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ETHNOMATHEMATICS-BASED LEARNING DESIGN OF MOUNTAINOUS PAPUA TO INCREASE STUDENT ENGAGEMENT AND CREATE MEANINGFUL LEARNING

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Abstract

The application of ethnomathematics in teaching has many benefits. Cultural diversity can be an interactive learning resource for students. One culture that has high ethnomathematics potential is the Papuan Mountain culture. Although several examples of ethnomathematics have been found in Papuan culture, the design of ethnomathematics applications in learning is still very minimal. In addition, the lack of student involvement in the ethnomathematics exploration process is an important reason for the need to develop ethnomathematics-based learning based on 21st-century learning. The type of research is research development by using the nine stages of Dick and Carey's development. The results of research and development concluded that the mountain ethnomathematics-based learning design was developed in 4 main stages, namely analysis, development design, implementation, and evaluation. Strategies that can be used in ethnomathematics-based learning in Papua Mountains to increase learner involvement and create meaningful learning are exploration, oriented to problem statements, constructing knowledge and experiences of learners based on their culture. The results of the analysis show that the ethnomathematics-based learning design of the culture of the Papua Mountains is good and feasible to implement with a validity index of 0.802 while the reliability index of rater agreement on the learning design is good, namely 0.896.

Keywords: ethnomathematics, learning design, meaningful learning, student engagement

1. Introduction

Mathematics is one of the important subjects for students at school because it can train the ability to think logically, critically, creatively, and systematically (Widana et al., 2018). However, many students experience difficulties and disinterest in learning mathematics, because they feel that math is an abstract, difficult subject, and irrelevant to everyday life (Hasibuan, 2018; Lukman et al., 2020). The same thing is experienced by students in one of the private high schools in Nabire Regency, Central Papua. Therefore, efforts to improve the quality of mathematics learning continue to be made to attract to attract student interest and motivation. One alternative that can be done is to connect mathematics and real contexts that are close to students (Sari et al., 2018).

The strategy of connecting mathematics with the context of students' lives in the Papua region can be done by utilizing learning resources that come from the students' cultural environment. Learning resources are anything that can be used to assist the learning process, whether in the form of media, teaching aids, or other resources. Learning resources that come from students' cultural environment can provide meaningful learning experiences, because students can see and feel the connection between mathematics and real life. In addition, learning resources originating from the student's cultural environment are a means of cultural recognition (Pornpimon et al., 2014), preservation of local culture (Irawan & Kencanawaty, 2017; Hartanti & Ramlah, 2021), and learning based on noble national character (Sabon et al., 2021).

Ethnomathematics is one of the concepts that can be used to link mathematics with students' cultural environment. Ethnomathematics is mathematics that grows and develops within a particular cultural group, reflecting ways of thinking, communicating, and acting mathematically in social, economic, political, and religious contexts. Ethnomathematics can be found in various cultural activities, such as art, music, games, agriculture, trade, architecture, and others. Ethnomathematics can be an interesting and varied learning resource, and can develop students' critical, creative, and multicultural thinking skills, and improve student learning achievement. (Fajriyah, 2018; Uskono et al., 2020).

The application of ethnomathematics in teaching has many benefits. The application of ethnomathematics increases students' interest in the lesson, making it enjoyable, and enabling the teaching of culture (Ergene et al., 2020). Cultural diversity can be an interactive and interesting learning resource for students. Limited infrastructure and facilities are not a barrier to creating creative and meaningful learning that is learner-centered. This can be done by utilizing the resources around the students' environment, namely the cultural wisdom and potential of the local community. One culture that has high ethnomathematics potential is the culture of the Papua Mountains. Mountainous Papua is an area that does not have a coastline but has beautiful mountains and diverse tribes, languages, and customs.

The culture of the Papua Mountains reflects local wisdom and extraordinary natural wealth, which can be explored in mathematics learning. Some examples of ethnomathematics that have been found in the culture of Papua Mountains are number systems, measurement, geometry, patterns, and symmetry found in various activities, such as hunting, farming, trading, weaving, weaving, making *honai* houses, and holding traditional ceremonies (Andriono, 2021).

Research conducted by Saranga *et al.* (2023) which studied ethnomathematics in the traditional house of the Skouw Sae community found various mathematical elements contained in the traditional house. Some of the mathematical elements discovered include geometric shapes such as squares and rectangles, triangles, trapezoids, as well as three-dimensional shapes such as blocks, tubes and prisms. Apart from that, this research also reveals ethnomathematics activities such as calculating, determining location, measuring, designing and explaining. The results of this research have the potential to be developed as a mathematics learning tool. The results of research conducted by Paul Telussa & Tamaela (2023) found that ethnoscience-based science e-modules have positive implications. Teachers can more easily convey learning and understand the surrounding culture that is studied scientifically through the use of this e-module.

Then it was revealed by Theola *et al.* (2024) that it was found that mathematical concepts related to geometry can be found in the Honai Traditional House. The shape of the Honai house uses a tube and half-sphere shape. By paying attention to the characteristics of the Honai house shape, educators can teach curved spatial shapes. Apart from that, educators can also further teach about the surface area of cylinders and balls by implementing mathematical formulas into the context of the process of making a Honai house.

The Research conducted by Heryan (2018) examines ethnomathematics in Papuan culture in general, taking examples of hunting, farming, and trading activities. This research shows that ethnomathematics in Papuan culture can improve the mathematical communication skills of high school students and make math lessons meaningful.

An exploration of Papuan ethnomathematics was also conducted by Sroyer, Nainggolan, and Hutabarat (2018). The results of the study provide an overview of geometry content in traditional houses and traditional Biak musical instruments. However, the research is still exploratory and has not been proven effective and useful in improving students' abilities. Based on this research, it is known that the design of Papua ethnomathematics, applications in learning is still very minimal. In addition, previous research still has limitations, namely the lack of student involvement in the ethnomathematics exploration process (Sroyer et al., 2018). This is not in line with the principles of learning in the 21st-century as stated in Permendikbud No.22 of 2016, one of which is learning based on students finding out. Learners are not placed in the position of learning objects but become subjects in learning. Therefore, the development of ethnomathematics-based learning needs to be done by paying attention to the principles of 21st century learning. The development of learner-centered learning requires various preparations such as relevant teaching materials, good learning process planning, and learner worksheets (LKPD) that can stimulate learner involvement (Laurens & Matitaputty, 2018).

This research aims to fill the gap of previous research by developing 21st-century learning based on ethnomathematics of the Papua Mountains to increase students' involvement in learning mathematics and create meaningful learning as a reference for teachers, prospective teachers, and as a culture-based learning resource for students. This research is expected to contribute to the development of meaningful, varied, and cultured mathematics learning.

2. Method

The research is a development research. It adapts nine of the ten principles of instructional development in learning according to Dick and Carey (Obizoba, 2015). The advantages of the Dick and Carey model emphasize the importance of evaluation and revision, ensuring that instructional materials are effective in achieving the intended learning outcomes (Iftitah, 2023). The Dick and Carey type of development has sequential and detailed stages in learning development that refer to the general stages of development. The development procedure carried out in nine of the ten stages of Dick and Carey's development is as follows:

a. Identify instructional goals.

At this stage, the identification of learning objectives is carried out by considering the needs of students, namely the involvement of students, and the meaningfulness of learning.

b. Conduct instructional analysis.

The instructional analysis stage is carried out to determine the indicators of the achievement of learning objectives.

c. Analyze learners and contexts.

This stage analyzes the learners' characteristics (prior knowledge, attitude, motivation, interest) and determines the learning context that is relevant to the learners.

d. Formulate learning performance objectives (Write performance objectives)

The stage of formulating learning performance is carried out by determining specific learning objectives (what is to be achieved in learning both cognitive, affective, and psychomotor elements of students).

e. Develop an assessment instrument.

At this stage, the assessment instrument is developed to evaluate the learning design.

f. Develop instructional strategy.

At this stage, the researcher develops the learning design by choosing the right strategy.

g. Develop and select instructional materials.

The next stage, selecting and developing teaching materials

h. Design and conduct a formative evaluation of instruction.

At this stage, researchers conduct qualitative and quantitative evaluations of the learning design by involving experts, teachers, and students to conduct a formative evaluation of the developed learning design.

i. Revise the developed product

The data collection techniques used in this study were interviews, literature study, and filling out an assessment questionnaire for teaching modules and student worksheets (LKPD) used in the ethnomathematics-based learning design of Papua Mountains. The instrument lattice used in Table 1.

Data analysis was conducted qualitatively and quantitatively. Qualitative data were obtained based on the results of interviews and literature study. The qualitative data were analyzed using the Miles and Huberman model, namely data reduction, data presentation, conclusion (Sugiyono, 2019). Quantitative data were obtained from the results of expert assessments. The data was used to prove validity using the Aiken formula and reliability estimation using the Alpha Cronbach and ICC methods. This method can determine the rater agreement index on the quality of learning design and the effectiveness of learning performance objectives to be achieved (Koo & Li, 2016).

Table 1. Teaching module and LKPD assessment grid

Indicators: Teaching Module	**Statement**
1. Content Feasibility:	
1	The content of learning resources based on ethnomathematics of the Papua Mountains is in accordance with the curriculum and basic competencies to be achieved.
2	The content of learning resources based on ethnomathematics of the Papua Mountains includes mathematical concepts relevant to the ethnomathematics of Papua Mountains.
3	The content of learning resources based on ethnomathematics of Papua Mountains has depth and breadth appropriate to the cognitive level of students.
4	The content of learning resources based on ethnomathematics of the Papua Mountains has a connection and integration between the mathematical concepts presented.
5	The content of learning resources based on ethnomathematics of the Papua Mountains has a balance between theory and practice in learning mathematics.
2. Feasibility of Presentation	
6	The presentation of learning resources based on ethnomathematics of the Papua Mountains uses language that is easy to understand and in accordance with EYD rules.
7	Presentation of learning resources based on ethnomathematics of the Papua Mountains uses illustrations, pictures, tables, graphs, or other media that support understanding of mathematical concepts.
8	The presentation of learning resources based on ethnomathematics of the Papua Mountains uses examples, exercises, and evaluations that are varied and in accordance with the teaching material.
9	The presentation of learning resources based on ethnomathematics of the Papua Mountains uses a logical and systematic sequence in presenting teaching materials.
10	The presentation of learning resources based on ethnomathematics of the Papua Mountains uses references that are current and relevant to the teaching material.
3. Feasibility of Display	
11	The display of learning resources based on ethnomathematics of the Papua Mountains uses colors, fonts, sizes, and distances that are comfortable to read.
12	The display of learning resources based on ethnomathematics of the Papua Mountains uses neat and consistent layouts, margins, spaces, and indents.
13	The display of learning resources based on ethnomathematics of the Papua Mountains uses clear symbols, formulas, tables, graphs, or other media.
4. Indicators: LKPD	
14	LKPD based on ethnomathematics of the Papua Mountains is in accordance with teaching materials and learning objectives.
15	LKPD based on ethnomathematics of the Papua Mountains is easy to understand and implement.
16	LKPD based on ethnomathematics of the Papua Mountains is interesting and fun.
17	LKPD based on ethnomathematics of the Papua Mountains is relevant to students' daily lives and cultural environment.
18	LKPD based on ethnomathematics of the Papua Mountains can improve understanding of mathematical concepts.

19	LKPD based on ethnomathematics of the Papua Mountains can improve mathematical connection skills.
20	LKPD based on ethnomathematics of the Papua Mountains can improve attitudes, interest, and motivation to learn mathematics.

learning trajectory activities. Several things that are done in this stageinclude analyzing the KI and KD curriculum, indicators and learning objectives, reviewing literature regarding the concept of reflection ingeometric transformation material, and PMRI, so that a conjecture or guess at student thinking can beformed. Apart from that, in this stage a Hypothetical Learning Trajectory (HLT) is createdwhich is applied in learning to help students learn reflection material. In this stage, the conjecture functions as a guideline that emerges and developsin each learning activity and is flexible and can be revised during the design experiment stage.

Design experiment is the second stage in this research. At this stage, a process of testing learningtrajectories that have been designed in the preliminary design is carried out. This stage aims to explore students' guesses, strategies and thoughts during the actual learning process. The stage carried out in this research was a teaching experiment stage which was tried out on several samples of research subjects.

Lastly, the Retrospective Analysis stage. At this stage, the conjectures in HLT are compared with the results from the design experiment stage. The results of this analysis can produce a description of the learning trajectory in reflective learning using the context of the Cirebon Red Mosque.

3. Results and Discussion

3.1 Results

The results of research and development based on the Dick and Carey learning design development steps are as follows:

a. Identify instructional goals.

Based on the results of the need assessment conducted by researchers that in learning mathematics in the context of learning at a private high school in Nabire Regency, Central Papua Province, it is known that the involvement of students is very limited if the learning design applied by the teacher is based on lectures and assignments. Students have expectations of meaningful and fun learning. Based on the needs of these learners, the learning design was developed to increase learner involvement and create meaningful learning.

b. Conduct instructional analysis

The purpose of developing this learning design is to increase learner engagement and create meaningful mathematics learning.

Engagement can be determined through learner behavior, emotions, and cognition. It can be measured through an interest in learning (emotional engagement), doing LKPD or task completion (behavior and cognitive engagement), and how they enjoy learning (emotional engagement). This aligns with Saqr *et al*. (2023) research that engagement is a multidimensional construct that integrates behavior dimension, emotions, and cognition. Behavioral engagement such as participation and commitment to school work. Emotional engagement is about the emotional experience in learning (e. g. interest or happiness). Cognitive engagement represents learners' thoughtful investment, understanding of critical concepts, and efforts to tackle learning tasks.

The meaningfulness of learning according to Rootman-Le Grange & Blackie (2018) can be known through contextual understanding. Meaningful learning is the process of teachers and students communicating about the relationship between learning activities in the classroom and students' experiences. Therefore, the meaningfulness of learning can be assessed through the process of learners constructing their learning and experience to complete the tasks/answer the contextual questions given.

c. Analyze learners and contexts.

Based on the characteristics of learners, namely learners in a private high school with the majority of students are Papuans and based on the needs of learners as described in point (1), the relevant learning context applied to increase learner involvement and create meaningful learning is ethnomathematics-based learning of Papua Mountains.

d. Formulate learning performance objectives (Write performance objectives)

The learning performance objectives are that students can relate their learning to the context of everyday life so that students have a meaningful learning experience and are actively involved in constructing their knowledge. In this case, students are expected to be able to analyze cone slices (parabola) based on their experience and environmental context and be able to solve contextual problems related to cone slices (parabola).

e. Develop an assessment instrument.

The assessment instrument developed is integrated into the learner worksheet (LKPD). Through the LKPD (Figure 1).

In the LKPD (Figure 1), a picture of *honai* has been presented as a stimulus to link mathematics with objects or cultures that students are familiar with. Through questions on the LKPD, students are guided to explore and associate objects in the picture with mathematical material. Teacher can find out the performance of students in constructing their knowledge and experience. Through the LKPD in Figure 1, students are also given the opportunity to reflect. This encourages students to find meaning in learning mathematics.

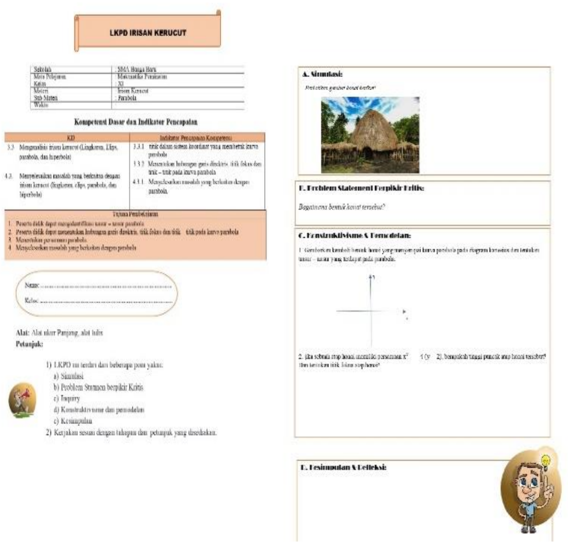

Figure 1. LKPD

f. Develop an instructional strategy

The strategy used in learning is in the first stage of exploring Papuan culture related to the topic of conical slices (Parabola). Learners are asked to explore parabolic shapes found in everyday life, one of which is *honai*. In the second stage, learners are then faced with the problem of critical thinking statements about the traditional Papuan *honai* house. In the third stage, learners do constructivism and modeling according to their knowledge and experience related to *honai* with the help of LKPD (Figure 1) that has been prepared. In the fourth stage, learners generalize (make conclusions) and reflect.

g. Develop and select instructional materials.

After choosing to formulate learning designs (1-6), researchers provide teaching materials in the form of teaching modules (Figure 2) and LKPD (Figure 1). The teaching module provided contains material on conical slices (Parabola) and an introduction to traditional Papuan mountain houses (*honai*) which are equipped with LKPD. Content about *honai* was obtained from the results of literature studies and checked again through interviews with sources who understand *honai*. The interview data was then analyzed using the Miles and Huberman model, (data reduction, data presentation, drawing conclusions) which was presented in the teaching module.

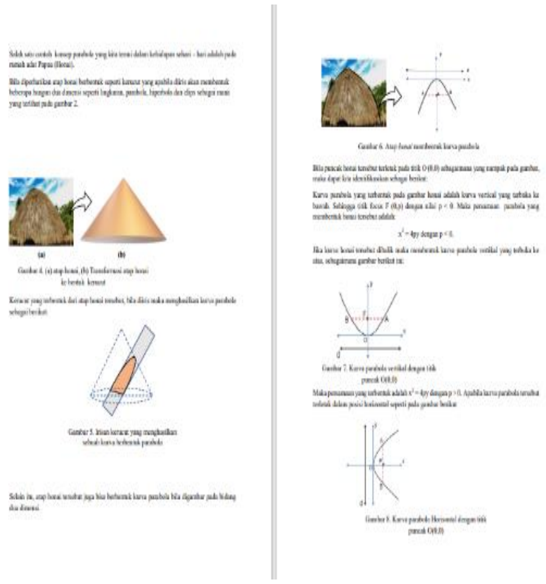

Figure 2. Teaching module

h. Design and conduct a formative evaluation of instruction.

Teaching modules and LKPD that have been prepared are then evaluated qualitatively and quantitatively by experts. Experts involved in the evaluation of teaching modules and LKPD are one community leader who understands traditional Papuan mountain houses (*honai*), two experts in mathematics learning, and two teachers. The qualitative evaluation results are in the form of input to improve the teaching module and LKPD.

Quantitative evaluation data were analyzed using the Aiken formula to determine validity, while Cronbach Alpha and intraclass correlation coefficients (ICC) to determine the reliability index and agreement index of experts who assess teaching modules and LKPD. Based on the results of the analysis, it is known that the validity of the teaching module and LKPD is 0.802. According to Retnawati (2016), a validity index close to 1 indicates a good index because it is related to the indicator. The results of the analysis obtained the reliability coefficient of the teaching module and LKPD developed was 0.896 which showed a good reliability index (Table 2).

Table 2. Cronbach Alpha reliability index

Cronbach's Alpha	N rater
0.896	4

The reliability index is also supported by the ICC value shown in Table 3.

Table 3. ICC

ICC	95 % Confidence Interval		Sig.
0.896	0.653	0.993	0.00

Based on Table 2 and Table 3, it is known that the ICC value is the same as the reliability coefficient using Cronbach's Alpha method with a 95% confidence index and a sig value. 0,00. This shows that the reliability index of the Teaching Module and LKPD is very good (Koo & Li, 2016).

i. Revise the developed product

Teaching modules and LKPD are then refined again according to expert input.

3.2 Discussion

Based on the results of the development of a creative learning design based on ethnomathematics of Papua Mountains carried out in 4 major stages, namely analysis, development design, implementation, and evaluation. At the analysis stage, an analysis of the needs of students and the characteristics of students at a private high school in Nabire Regency, Central Papua Province was carried out. The results of the analysis then become the basis for developing learning that takes into account the characteristics of students and the needs of students in learning. Learning development that pays attention to student needs is useful in determining student competencies that need to be developed (Ridha et al., 2020).

The learning design developed connects mathematics learning with the cultural concepts of students who generally come from the Papua Mountains area. The culture that can be applied in learning the topic of conical slices (Parabola) is the traditional house of the Papuan Mountains Community, namely *honai*. At the learning design stage, the selection of teaching materials, LKPD, and learning strategies are well-prepared and interconnected to create quality learning and achieve learning performance objectives. The learning strategy applied is a learning strategy based on 21st-century learning, namely learner-centered learning. This can be seen in exploration activities, orienting students to problem statements, and how students construct their knowledge and experience in learning, to make conclusions and reflect. This is in line with the research of Miranda, *et al*. (2021) that 21st-century learning needs to adopt student-centered models that encourage students to actively participate in the learning process to build a competent generation.

Based on teacher assessment, it is known that the learning design based on ethnomathematics of Papua Mountains can increase students' involvement in learning. This can be seen from the attitude, interest, and motivation of learners. Students seem to actively express ideas and discuss with friends to complete the LKPD. Student involvement appears in interest in learning, how student complete tasks, and enjoy learning. The impact of the application of mountainous Papua ethnomathematics-based learning is in line with Ergene, *et al*. (2020). Learning design that applies culture in learning has the impact of increasing students' interest in the lesson, making it enjoyable, and enabling the teaching of culture (Ergene et al., 2020).

In addition, mountainous Papua ethnomathematics-based learning trains students to improve their mathematical connection skills by constructing their knowledge about the elements of parabolas and linking their experiences with *honai*. This is related to the meaningfulness of learning according to Rootman-Le Grange & Blackie (2018) which is related to contextual understanding. Meaningful learning is a process where teachers and learners communicate explicitly about the level of representation or connection between classroom learning activities and learners' experiences. Galloway & Bretz (2015) also argued that meaningful learning can be known through learners' activeness in integrating knowledge and attitudes in completing tasks. Therefore, the success of students in constructing their knowledge and experience to complete the tasks/answer the contextual questions given shows that the learning design based on the ethnomathematics of the Papua Mountains can have an impact in creating meaningful learning.

The learning design contained in the teaching module and LKPD has been evaluated qualitatively and quantitatively to determine the quality of the learning design and improve quality of learning design. The results of the analysis showed that the rater agreement index on the learning design in terms of feasibility of content, presentation, and appearance was classified as good according to the criteria applied by Koo & Li (2016). This shows that the learning design based on ethnomathematics of the Papua Mountains is ready to be applied to learning in schools on a large scale.

4. Conclusion

Based on the results of research and development, it is concluded that mountainous ethnomathematics-based learning design is developed in 4 main stages, namely analysis, development design, implementation, and evaluation. Strategies that can be used in mountainous Papua ethnomathematics-based learning to increase learner involvement and create meaningful learning are exploration, oriented to problem statements, and constructing learner knowledge and experience. Qualitative and quantitative evaluation results show that the learning design based on ethnomathematics of Papua Mountains is good and feasible to implement. Learning design based on ethnomathematics of Papua Mountains can increase students' involvement in learning and create meaningful learning.

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