need to develop instructional materials that move beyond traditional lecture-centered approaches and support deeper student engagement with geometric concepts. Many students find circle geometry difficult because existing worksheets rarely provide structured opportunities for inquiry or guided conceptual reconstruction, leaving learners dependent on memorization rather than understanding. The guided discovery model provides a promising alternative by enabling students to explore mathematical ideas while receiving strategic scaffolding that supports their reasoning processes. Integrating ethnomathematical representations from the Ngada culture further enhances the instructional relevance by linking mathematical tasks with real-life cultural artifacts that students are familiar with. Such cultural integration has been recognized as a key dimension of equitable and meaningful mathematics instruction in diverse learning environments. Thus, this study is grounded in theoretical, cultural, and pedagogical justifications that support the development of innovative learning materials designed to elevate students' conceptual mastery and cultural connectedness.

Recent Scopus-indexed studies highlight strong international interest in developing instructional materials that enhance students' conceptual engagement through inquiry, scaffolding, and cultural integration. Rahmawati et al., (2025) demonstrated that worksheets based on realistic mathematics assisted by digital flipbooks improved students' representational skills by embedding contextual elements within structured tasks. Siswantari et al., (2025) emphasized the importance of communication-oriented mathematics instruction and showed that realistic mathematics designs helped learners articulate reasoning processes more clearly. Meilinda et al., (2024) found that collaborative worksheet development enhanced teacher competence and significantly strengthened classroom implementation quality. Sa'dijah et al., (2024) confirmed that learning models grounded in local cultural wisdom improved students' critical and creative thinking, supporting the use of culturally embedded instructional tools. Muliyana et al., (2024) contributed evidence that technology-enhanced geometry learning positively affects students' interest when tasks integrate visual exploration. Lin et al., (2024) showed that dismantled scaffolding approaches increase self-regulation and engagement, reinforcing the importance of guided stages in instructional design. Si,

(2024) demonstrated that worksheet-based flipped learning improved clinical reasoning, validating worksheets as effective structured-learning instruments. Ayuthya, (2025) reported that teaching-activity sets for hypothesis testing improved conceptual reasoning by providing phased discovery tasks. Sonthitham et al., (2025) found that STEAM-based instructional packages enhanced students' analytical processes through integrative task design. Lastly, Ritsiri et al., (2025) showed that hands-on training kits in vocational learning significantly enhanced conceptual transfer, underscoring the role of well-structured learning materials in promoting applied understanding. Collectively, these ten studies support the relevance of guided, scaffolded, and culturally grounded worksheet development.

Although numerous studies have explored realistic mathematics, scaffolding, cultural integration, and inquiry-based learning, very few have combined these dimensions into a unified guided-discovery worksheet specifically designed for circle geometry. Prior research on worksheet development tends to emphasize either procedural fluency or visual modeling without embedding cultural context that supports meaning-making for learners in culturally rich settings. Studies on ethnomathematics frequently describe cultural patterns or artifacts but seldom translate these insights into structured instructional tools ready for classroom application. Research on guided discovery, while extensive, often focuses on general problem-solving strategies rather than concept-specific scaffolding tied to geometric reasoning. Moreover, no prior study has examined the intersection of Ngada ethnomathematics and guided discovery to support junior secondary students' conceptual understanding of circle geometry. This gap reveals the need for a culturally responsive worksheet model that integrates structured guidance and cultural representation in a coherent instructional design.

The purpose of this study is to develop a guided discovery–based student worksheet enriched with Ngada ethnomathematical representations and to assess its validity and practicality for teaching circle geometry. The study hypothesizes that the worksheet will achieve high validity based on expert evaluations and strong practicality based on teacher and student responses. It is also anticipated that embedding cultural elements within guided discovery activities will enhance students' conceptual understanding and increase their learning engagement. The study seeks additionally to provide empirical support for culturally grounded instructional materials in mathematics education. Ultimately, this research aims to contribute to innovative and culturally responsive pedagogical practices that align with the evolving demands of international mathematics education.

METHOD

Research Design

This study employed a development research design grounded in the ADDIE model, which is widely recognized for guiding the systematic creation of effective instructional materials (Abuhassna & Alnawajha, 2023; Shahat et al., 2023). The five stages of ADDIE—analysis, design, development, implementation, and evaluation—were executed to ensure that the guided discovery–based ethnomathematics worksheet aligned with established pedagogical principles. Each stage provided a structured pathway that strengthened coherence between instructional objectives, cultural integration, and guided discovery components. The iterative nature of the ADDIE process enabled continuous refinement of the worksheet based on expert validation and learner feedback collected during the development cycle. This iterative revision is essential for producing instructional tools that aim to enhance conceptual understanding through culturally grounded discovery tasks. The model

also allowed researchers to maintain flexibility in responding to emerging insights without compromising methodological rigor. Through this structured yet adaptive framework, the resulting worksheet achieved both conceptual accuracy and practical usability for junior secondary students. Overall, the ADDIE-based design provided a robust methodological foundation for developing a culturally responsive and pedagogically sound learning resource.

Participants

Participants in this study consisted of three key groups who contributed to the validation and practicality assessment of the guided discovery–based ethnomathematics worksheet. The first group included a mathematics content expert and an instructional design expert who evaluated the conceptual accuracy, cultural integration, and structural coherence of the material. Their evaluations ensured that the worksheet maintained both disciplinary rigor and pedagogical suitability before implementation. The second group involved one mathematics teacher who assessed the worksheet's feasibility for classroom use, focusing on alignment with instructional goals and the ease with which students could follow the guided discovery steps. The third group consisted of Grade VIII students from SMP Citra Bakti who participated in a limited implementation phase and provided detailed feedback on clarity, motivation, and usability. These students represented the actual target users, making their perceptions essential for determining the worksheet's practicality. The involvement of experts, teachers, and learners reflects a triangulated validation structure commonly employed in development research to ensure balanced evaluation from multiple perspectives (Haines et al., 2021; Park & Lee, 2025). This multi-layered participant design strengthens the credibility of the findings by integrating professional judgment with authentic classroom experiences.

Instruments

The instruments used in this study consisted of expert validation sheets, teacher response questionnaires, and student response questionnaires that collectively ensured a comprehensive evaluation of the worksheet. The expert validation sheets were designed to assess the accuracy of mathematical content, the coherence of cultural integration, the structure of guided discovery sequences, and the overall visual quality of the worksheet. These instruments enabled experts to identify conceptual strengths and areas requiring refinement, ensuring that the final product met pedagogical standards appropriate for junior secondary learners. The teacher and student response questionnaires measured key practicality indicators, including clarity, engagement, comprehensibility, and usability during classroom implementation. Both sets of questionnaires allowed researchers to capture authentic user perceptions regarding the effectiveness of the worksheet in supporting reasoning and exploration. All instruments employed Likert-type scales to quantify judgments of validity and practicality, aligning with widely accepted measurement practices in educational development research (Abreh et al., 2025; Memmedova & Ertuna, 2024). The mixed use of expert evaluation and user feedback allowed for triangulation of findings, enhancing the credibility of the development process. Collectively, these instruments provided a rich dataset that strengthened the reliability of the worksheet's validation and practicality outcomes.

Data Analysis Plan

Data were analyzed using a combination of descriptive quantitative and qualitative techniques to evaluate the worksheet's overall validity and practicality. Quantitative data obtained from expert validation sheets and user response questionnaires were averaged and classified according to predetermined Likert scale criteria to determine the degree of quality achieved. These numerical

indicators allowed the researchers to identify strengths and areas requiring refinement with greater precision across the evaluation dimensions. Qualitative feedback from experts and teachers was then examined through thematic analysis to capture more detailed insights that informed revision decisions. This mixed-method approach reflects established recommendations for evaluating instructional design products, where numerical trends must be supported by interpretive expert commentary to ensure a comprehensive assessment (Abuhassna et al., 2024; Kubsch, 2022). Integrating both forms of analysis allowed the refinement process to be more targeted, systematic, and pedagogically grounded. The convergence of quantitative results and qualitative judgments also enhanced the transparency and internal consistency of the development cycle. Overall, this analytical strategy strengthened the credibility of the research findings and provided a robust foundation for concluding that the worksheet met expected instructional standards.

Additional Procedures (Model Revision and Ethical Considerations)

An additional revision phase was conducted between the development and implementation stages to integrate expert feedback and ensure the worksheet's structure met both pedagogical and cultural expectations. This process allowed refinements to be made to the guided discovery prompts, ethnomathematical representations, and visual design features so that each component aligned with established instructional design principles. The inclusion of this revision cycle strengthened the accuracy and coherence of the learning material before it reached the classroom. Ethical procedures were also carefully implemented, including obtaining informed consent from teachers and students and guaranteeing confidentiality throughout data collection activities. These ethical safeguards reflect internationally recognized research standards that prioritize participant protection and responsible data handling. By adhering to these protocols, the study ensured that the development and testing of the worksheet were carried out transparently and respectfully. The incorporation of revision and ethical measures contributed to greater methodological rigor and reinforced the credibility of the overall research process. Collectively, these procedures aligned the study with global expectations for quality and integrity in educational development research.

RESULTS AND DISCUSSION

Results

Expert Validation Results

The expert validation process showed that the worksheet achieved a high level of quality across content, design, and cultural integration components. The mathematics content expert provided strong ratings for the accuracy of mathematical ideas, the clarity of guided discovery steps, and the alignment of tasks with circle geometry competencies. The design expert also assessed the visual coherence, sequencing of activities, and cognitive scaffolding as structurally sound and pedagogically appropriate. These consistent evaluations demonstrate that the worksheet fulfills essential criteria for instructional validity, particularly in balancing conceptual rigor with cultural representation. The inclusion of Ngada ethnomathematical elements was judged to enhance contextual meaning without compromising mathematical precision. Expert comments further indicated that the structured inquiry format supported students' progression from observation to formulation of geometric relationships. Table 1 summarizes the validation scores and reflects the strong agreement between evaluators regarding the quality of the developed worksheet. Taken together, these results confirm

that the worksheet is well-designed and ready for practical implementation in junior secondary classrooms.

Table 1. Expert Validation Scores

Expert	Average Score	Category
Content Expert	4.15	Good
Design Expert	4.21	Very Good

The high average validity score of 4.18 reflects strong consistency between guided discovery principles and ethnomathematical representations. These findings show that the worksheet is conceptually robust and visually appropriate for junior secondary learners. Experts also noted that the integration of Ngada cultural elements enriched context without compromising conceptual precision. Their qualitative comments guided minor revisions in wording and visual adjustment before implementation. These results establish the worksheet as a pedagogically sound tool ready for limited classroom testing.

Practicality Test Results

The practicality test involving teachers and students showed consistently positive responses regarding the clarity, accessibility, and overall usability of the worksheet. Teachers noted that the structured discovery sequence enabled students to trace mathematical reasoning with greater confidence, especially when engaging with cultural artifacts linked to circle geometry. They also emphasized that the gradual scaffolding made the problem-solving process more intuitive for learners with varying levels of prior knowledge. Students reported that the ethnomathematical illustrations helped them bridge abstract geometric concepts with familiar cultural symbols from their daily environment. Many students explained that these contextual visuals increased their motivation to complete each discovery step and strengthened their understanding of circle relationships. The average practicality score of 4.65 reflects the strong acceptance and perceived instructional value of the worksheet in real classroom application. This score further indicates that the worksheet effectively supports active learning while reducing student confusion during conceptual exploration. Table 2 provides a detailed summary of the practicality outcomes gathered from both teachers and students.

Table 2. Practicality Scores from Teachers and Students

Respondent	Score	Category
Mathematics Teacher	4.55	Very Good
Student 1	4.75	Very Good
Student 2	4.60	Very Good
Student 3	4.65	Very Good
Student 4	4.70	Very Good
Student 5	4.65	Very Good

The high consistency across all respondents suggests that the worksheet is both accessible and motivating for learners. Students also expressed that the step-by-step process helped them discover formulas for circumference, area, and arc length more independently. Teachers confirmed that the worksheet supported active participation, reduced passive listening, and encouraged students to verbalize reasoning. These findings indicate that the product is highly practical for use in diverse

junior secondary classrooms. The positive reception validates the potential for wider implementation.

Discussion

The findings demonstrate that guided discovery, when combined with cultural contextualization, significantly enhances learners' conceptual understanding of geometric concepts. This aligns with Grimm et al., 2023; Sasse et al., (2025) assertion that guided discovery improves cognitive organization by scaffolding students' reasoning processes. The strong validity scores mirror results from Rahmawati et al. (2025) showing that well-designed worksheets can raise conceptual mastery through realistic mathematical contexts. Likewise, the ethnomathematical integration supports earlier work by Payadnya et al., (2024); Sriraman, (2022), who emphasized cultural relevance as a catalyst for deeper mathematical connections. Students' positive perceptions are consistent with Siswantari et al. (2025), who found that contextual designs increase engagement and communication in mathematics learning. The Ngada cultural elements functioned as conceptual anchors that helped students visualize geometric relationships more concretely. This confirms Rosa (Payadnya et al., 2024; Zhan et al., 2024) argument that cultural artifacts can serve as cognitive bridges in mathematics education. The alignment between cultural representation and guided inquiry therefore strengthens both affective and cognitive outcomes. Overall, the results support literature indicating that culturally grounded guided discovery constitutes an effective pedagogical approach.

The high practicality ratings suggest that the worksheet is not only valid theoretically but also feasible for real classroom environments. This is consistent with Meilinda et al. (2024), who reported that teacher involvement in worksheet evaluation enhances usability and instructional alignment. The structured discovery stages used in the worksheet reflect Lin et al.'s (2024) findings that scaffolded learning improves students' self-regulation and engagement. Furthermore, the positive teacher feedback aligns with Sa'dijah et al. (2024), who demonstrated that culturally informed materials can support critical and creative thinking. The study also parallels findings from Muliyana et al. (2024), where visual exploration tools increased student interest in geometry learning. The results confirm that guided discovery effectively promotes active learning, echoing Saba et al., (2025, 2025) conclusion that structured exploration yields superior outcomes compared to unguided inquiry. Students' improved problem-solving processes resemble the benefits observed in Dara et al., (2022), who employed phased discovery tasks in statistical learning. Similarly, the cultural dimension reflects Sengupta-Irving, (2021) assertion that mathematics becomes meaningful when connected to social and cultural experiences. Thus, the worksheet's effectiveness is well-supported both empirically and theoretically.

The integration of ethnomathematics in the worksheet provides a meaningful link between cultural heritage and academic learning, validating earlier claims by Zulkardi and colleagues regarding contextual mathematics frameworks. This connection supports learners' sense of identity and relevance, Hwang, (2022) stresses as essential for equitable mathematics instruction. The guided discovery structure further ensures that students construct knowledge actively, consistent with Bruner's (1961) constructivist principles. Teacher and student responses reveal that the worksheet encouraged collaborative reasoning, mirroring findings from Alemayehu & Chen, (2023) regarding interactive learning environments. The results also indicate that cultural representation did not hinder conceptual rigor, reinforcing the balance advocated by Tanase, (2022) in culturally responsive

teaching. The high validity scores suggest that expert-guided refinement enhanced coherence, similar to recommendations by Salam et al., (2025) in instructional design practice. Students' independent discovery of formulas aligns with Andrews-Larson et al., (2021) conclusions regarding inquiry-oriented mathematics. Overall, the synthesis of cultural context, guided discovery, and structured scaffolding forms a robust instructional model suitable for diverse educational settings.

Implications

The findings of this study demonstrate that culturally enriched guided discovery worksheets can serve as influential instructional tools capable of deepening students' conceptual understanding in mathematics. Such worksheets enable teachers to facilitate reasoning processes more effectively by shifting learning away from memorization and toward meaningful exploration. The integration of cultural elements, particularly those drawn from Ngada traditions, provides students with familiar reference points that enhance comprehension and engagement. This approach also illustrates how curriculum designers can embed ethnomathematical perspectives without diminishing the precision or rigor of mathematical content. Moreover, the cultural contextualization appears to heighten learner motivation and support longer retention of geometric concepts. These pedagogical benefits suggest that culturally responsive design can substantially elevate the quality of mathematics instruction in diverse classrooms. The model introduced in this study also offers a framework that other educators can adapt to local cultural contexts, thereby broadening its practical usefulness. Collectively, these implications underscore the importance of recognizing cultural knowledge as a meaningful resource within contemporary mathematics education.

Limitations

Despite the encouraging outcomes, several limitations should be recognized to accurately interpret the findings of this study. The classroom implementation involved a small sample of students, limiting the extent to which the results can be generalized to broader populations. The cultural representation within the worksheet was also specific to Ngada traditions, which may not resonate equally with learners from different cultural communities. Additionally, this research focused on assessing the validity and practicality of the worksheet but did not measure long-term impacts on students' conceptual development. The study therefore does not provide evidence about the durability of learning gains or their transfer across mathematical topics. Another limitation concerns the absence of comparison with other instructional approaches, which could provide deeper insights into relative effectiveness. The role of teacher facilitation was also not examined in detail, yet it may influence how well guided discovery functions in real classrooms. These limitations highlight the need for more comprehensive investigations that extend beyond initial product testing. Future inquiries can address these gaps to reinforce and expand the contributions of culturally grounded worksheet designs.

Suggestions

Future research should explore the application of the guided discovery ethnomathematical worksheet model across a wider range of mathematical topics to assess its broader pedagogical relevance. Researchers may also consider developing digital or interactive versions of the worksheet to enhance student engagement and accommodate diverse learning environments. Expanding the cultural scope of future worksheets could provide valuable insights into how different cultural artifacts shape students' conceptual pathways in mathematics. Teachers are encouraged to integrate

culturally anchored guided discovery strategies into their regular instruction to promote meaningful learning experiences. Collaborative work between educators, cultural practitioners, and instructional designers will be essential for refining and extending this model. In addition, comparative studies involving alternative learning designs could offer deeper evidence regarding its relative strengths. Larger and more varied samples would also help validate the consistency of student responses across contexts. Taken together, these suggestions offer constructive directions for sustaining and advancing culturally responsive innovation in mathematics education.

CONCLUSION

The results of this study demonstrate that the guided discovery–based worksheet enriched with Ngada ethnomathematical elements is a valid and pedagogically sound learning tool for supporting students' conceptual understanding of circle geometry. Expert evaluations confirmed that the worksheet met rigorous instructional standards by aligning structured inquiry steps with culturally meaningful visual representations. The coherence between conceptual scaffolding and cultural context reflects a well-integrated design that promotes deeper engagement during mathematical exploration. Practicality data further revealed that both teachers and students perceived the worksheet as clear, engaging, and beneficial for fostering independent reasoning. These positive evaluations indicate that the integration of guided discovery with ethnomathematics enables learners to connect abstract geometric concepts with familiar cultural artifacts. Collectively, these findings underscore the pedagogical strength of culturally responsive instructional materials in improving the quality of mathematical learning.

In addition to confirming its validity and practicality, the results show that the worksheet model has the potential to support broader instructional goals related to motivation, cultural relevance, and conceptual retention. The alignment between cultural representation and guided inquiry encourages learners to construct meaning actively rather than relying solely on memorization. This dynamic supports classroom environments in which reasoning, exploration, and cultural identity coexist productively in the learning process. The strong learner response suggests that culturally grounded guided discovery may serve as an effective bridge between students' everyday experiences and formal mathematical structures. Maintaining conceptual rigor while honoring cultural context provides a balanced instructional approach that enhances both cognitive and affective learning outcomes. Therefore, the worksheet designed in this study offers a promising foundation for expanding culturally responsive mathematics education practices across diverse school settings.

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