Integrating ethnomathematics into open-ended problem based teaching materials

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Abstract. The idea of integrating ethnomathematics into open-ended problem-based presentation gives a new nuance to mathematics teaching at school. Ethnomathematics is mathematics that develops in a particular culture, and as an alternative in developing mathematics teaching materials which have so far tended to be conventional and less contextual. One way to realize it is by developing open-ended problem-based ethnomathematics which is valid, practical, and effective as an effort to enhance mathematics learning activities and achievement. The development of the teaching materials followed Plomp’s product development procedure. The result of expert validation showed that the teaching materials that have been developed fell into the category of very valid with a few revisions. The student and teacher responses related to the use of the teaching materials showed that the teaching materials fell into the category of very practical with some suggestions for revision. The result of observation related to student activity fell into the category of active and the result of the mathematics learning achievement test of the students underwent an increase in every cycle, so that it showed that the teaching materials developed was effective in enhancing the students’ activities and mathematics teaching achievement.

1. Introduction

An issue that motivated that development of Curriculum 2013 as the improvement of the school-based curriculum (KTSP) in Indonesia was the demand that mathematics teaching at school has to facilitate the students to be active, creative and critical (Abi [1]). This was based on the survey by International agencies such as TIMSS and PISA which still put Indonesia in the lower zone. In addition, the Ministry of Education and Culture explained that Indonesia is preparing for 2010-2035, the period when Indonesia enters the golden generation, since the number of population with the school ages is very high. The students are expected to survive when the condition is always changing, uncertain, and competitive. Furthermore, the Regulation of Minister of National Education No. 23 of 2006 on School Graduate Competence Standard stipulates that through mathematics, the students are expected to acquire logical, critical, creative and innovative thinking ability. Thus, the effort to enhance the quality of mathematics teaching at every level of education becomes a necessity to prepare an individual with critical and creative thinking ability who will be able to solve problems in his or her daily life.

At the elementary school level, the mathematics teaching which stresses on the importance of the students’ rationality and integrates problem solving is more likely to be implemented (Muhsinin [2]). This is supported by the content of the curriculum that includes the mathematics competence standard...
that has to be attained by the students in learning. The intended competence standard is not the acquisition of mathematics as science, but as mathematical ability needed to understand the world, the ability to compete and succeed in life. Depdiknas [3] stated that the mathematics teaching activity is expected to start with the introduction of a problem based on the situation. By posing problems based on the situation, the students will gradually be guided to acquire mathematical concepts.

Based on the problem identification and the demand of the curriculum above, it is deemed necessary to make an effort to improve the teaching implementation that is student centered and is able to maximize reasoning ability and problem solving ability. The teaching that is capable of creating such learning condition is Problem-Based Learning. Yuliana [4] stated that by posing problems at the beginning of the lesson, the students are gradually guided to acquire mathematical concepts. However, teachers need to think of the appropriateness of the types of problems at the beginning of the lesson [5]. Selecting relevant types of problems to be given to the students in the problem-based learning is very important in order the students’ logical, critical, creative and innovative thinking ability can be developed. The type of problems appropriate to facilitate student thinking creativity in PBL is open-ended problem. In the open-ended problem, the students are faced with a problem with many alternative solving procedures and one or many correct answers.

Sudiarta [5] states that open-ended problem is formulated in such a way that it has some or even many correct solutions, and can be solved by many ways. By providing the students with open-ended problems, a low ability student can also give an answer. Besides, the open-ended problems also require the students to explain their thinking patterns through reasoning which can become one source of information for the teacher in looking at the students’ ability.

An important element to be considered in presenting open-ended problems to prevent meaningless and dry learning is the content of the problem itself. Problems presented should fit with the students’ culture [6]. Some people say that students admit the importance of mathematics, but often have difficulty in learning it. This problem arises from a cultural conflict, the mismatch between the cultural tradition outside of the school, i.e., at home or in the community with what they meet at school [7]. Cultural difference causes differences in perspective and has an impact on differences in knowledge. Thus, a link is needed to bridge outside of the school mathematics and mathematics inside the school. Adam [8] stated that one of the ways is by making use of ethnomathematics as the beginning of formal mathematics learning which fits with the concrete operational stage of development of the students.

Gerdes [9] states that ethnomathematics is applied by a particular cultural group, labor/ farmer group, children in a particular social class, professional class, etc. This means that ethnomathematics is not a mere talk about a particular ethnic group. Mathematics teaching needs to bridge daily mathematics that is based on a local culture and school mathematics. Zaenuri explains that various forms of ethnomathematics in a community is related with the mathematical concepts such as the concepts of plane, space, set, etc. [1], so that they can be integrated into mathematics teaching both at elementary (elementary school and junior secondary school) and high school (senior high school/senior vocational school). The implementation of ethnomathematics as the means to motivate and stimulate students can overcome boredom and give a new nuance to mathematics teaching. Since the students are already familiar with ethnomathematics, it is easier to ask them to relate the parts of culture that they have known with the mathematics materials.

Based on the explanation above it can be interpreted that ethnomathematics is an integration of culture into mathematics teaching or, in other words, ethnomathematics has cultural elements. Cultural difference causes a difference in perspective which brings about an impact on differences in the students’ knowledge, so that ethnomathematics nuanced open-ended problems are used as the bridge between outside of school mathematics and school mathematics. The culture introduced depends on where and to whom it is taught. In this paper the researchers take cultural elements and habits of Balinese community, especially in the district of Tembuku, Bangli Regency who work mostly as carpenters, artisans and unique traditional plays makers.
The examples of the elements that can be accommodated in the teaching are as follows. Women in Bali are probably not familiar with the definition of a circle as set of points with equal distances. They may not know how to draw a picture of a circle by using a compass as what the students do at schools. They may not know that the angle in a circle is 360°. But they can really draw a circle by using simple instruments, only by using busung (a fresh coconut leaf), semat (a sharp rib of coconut leaf that is used to stick parts of the busung), and a knife. The way how to cut the leaf into the same size is by folding the center and then sticking the edges, so that we get the shape as shown in Figure 1 below.

![Figure 1. Tamas (Balinese Handicraft with a Circle Shape)](image)

Another ethnomathematical shape is the one that is used in buildings or ornaments that are found in Bali as shown in Figure 2 below.

![Figure 2. Balinese Buildings Ornaments](image)

The insertion of ethnomathematics into the presentation of open ended problems will give a new nuance in mathematics teaching at school based on the consideration that Indonesia consists of various ethnics and cultures, and every culture has its own way to solve the problem that it faces. Another consideration is that mathematics learned at school does not fit with the local community life that it is difficult for the students since there are two different schemata learned in the environment and at school. Hence, the presentation of an open-ended problem with ethnomathematical nuance is expected to facilitate the students’ creativity which later will give a positive impact to the students’ learning activities and achievements.

However, the lack of valid, practical and effective open-ended based teaching materials with ethnomathematical nuance is a constraint in the implementation of open-ended problem-based teaching model with ethnomathematical nuance at school. This is supported by the research by Sudiarta [5] that has developed an open ended-problem oriented mathematics teaching, but in its implementation the teacher still had difficulties in looking for ideal open-ended problems. In the same vein Tandidiling [6] in the study that has developed a school mathematics with local culture-based ethnomathematical approach states that no teaching materials that supported it.

Based on the problem above, it is necessary to do a research to obtain and develop mathematics teaching materials. Related to the aforementioned background, the question addressed in this study was “how the quality of the developed open-ended problem based learning materials with ethnomathematical nuance can be used to increase the seven grade students’ learning activities and achievements in the triangle and rectangular topics?”
2. Methods

The development of teaching materials in this research followed the procedure of teaching materials development in Plomp [10]. The procedure was divided into four stages as follows.

Preliminary investigation. The activities at this stage were analyzing the situation and identifying the problems faced by the students and the teachers in mathematics lessons in the classroom. The things done were: (1) reviewing the result of the 7th grade students learning achievement in the last two years and administering a pretest to the 7th grade students (class VII A ) SMPN 3 Tembuku Bangli for a limited field try-out; (2) reviewing mathematical teaching process; (3) doing interviews with the teachers and the students about the problems in teaching mathematics; and (4) reviewing the teaching materials used. From the result of analysis a solution was made by analyzing the relevant theories and relevant research findings.

Design stage in which a probable solution to the problem identified at the preliminary investigation stage was designed by (1) reviewing the relevant theories to improve the learning quality, and planning the implementation of PBL model to be presented using open-ended problems and integrating ethnomathematical elements; and (2) designing teaching materials relevant to the characteristics of open ended PBL model that integrated ethnomathematics.

Realization stage in which the solution designed was realized to to produce Prototype 1. The prototype had open ended problem-based teaching materials integrating ethnomathematical values whose validity, practicality and effectiveness were tested.

Test, evaluation and revision stage with the following activities: (1) validating the teaching materials of prototype I which was done by two experts (validators). Based on the result of this validation, a revision was made to obtain teaching materials of prototype 2. After prototype 2 was obtained, a limited field try-out was carried out. (2) the try-out had the purpose of finding out the practicality and effectiveness of the teaching materials. The try-out activity was divided into three cycles. Every cycle consisted of planning, observation, and evaluation as well as reflection stages to see whether the teaching materials developed have met the criteria desired.

The data collected were then processed descriptively. The success indicator was that the teaching materials developed at least had to fall into the category of valid, practical, and effective according to Nieveen’s criteria [11]. To attain the category of valid, the mean score of the validation sheet should at least reach \( 2.5 \leq \text{Sr} < 3.5 \) (from validator 1 and validator 2) to make it possible to do a limited field try-out. The teaching materials developed can be called practical if at least the mean score of the sheet for observing the implementability of teaching materials given by the teacher and the researchers, the mean score of the questionnaire of the students’ response, and the mean score of the teacher’s response were in the interval of \( 2.5 \leq \text{Sr} < 3.5 \). The teaching materials could be said effective if the test score of the students’ mathematics learning achievement at least reached the standard set out by the school, i.e., 70, and the mean score from the sheet for observing the students’ mathematics learning activities obtained was at least in the interval \( 2.5 \leq \text{Sr} < 3.5 \).

3. Results and Discussion

3.1 Results

The results are explained based on the finding(s) of each stage in Plomp’s development model. At the preliminary stage the causes of the low level of activities and achievement in mathematics learning achievement of the students were identified as follows: (1) the teaching did not give the opportunity to the students to find by themselves the concepts being learned. The teacher generally concentrated too much on the practices in solving problems which were more procedural and mechanistic than meaningful; (2) the teaching of mathematics seldom started with the introduction of a problem that fitted with the situation. By posing problems at the beginning, the students were gradually guided to acquire mathematical concepts. (3) the teaching tended to focus on the presentation of closed ended problems which did not give enough time for the students to be creative. (4) the students admitted that mathematics was important, but some of them often had
difficulties in learning it. This was caused by cultural conflicts, the mismatch between the cultural tradition that the students met outside the school and what they met at school.

Based on the findings at the preliminary stage above, at the design stage, the researchers collaborated with the teacher in reviewing constructivist learning theory and relevant research findings to overcome the problem. The solution was by implementing open-ended PBL, and presenting open-ended problems which were integrated with ethnomathematical nuance. The first real attempt made was to design the teaching materials that supported the characteristics of the teaching, i.e., open-ended-based teaching materials with ethnomathematical nuance. Then, the researchers realized the design until having a draft or prototype ready to be measured in terms of its validity, practicality, and effectiveness at the test, evaluation and revision stage.

At the test, evaluation, and revision stage, the prototype was validated by 2 validators from the Mathematics Education Department, Universitas Pendidikan Ganesha, validator I was chosen by considering his experience in doing a research about ethnomathematics, and validator II was selected based on his experience in doing a research about problem-based teaching materials development. Thus, the two validators could be said to have met the criteria to evaluate the quality of the teaching materials developed in this research. The following is presented the recap of the results of the validators’ evaluation of the open-ended problem-based teaching materials with ethnomathematical nuance in Table 1 below.

### Table 1. Recap of the Results of the Validation of Teaching Materials

| No | Aspects evaluated          | The mean score given by validators | Total | Mean |
|----|----------------------------|-----------------------------------|-------|------|
|    |                           | I       | II     |       |
| 1  | Content of the Teaching materials | 3.50    | 3.50   | 7.00  | 3.50 |
| 2  | Presentation technique     | 3.67    | 4.00   | 7.67  | 3.84 |
| 3  | Physical form              | 4.00    | 4.00   | 8.00  | 4.00 |
|    | Total                      |         |        |       | 11.34|
|    | Mean                       |         |        |       | 3.66 |

Table 1 shows that construct validity of the teaching materials meets the criteria of validity (very valid), since the mean score of validity was in the interval $3.5 \leq \text{Sr} \leq 4.0$. Then, the level of practicality of the teaching material was measured by looking at the students response questionnaire and teacher response questionnaire which were filled in by the teacher and the students after teaching using the materials. The following is presented the recap of the result of the validators’ evaluation of the open-ended PBL materials with ethnomathematical nuance in Table 2 below.

### Table 2. Recap of the Results of the Practicality of Teaching Materials

| No | Research Instruments          | Practicality |
|----|-------------------------------|--------------|
|    |                               | Mean | Criteria |
| 1  | Student Response Questionnaire| 3.36 | Practical |
| 2  | Teacher Response Questionnaire| 3.25 | Practical |

The level the effectiveness of the teaching materials was seen from two aspects, i.e., (1) the mean score from the observation of students learning activity by the teacher and the two researchers during the three cycles and (2) the result of the students’ achievement in learning mathematics at every cycle after learning by using the materials developed. The recap of the results of the observation of the students learning activity and achievement a presented in Table 3 and Table 4 below.
Table 3. Result of the Observation of the Students Activity using the Teaching Materials

| Observer | Cycle I | Cycle II | Cycle III |
|----------|---------|----------|-----------|
|          | 1 2 3 4 5 6 7 8 9 |          |           |
| Observer 1 | 2.40 2.40 3.00 3.20 3.20 3.40 3.60 3.80 4.00 |          |           |
| Observer 2 | 2.00 2.60 2.80 3.00 3.20 3.60 3.60 3.80 3.80 |          |           |
| Observer 3 | 2.60 2.60 2.60 3.20 3.20 3.20 3.80 3.80 4.00 |          |           |
| Mean      | 2.56   | 3.25     | 3.80      |           |
| Category  | Active | Active   | Very Active |

Table 4. Mathematics Learning Achievement in Every Cycle

| Cycle | Criteria of Completeness | Number of Students | Percentage | Mean Score | Category |
|-------|--------------------------|--------------------|------------|------------|----------|
| Cycle I | Score ≥ 70 | 19 | 63.33% | 69.80 | Not Yet Complete |
|        | Score < 70 | 11 | 36.67% |        |          |
| Cycle II | Score ≥ 70 | 24 | 80% | 73.56 | Complete |
|         | Score < 70 | 6  | 20%  |        |          |
| Cycle III | Score ≥ 70 | 27 | 90% | 76.43 | Complete |
|         | Score < 70 | 3  | 10%  |        |          |

3.2 Discussion
This research has produced open ended PBL materials which integrated ethnomathematical content with the expected level of validity, practicality and effectiveness. There was an increase in students learning activity and achievement after using the materials. Thus, by presenting materials and integrating content close to the students’ habit, the teaching will become more meaningful, interesting, and increase the students’ learning activity and achievement in mathematics.

The increase was obtained through the stages in the open ended PBL model which facilitated the students to do problem solving activities and to use their reasoning in solving problems given. The most important characteristic in presenting open ended problems is the presence of the opportunity for the students to use a number of methods that they regard most suitable in solving the problems. It means the questions in the open ended problem are oriented to guide the development of understanding of the problem given. Sawada [12] states that open ended problem needs responses about the thinking process, ability to make a generalization and to find relations between two concepts. Hence, the success in presenting open ended problem does not depend only on the format and the materials, but is very much dependent on the procedure, condition and the technique of presentation, so that the students are directed to use their critical and creative thinking ability to solve the problem given, which has the effect on the students’ activity in the learning process. This is shown by the students’ responses after using the materials, in which the students do not hesitate to use their abilities because they are free to use them in solving the problems presented in the teaching materials.

This problem arises from a cultural conflict, the mismatch between the cultural tradition outside of the school, i.e., at home or in the community with what they meet at school. Culture determines the students’ view in responding to something, including in understanding mathematics teaching materials, when a materials is too far from the culture schema its students’ they will have difficulty in understanding it. Cultural differences cause a difference in perspective which brings about an impact on differences in the students’ knowledge, so that ethnomathematics nuanced open-ended problems are used as the bridge between outside of school mathematics and school mathematics. Francois [13] stated that ethnomathematical content is required in mathematics teaching which is able to relate mathematics and their culture. By integrating ethnomathematics into the teaching it makes it more possible a material learned to be understood by the students. The characteristics of ethnomathematics which is developed in this study is by integrating the mathematical topics of the area of triangle and rectangle that be implemented by the group of people, tradition, children, and professional classes in the Tembuku District, Bangli Regency, Bali.
To take an example, researcher implemented a traditional play of kelas-kelasan which is commonly played by children in Tembuku district, Bangli regency. Kelas-kelasan is a game that similar with engklek in Bahasa Indonesia. It can be done on the ground, field, or floors. The surface for the setting of the game usually in form of squares. In this study, the researcher modified the surface by using various plane, such as square, rectangle, trapezoid, and others. For drawing and finding the length and width the surface, the students only need a chalk and tape measure. In the following Figure 3, the example of students’ worksheet that integrating the ethnomathematics in serving open-ended problem by using kelas-kelasan traditional game can be observed.

Figure 3. Integrating the kelas-kelasan game into the presentation an open-ended problem.

The integration of ethnomathematics in open-ended problem can also be seen in the technic used by traditional carpenters in Tembuku Regency. The majority occupation of the people in Tembuku is as a carpenter and most of the students help their parents to work after school or during the school holiday. An interesting fact of the carpenters in Tembuku Regency is they have no formal school background but able to implement mathematics in proper way, because it was taught by their ancestors as a culture. For instance, to put the lamp right in the center of ceiling which has the form as rectangle. Without knowing the characteristics of a rectangle they are certainly put two robes from the opposite angles and put the lamp in the intersection of the robes. The example of students’ worksheet which is integrating the traditional carpentry techniques to the characteristics of rectangle can be seen in Figure 4.

Figure 4. Integrating the carpenter’s technic in an open-ended problem

Besides the aforementioned two ethnomathematical contents, there also other cases that can be used as a mathematical problem. It can be seen in the Balinese traditional crafting or ornaments in Tembuku Regency and Balinese traditional hand-made offering that mostly done by Hinduism women. The skills are informally come from one generation to the next generation and become the occupation for the Balinese people.
Therefore, the role of ethnomathematics in an open-ended mathematical problems can be classified into three major aim, which are: (1) provides a rich teaching and learning environment, not only inside classroom but also outside classroom, this create a positive motivation for the students to learn mathematics in meaningful way, (2) gives the students chance to construct their own concept and understanding based on their real experiences, and (3) develops a respect feelings toward the nation and its tradition, art and culture.

The result of the study comforms to the finding by Ricardo [14] about the role of ethnomathematics in implementing mathematics teaching in Curriculum 2013, who also concludes that by integrating ethnomathematics the students are facilitated and able to construct mathematical concepts with their prior knowledge through their environment. In adition, the result of the study is similar to the result of the research by Eka Mahendra [15] about Project Based Learning with ethnomathematics content in mathematics teaching, that the implementation of Project- Based Learning with ethnomathemathic content has a significant effect on the motivation and learning achievement in mathematics of the junior high school student.

4. Conclusion
Based on the discussion at can be concluded that through the stages in Plomp’s product development model open ended problem based teaching materials with ethnomathematics content which are valid, practical, and effective to enhance the activity and mathematics learning achievement of the students of junior high school in plane geometry. The integration of ethnomathematical content into the presentation of open-ended problem, implied to the concept and knowledge that are constructed by students become real based on their on environment so that the teaching becomes more meaningful. The different culture of the students affect to the different point of view which create different understanding. Hence, it is important for the teacher to serve the open-ended mathematical problem with ethnomathematics context in the beginning of lesson which can be used as the bridge for the practical mathematics outside classroom and what they learn in the formal lesson. Therefore, the previous problem about the conventional and not contextual text book can be solved.

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