Realistic mathematics learning based on the ethnomathematics in Bengkulu to improve students’ cognitive level

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Abstract. Mathematical learning based on ethnomathematics applying local culture can change the perception of the society about the applications of mathematics in everyday life. The purpose of this study was to describe the increase in high school students’ cognitive level through the implementation of realistic mathematics learning model based on ethnomathematics in Bengkulu. This study was an assessment phase of development research employing a 2×2 factorial experimental design with students’ initial performance being controlled. There were three main findings of this study. First, mathematical understanding of students taught using realistic mathematics learning was higher than those who taught using the conventional method (the learning materials in both groups was non-ethnomathematics oriented). Second, mathematical understanding of students learned the ethnomathematics oriented materials was higher than those learned non-ethnomathematics oriented materials (realistic mathematics learning applied in both groups). Third, mathematical understanding of students who learned the ethnomathematics oriented materials was lower compared to the students learned the non-ethnomathematics materials (the conventional learning method applied in both groups).

1. Introduction
To improve the understanding of mathematical concepts, learning must begin with the real objects in daily life [2,3], which were culturally oriented concerning horizontal mathematics known as the ethnomathematics [4]. It builds a system of knowledge offering the possibility of a more harmonious and good relationship in human behavior and between human and nature [5,6,7,8,9]. Ethnomathematics is the representation of a daily mathematical practice or the culture of a particular group in a socio-cultural environment [10,11,12]. It can build mathematical reasoning and mathematics as a cultural construct [5] [11]. According to Freudenthal [13,14], mathematics is a human activity, and thus the objects of mathematics in mathematics learning should begin with real problems in everyday life or those close to the student’s mind. Mathematical learning based on the ethnomathematics applying local culture can change the perception of the society concerning the lack of connection between mathematics and daily life [15,16].

Mathematics learning emphasizes more on students to understand facts, concepts, principles, and operations. Understanding of the mathematics concepts is the result of construction or reconstruction of mathematical objects. The construction or reconstruction is done through activities of mathematical
actions, processes, objects organized in a scheme to solve questions or problems [18,19]. To understand the concepts of high school mathematics, students are expected to perform an intelligent and responsible action based on knowledge, skills, and values integrated through the process of abstraction, idealization, and generalization used to carry out tasks or solve problems associated with high school mathematics.

However, the results of preliminary research conducted in several high schools in the province of Bengkulu showed that students made mistakes of the concept and principles of understanding mathematics. The errors of concepts and principles committed by the students included the limit of a function. When the students asked to solve the problem of the limit of a function: \( \lim_{x \to 1} \sqrt{x} - 1 \), 76% of students made mistakes concerning the concepts/principles in solving the problem. 57% of students’ answer was 0/0, 14% was 1, 5% was 0, and the remaining 24% provided the correct answer of \( \frac{1}{2} \). Since the quadratic equation plays an important role in solving the problem related to the limit, the students’ understanding of the quadratic equation was traced by asking them to solve the problem of \( \frac{x^2 - 3x + 2}{x - 2} = 12 \). Evidently, 38% of students solved the problem by presenting \( (x-2)(x-1) = 12 \), followed by \( x-2 = 12 \) or \( x-1 = 12 \) and concluded that the solution was \( x = 14 \) or \( x = 13 \). This result shows that 38% of the students committed errors concerning the concepts and principles in solving the quadratic equations. These errors are due to a low abstraction process leading to students having difficulty in solving mathematical problems.

Based on students’ difficulties in performing the abstractions related to the concept and the principle of the limit of a function, it is implied that the mathematics learning in high school still mostly focus on theory and is not related to daily life. The students learn mathematics mechanistically without understanding the application of the theory learned. As a result, students experience difficulty in understanding the mathematics learning materials and tend only to memorize the concepts/principles learned. Most students of senior high school study mathematics merely to pass the national exam. Consequently, they find it difficult to solve everyday life problems even when they are closely related to the mathematics content being studied. Besides, mathematics learning does not connect with and explore the phenomenon around students despite mathematics being a human activity [2,3]. According to [21], to overcome the cognitive conflict and students’ mistakes as experienced by the students mentioned previously, realistic mathematics learning model is required. To achieve the vertical mathematical process well, [6] [22] [24] suggested applying ethnomathematics-based learning. Mathematics learning based on the ethnomathematics enables the process of the abstraction, idealization, and generalization of concepts and principles of mathematics. When it is viewed based on the characteristics of mathematics, mathematics is a human activity which was the utilization of the reality and environment understood by the learners to expedite the process of learning mathematics to achieve a better mathematics education [2-3,13].

Based on the review discussed earlier, a mathematics learning based on the ethnomathematics is needed as a starting point. In short, based on the ethnomathematics, mathematics considers the quantitative, relational and cultural aspects of the society that are integrated with the concrete things that can be observed or understood by learners through the process of mathematization as mathematics is a reflection of the real world through an empirical abstraction process [2,3].

Improving students’ mathematical ability can be conducted through meaningful learning. Learning mathematics is meaningful if it is close to the students’ mind [2,3] [13] [25] so that students can be a problem solver in everyday life, have an excellent mathematical communication and provide a correct mathematical representation [31]. In learning mathematics, students perform the process of mathematical communication either orally or in writing. The improvement of mathematical communication and representation of high school students is increased when the starting point is the down-to-earth problems [31]. Mathematics learning exposes students to the process of interaction and multi-direction
communication between students, teachers and learning instrument allowing a growing dynamic during the learning in the classroom.

Mathematics is the miniature of democracy and our society. Therefore, mathematics learning should be implemented using the ethnomathematics, and/or local culture as the starting point [6-7, 9, 26-27]. The results of previous studies [24] [11] showed that learning with ethnomathematics approach is more effective compared to the conventional approach. One reason is that ethnomathematics plays an essential role in building a civilization rejecting the gaps, arrogance and fanatical attitudes [8]. The ethnomathematics-oriented learning can increase student activities as well as enhance students' motivation, interest, and confidence. Ethnomathematics can build mathematical reasoning and mathematics as a cultural construct.

In everyday life, ethnomathematics forms a system of knowledge offering the possibility of a more harmonious and good relationship in human behavior as well as between humans and nature [8]. Ethnomathematics is a representation of a daily mathematics practice or a culture of a particular group in a socio-cultural environment [8,9]. However, mathematics education is not political [16]. Thus, mathematics education must be free from the influence of power. So that according to [15] [28] by The application of ethnomathematics, in the form of local culture, in mathematics learning can reduce the perception of the society concerning the lack of connection between mathematics and daily life.

By applying the surrounding culture as the starting point of mathematics learning, ethnomathematics can be the integrated component of mathematics education. Therefore, ethnomathematics can be integrated into the mathematics curriculum intensively [12]. This is rational as ethnomathematics is a sub-field of mathematics history and mathematics education with a natural connection to anthropology and science [9].

To implement mathematics learning to achieve the mastery of mathematical representation, mathematical communication, and problem-solving skills, a conceptual framework of learning model is required [29]. The learning model using problems in everyday life or that is close to the students' mind [2,3] [13], the culture of the local community [6] [8,9] [13], as the starting points. The model is a model of realistic mathematics learning based on ethnomathematics [22].

Realistic mathematics learning model based on ethnomathematics highly benefits the students in the process of abstraction, idealization, and generalization [30] [18] [20] [32], by utilizing off and for the model [13]. The abstraction ability is an ability to pay attention and determine the nature, attributes, or special characteristics that were important by putting aside different unimportant things. Based on the results of Widada's research [32] [30] [18] [20], there were six levels of abstraction performed by students, i.e., Level 0: Concrete Objects; Level 1: Semi-concrete models; Level 2: Theoretical Models; Level 3: Language in Domain; Level 4: Geometry Language; and Level 5: Inference Model. Widada’s Research (2016b) found that in term of the cognitive structure of learners that was reviewed based on the abstraction ability in the formation of mathematical concepts, 74% of students had the constructive functional element and 26% of students whose constructive elements were predictive. Thus, most cognitive structures of learners in performing abstraction is functional.

Research conducted by Widada [18] [30] [32] produced a description of the learners’ abstraction ability in understanding mathematical concepts of Level 0 (Concrete Objects), Level 1 (Semi-concrete), Level 2 (Theoretical Models), Level 3 (Languages Domain in example), Level 4 (Mathematics Language), and Level 5 (Inference Model). While, in the process of understanding the concept of mathematics, Widada [32] have conducted a long-term study concerning the students’ cognitive structure in understanding mathematics. The results of Widada's study [18] reinforced and complemented the theory of Cognitive Development (scheme) of students (Extended Level Triad ++) in learning mathematics [17].

Based on the progression scheme of Extended Level Triad ++ [32], the learning model based on Extended Level Triad ++, learning model close to the student's mind is developed. The learning model is
outlined in the learning syntax consisting of three cycles: Problem Launch, Exploration, and Conclusion. Based on the three main cycles, more detailed steps can be derived: (1) Preliminary phase; (2) Thinking Phase, (3) Coupled Phase, (4) Exploration Phase, (5) Discussion of Exploration Phase, (6) Conclusion Phase; and (7) Closing phase [20].

To achieve the highest level of mathematization process [14], in the horizontal mathematization, students with their knowledge can organize and solve the existing problems in real-world situations. In other words, horizontal mathematics moves from the real-world to the world of symbols. While vertical mathematization is the process of reorganizing using mathematics itself or "real-world" as the source of mathematization and a place to reapply the mathematical concepts. Thus, the vertical mathematization moves from the world of symbols. Gravemeijer [2-3] suggested that there are three main principles of realistic mathematics learning, namely: rediscovering and progressive mathematization, didactic phenomena, self-building models. Treffers [13] revealed the characteristics of realistic mathematics learning as the use of context, use of models, bridging by vertical instrument and students’ contribution. By the production and construction, students were encouraged to reflect on parts they find important in their learning [23].

A study [31] showed that the mathematics problem-based learning on Earth Raflesia Bengkulu (ethnomathematics in Bengkulu) could improve students' ability to solve the problems, increase their cognitive process through a higher level of thinking, creative and critical thinking resulting in students being able to perform mathematical representation and communication correctly.

Thus, mathematics learning in high school should be taught by implementing the mathematics learning model employing a realistic mathematics education approach based on ethnomathematics in Bengkulu.

2. Methods
This study was an assessment phase of Plomp’s developmental research model [1]. In this phase, we conducted the test, evaluation, and revision of the teaching materials, the realistic mathematics learning model based on ethnomathematics in Bengkulu. Once these materials met all the required standard, we implemented them in the classroom. In the implementation, we employed a $2 \times 2$ factorial experimental design. The preceding stage was the preliminary research and prototype phase. The learning approach included realistic and expository mathematics, while the approach of mathematics materials included ethnomathematics and conventional. The population of the study was all students in one of senior high school in Bengkulu, with a sample of 80 students. The sample was selected by the intact group technique. The realistic mathematics learning approach based on ethnomathematics in Bengkulu was implemented in the experiment class, and the conventional approach was implemented in the control class. Data collection was carried out using the instrument of mathematics understanding ability. It was used to measure students' cognitive level of mathematics understanding. Data were analyzed by Analysis Covariance (ANCOVA) test.

3. Result and discussion
Based on the data of realistic mathematics learning experiment with ethnomathematics in Bengkulu, the analysis of covariance was conducted and the results are presented in Table 1.

Table 1 shows that $F_0 (A) = 21.290$, $df = (1.79)$ and $p$-value $= 0.00<0.05$, $H_0$ was rejected. It means that there was a significant difference in mathematics understanding ability between students taught by realistic and conventional mathematics learning approach after controlling the students' initial ability. Table 1 also displays that $F_0 (B) = 29.466$, $df = (1.75)$ and $p$-value $= 0.00<0.05$, $H_0$ was rejected. This
means there was a significant difference in mathematics understanding ability between students who were
given the ethnomathematics-oriented the non-ethnomathematics learning materials after controlling
students' initial ability. Besides, Table 1 also presents $F_{o}(AB) = 40.960$, df(1.75) and $p$-value =
0.00<0.05, Ho was rejected indicating that there was an interaction effect of the learning approach and
mathematics materials orientation to the ability of mathematics understanding ability after controlling
student's initial ability. It is also shown that $F_{o}(X) = 278.460$, df(1.75) and $p$-value = 0.00<0.05, Ho was
rejected meaning that there was the linear covariate effect of student's initial ability and mathematics
understanding ability. As for the corrected model, $F_{o} = 246.049$ with df (4,75) and $p$-value = 0,00<0.05
Ho was rejected. Thus, the students' initial ability, learning approach and mathematics material orientation
together influence the mathematics understanding ability.

**Table 1. Tests of Between-Subjects Effects**

| Source          | Type III Sum of Squares | df  | Mean Square | F     | Sig. |
|-----------------|-------------------------|-----|-------------|-------|------|
| Corrected Model | 13518.576               | 4   | 3379644     | 246,049 | .000 |
| Intercept       | 447.232                 | 1   | 447.232     | 32560 | .000 |
| A               | 292.435                 | 1   | 292.435     | 21.290 | .000 |
| B               | 404.733                 | 1   | 404.733     | 29.466 | .000 |
| A * B           | 562.616                 | 1   | 562.616     | 40.960 | .000 |
| X               | 3824.826                | 1   | 3824,826    | 278.460 | .000 |

**Table 2. Parameter Estimates (1)**

| Parameter      | B  | Std. Error | t   | Sig. |
|----------------|----|------------|-----|------|
| Intercept      | -66.633 | 6.452   | -10.327 | .000 |
| [A = 1.00]     | 3.599 | 1.159 | 3.106 | .003 |

Based on Table 2, $t = 3.106$ and $p$-value = 0.003<0.05 means Ho was rejected. This means that the
average ability of students’ mathematical comprehension to be taught with realistic mathematics learning
approaches was higher than students who were taught using conventional learning approach after
controlling students' initial ability.

**Table 3. Parameter Estimates (2)**

| Parameter      | B  | Std. Error | t   | Sig. |
|----------------|----|------------|-----|------|
| Intercept      | -69.954 | 6.175 | -11.329 | .000 |
| [B = 1.00]     | 4,871  | 1.098 | 4,436 | .000 |

Table 3 presents $t = 4.436$ and $p$-value = 0,000<0.05 meaning Ho was rejected. This means that the
average ability of students' mathematics understanding learned using the ethnomathematics-oriented
material was higher than those given non-ethnomathematics oriented material after controlling the initial
ability.
| Parameter       | B  | Std. Error | T      | Sig.  |
|-----------------|----|------------|--------|-------|
| Intercept       | -37.636 | 6.979     | -5.393 | .000  |
| X               | 1.748   | .105      | 16688  | .000  |
| [A = 1.00] * [B = 1.00] | 12001  | 1.391     | 8.628  | .000  |

Based on the results shown in Table 4, it is identified that $t = 8.628$ and $p$-value $= 0.000 < 0.05$, meaning $H_0$ was rejected. It indicates that there was an interaction effect between the learning approach factor and mathematics materials orientation to the mathematics understanding ability after controlling the student's initial ability.

| Parameter       | B  | Std. Error | t      | Sig.  |
|-----------------|----|------------|--------|-------|
| Intercept       | -37.636 | 6.979     | -5.393 | .000  |
| X               | 1.748   | .105      | 16688  | .000  |
| [A = 1.00] * [B = 1.00] | 11.316 | 1.466     | 7.721  | .000  |
| [A = 1.00] * [B = 2.00] | -3.652 | 1.402     | -2.604 | .011  |

Table 5 describes the results of t-test (column A1B1) showing $t = 7.721$ and $p$-value $= 0.000 < 0.05$ indicating that $H_0$ was rejected. Thus, mathematics understanding ability of students who were taught with a realistic mathematics learning approach was higher than those taught by the conventional learning approach (both groups of students were given ethnomathematics-oriented materials, and students’ initial ability was controlled). Furthermore, the t-test result on column A1B2 shows that $t = -2.604$ and $p$-value $= 0.011 < 0.05$ meaning $H_0$ was rejected. Therefore, the mathematics understanding ability of students learned using realistic mathematics learning approach was lower compared to the students learned by the conventional learning approach (both groups of students were given mathematics materials of non-ethnomathematics after controlling the students' initial ability).

The results of a study [31] showed that, during the learning process of realistic mathematics based on ethnomathematics in Bengkulu, the students could dominate the learning activities. Horizontal mathematical activity conducted by the students in solving the problem about "ikan sejerek bere secupak madar." This suggests that mathematical models based on ethnomathematics and local culture can reduce the perception of society about the lack of connection between mathematics and to daily life as revealed by Septianawati and Puspita [15] and François and Karen [16]. By applying realistic mathematics learning approach based on ethnomathematics in Bengkulu, students' cognitive level can reach the highest level as described by Widada [32].

4. Conclusion

Based on the results of the ANCOVA, it can be concluded that: after the students' initial ability was controlled, the average mathematical understanding ability of students taught in the classroom implementing the realistic mathematics learning approach was higher compared to those taught by implementing the conventional learning. Also, the average ability of students' mathematical understanding who learned the ethnomathematics-oriented materials was higher than students who were given non-ethnomathematics materials (their initial ability was also controlled).
As for the students who were given ethnomathematics-oriented materials, mathematics understanding ability of those learned by implementing the realistic mathematics learning approach was higher than students those used the conventional learning approach after controlling the students' initial ability. Also, for students learned the non-ethnomathematics oriented materials, mathematics understanding ability in the classroom utilizing the realistic mathematics learning approach was lower than their counterpart after the students' initial ability being controlled.

The results also indicate that for the students studied using the realistic mathematics learning approach, the mathematics understanding ability of students given the ethnomathematics-oriented materials was higher than the students learning with the non-ethnomathematics materials after controlling the students' initial ability. Finally, when students were taught using a conventional learning approach, the mathematics understanding of students obtained the ethnomathematics-oriented materials was lower compared to the students with non-ethnomathematics materials after controlling the student's initial ability.

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