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An implementation of ethnomathematics-science, technology, engineering, mathematics (ethno-STEM) to enhance conceptual understanding

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Abstract

The Ethnomathematics-based STEM (Ethno-STEM) approach is currently one of the topics that receive attention to improve students' conceptual understanding. This study aimed to investigate the effect of the Ethno-STEM approach on students' conceptual understanding. This study utilized quantitative data with a quasi-experiment. One class was chosen through a simple random sampling technique. The instruments used were conceptual understanding tests and an observation sheet of learning implementation. The data analysis techniques used were descriptive and inferential analysis, as well as the criteria of effect in instruction. Key findings point towards the importance of building an Ethno-STEM approach that supports the conceptual understandings. Identification of critical elements of the teachers' supports led to recommendations for teacher preparation for mathematical learning. We see the study as having value for research and practice by raising a new approach related to Ethno-STEM and demonstrating the need for the development of theory to explain the relationships identified by this study.

INTRODUCTION

Strengthening students' capabilities in Science, Technology, Engineering, and Mathematics (STEM) is crucial for future economic and technological growth in many countries throughout the world (Morrison et al., 2020; Wilson, 2020). One critical need in the preparation of future teachers for work in educational environments involving student-centered exploration of STEM; for instance conceptual understanding, critical and creative thinking, and mathematical reasoning (Ramful et al., 2017). Also, Indonesian educators lack a localized evidence base to guide STEM initiatives, resulting in an approach to improve conceptual understanding (Jones, 2019). Therefore, there is a pressing need to identify effective and appropriate STEM practices to meet the needs of all students.

Assessing conceptual knowledge is notoriously difficult (Chang et al., 2016; Shaughnessy et al., 2020). Even the definition of conceptual knowledge has long been discussed. In mathematics, there seems to be a consensus to define conceptual knowledge as the understanding of mathematical principles (Ilyas et al., 2019). Conceptual understanding is a skill that allows an individual to comprehend and explain the meaning or points of a concept (Ma'Rufi et al., 2020). Providing that the students fully understand a mathematical concept, not just retention, can support the students to solve the problems requiring higher-order thinking skills. This issue is not unique to approaches regarding how to teach for conceptual understanding. Therefore, understanding the implementation of STEM to recent calls to

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Mathematics instruction in Indonesia did not fully support students' conceptual understanding of mathematical topics (Safrudiannur & Rott, 2019). The learning implemented was teacher-centered instruction. Teachers tended to provide formulas and concepts verbally even though a learning environment becomes the essential factor affecting students' mathematics achievement (Han et al., 2015). The teachers should have the ability to implement creative and innovative learning that allows students to participate fully in the learning process. It is in line with the demand for teachers in the era of 4.0. One of the approaches in learning that could be implemented by them to meet the must-haves is the STEM (Science, Technology, Engineering, and Mathematics) approach.

STEM conforms to the objectives of Kurikulum 2013 in Indonesia, which emphasized the process of critical, creative, and innovative thinking skills. They are essential aspects of national development. The teachers can employ STEM as a learning approach that combines the discipline of science, technology, engineering, and mathematics (Cangelosi et al., 2013; Milaturrahmah et al., 2017). The integration of STEM provides interactive learning for students, which facilitates them to comprehend and develop their conceptual understanding (Farmer et al., 2015; Stohlmann, 2019). It supports the students to collect data and then analyze and solve questions and to comprehend its relationship with other problems. STEM accommodates the students to participate in the learning process naturally, which provides them with a meaningful learning environment, including conceptual understanding.

Several studies already reported the merits of integrating STEM into learning media. A study reported that the integration of STEM into a mobile application of augmented reality could improve students' achievement (Wahyu et al., 2020). Several researchers also suggested that modules or students' worksheet with a STEM approach could enhance their skills in critical and creative thinking (Lestari et al., 2018; Retnowati et al., 2020; Sarnita et al., 2019). Also, some even revealed that the module with the STEM approach that they developed is valid to be used and implemented in mathematical topics such as quadrilateral and set (Aminingsih & Izzati, 2020; Utami et al., 2018). They reported that students and teachers felt interested in using the module.

Implementing STEM into the learning process also could be one of the alternatives. Many research findings highlighting the importance of STEAM learning strategies such as problem-based learning, connection to the real world, and rigorous learning experiences (Elia, 2020; Siyepu, 2013). Also, the implementation of STEM into project-based learning effectively increases students' critical thinking skills in the topic of science. Moreover, this learning also can facilitate the development of higher-order thinking skill and tackles the problem of students' low skill in creative thinking (Wahono et al., 2020; Widiastuti & Indriana, 2019) as well as enhance students' interest and motivation (Gürbüz & Erdem, 2016; Widiastuti & Indriana, 2019).

Besides STEM, another alternative to increase students' conceptual understanding by integrating ethnomathematics. It connects the cultures in society with mathematics. Its objective is to allow the students to explore how people utilize mathematics from the perspective of their culture (Utama et al., 2019). It is reputable as an educational practice that does not only fosters a love for our culture but also enhances students' capacity in creative thinking (Ambrosio et al., 2013; Norton & D'Ambrosio, 2008). Like STEM, ethnomathematics also has many merits in its application in the learning process. Several studies reported that its integration into learning media and the learning process on the topic of Geometry affected students' critical thinking, communication, and problem-solving skills in mathematics (Fujita et al., 2017; Newton & Kasten, 2013). To summarize, the implementation of STEM and Ethnomathematics (Ethno-STEM) as a learning approach has many advantages, including in mathematics learning. Additionally, although their combination could support students' critical, reflective, and creative thinking as well as their problem-solving skill and their conceptual understanding, there has been a lack of research that combines them as a learning approach. Therefore, the researcher finds it necessary to conduct a study investigating the effect of the Ethnomathematics-based STEM (Ethno-STEM) approach on the fifth-grade students' conceptual understanding.

In this article, I attempt to illustrate the possibility of productive bridging between conceptual understanding and the Ethno-STEM approach. I will present an overview of a series of studies that investigated students' understanding of geometry. These studies were grounded on a conceptual change approach to learning, taking a cognitive-developmental perspective on the acquisition of geometry knowledge. They resulted in the design of an experimental intervention that systematically employed principles for instruction stemming from conceptual change perspectives on learning, notably the use of bridging analogies and other analogies to foster students' understanding of a highly counter-intuitive idea. I will highlight the relevance of such studies for mathematics education while also discussing their limitations from the point of view of instruction.

METHODS

To answer our research questions, we set up an exploratory field study with a quasi-experimental design. A pretest-posttest-control-group experiment was set up to investigate the influence. It involved one group to be given a pretest and posttest before and after treatment, respectively.

The experimental unit of this research was the fifth-grade students. This study employed simple random sampling to choose a class as a participant. The teachers then implemented an ethnomathematics-based STEM learning approach. The instruments used to collect data were a test of conceptual understanding and an observation sheet of learning implementation. There were two steps in collecting the data on students' conceptual understanding. Firstly, a pretest was administered by the teachers to the students before the implementation of the learning. Lastly, the post-test was employed to examine their understanding after the instruction. Regarding the learning implementation, its data was collected by an observer who observed the learning activities based on the lesson plan. The lesson plan consisted of the phase or steps to implement the learning methods.

The data analysis techniques used were descriptive and inferential statistical analysis. The former was utilized by analyzing the test result and the data of the learning implementation. The study used the pretest and posttest scores of each student to obtain the *gain score* (g), which shows the enhancement of their conceptual understanding. As for the latter, it examined the research hypothesis by employing a one-sample t-test. The significance level used was $\alpha = 0.05$. The hypothesis test was carried out to examine whether the enhancement of conceptual understanding after the instruction was significant or not. The hypothesis is as follows:

$$H_0: \mu_B \leq 0{,}29 \qquad \text{vs} \qquad H_1: \mu_B > 0{,}29$$

μ_B = Parameter of difference in the average normalized-gain score from the test of conceptual understanding of fifth-grade students.

The integration of Ethno-STEM is said to be effective in enhancing students' conceptual understanding if it satisfies several criteria. First, The descriptive criteria. Descriptively, the instruction is said to affect the mathematics conceptual understanding if it meets the following criteria: (1) The average score of normalized-gain is within the average category ($0,3 \leq g < 0,7$); (2) The average score of observation results on the learning implementation is in the category of good (80 - 89). Second, Criteria in Inferential Analysis. The instruction is effective in enhancing students' conceptual understanding providing that the normalized-gain score's difference with 0.29 is significant.

RESULTS AND DISCUSSION

The learning activities observed were the implementation of the Ethno-STEM approach based on the lesson plan. Two categories were used by an observer to assess the integration of Ethno-STEM as a learning approach in six lessons. They were "Yes" and *"No"*, which means implemented and not implemented, respectively. The following Table 1 presents the results of the learning implementation.

Table 1. Results of Observation on The Implementation of Ethno-STEM as Learning Approach

Lesson	The Average of Percentage (%)	Category
I	87,50	Good
II	82,35	Good
III	81,25	Good
IV	86,96	Good
V	82,35	Good
VI	81,25	Good
Average Score	83,61	Good

Source: Result of analysis of primary data (2020)

Based on Table 1, the average score of learning implementation is in a good category. Therefore, the integration of Ethno-STEM as a learning approach meets the criterion of effect descriptively.

In terms of students' conceptual understanding, the maximum score is 100. Their pretest score was in a low category, with an average score of 48.39 and a standard deviation of 14.91. After the instruction, their average score improved to a very high one, with an average score of 85.36 and a standard deviation of 7.68.

Concerning the data of the pretest and posttest, the researcher analyzed the gain score, which showed the enhancement in conceptual understanding after the learning implementation. Table 2 reveals its results.

Table 2. Descriptive Statistics of The Enhancement of Students' Conceptual Understanding

Statistics	Statistical Value	Statistics	Statistical Value
Sample Size	20	Average	0,734
Ideal Score	1,00	Variance	0,009
Maximum	1,00	Standard Deviation	0,093
Minimum	0,59		
Range	0,41		

Source: Result of analysis of primary data (2020)

Data on students' improvement are classified into three categories of gain scores. Its frequency distribution is presented in the following Table.

Table 3. Normalized Gain Classification on Students' Conceptual Understanding in Mathematics

Coefficient of Normalized-gain	Classification	Frequency	Percentage
g < 0,3	Low	0	0%
0,3 ≤g<0,7	Average	8	40%
g ≥ 0,7	High	12	60%
Total		20	100%

Source: Result of analysis of primary data (2020)

Based on Table 2 and Table 3, the average score of enhancement in students' conceptual understanding is in the high category with a mean score of 0.734 out of 1 as the maximal score and a standard deviation of 0.093.

After analyzing the data by using descriptive statistics, the inferential analysis examined the data of the enhancement average in students' conceptual understanding. The test used was a one-sample t-test, and the results of the test are as follows.

Table 4. Hypothesis Test of Enhancement in Students' Conceptual Understanding in Mathematics

						95% Confidence Interval of Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Gain PKM	21,368	19	,000	,44337	,3999	,4868	21,368

Source: Result of analysis of primary data (2020)

Based on Table 4 in the columns of *Sig. (2-tailed)* and *t*, the score which is less than 0.05, and the positive score of 21.36 implied that students' average enhancement is significantly higher than 0.29. Therefore, it satisfies the criterion of effect, and it is evident that there was an increase in student's conceptual understanding after the implementation of Ethno-STEM as a learning approach.

To summarize, the criteria achieved in descriptive statistics are presented in the following Table.

Table 5. Criteria Achieved by The Integration of Ethno-STEM as a Learning Approach in Descriptive Statistics

Criteria of Effect	Accomplishment	Category
The average score of normalized-gain in students' conceptual understanding	0,734	High
The average score of the implementation of the Ethnomathematics-based STEM learning	83,61	Good

Source: Result of analysis of primary data (2020)

Table 5 shows that students' score enhancement in terms of their conceptual understanding is in the high category with a mean score of 0.734, and the category for the average score achieved for learning implementation is good with a mean score of 83.61. Descriptively, this score implied that Ethno-STEM as a learning approach influenced the conceptual understanding of the fifth-grade students.

As for the inferential statistics, Table 6 presents the criteria achieved for the increase in student's conceptual understanding.

Table 6. Criteria Achieved by The Integration of Ethno-STEM as Learning Approach in Inferential Statistics

Criteria of Effect	Probability
Enhancement of conceptual understanding through the integration of Ethno-STEM approach	0,000<0,05

Source: Result of analysis of primary data (2020)

Based on Table 6, the probability value which is less than 0.05 means that the alternative hypothesis ($H_1 : \mu_B > 0{,}29$) is accepted. It confirmed that there was a significant increase in student's conceptual understanding. Therefore, Ethno-STEM as a learning approach affected the conceptual understanding of fifth-grade students.

The mathematics conceptual understanding of the fifth-grade students on the topic of solid geometry was initially in the low category. They did not gain much learning experience that impacts their understanding during the learning process. Nonetheless, the average score of their conceptual comprehension after the integration of Ethno-STEM as a learning approach was in the very high category. There was a high enhancement in their conceptual understanding. Some studies also reported that by implementing STEM in learning, students' comprehension of concepts could develop (Heryuriani & Musdayati, 2020; Watson et al., 2017). Similarly, there was also an enhancement in students' conceptual understanding after the implementation of STEM-A (Sciences, Technology, Engineering, Mathematics, and Animation) (Utami et al., 2018). Moreover, STEAM not only supports the development of students' understanding but also enhances students' learning interest (Farmer et al., 2015).

STEM as a learning approach facilitates students to learn geometry. There were numerous opportunities for them to train their reasoning skills needed to contemplate and comprehend the geometry concept during the concept application in the learning process (Farmer et al., 2015; Park et al., 2018). Another study even reported that integrating STEM into TAPSS (Thinking Aloud Pair Problem Solving) learning could enhance students' learning activities and learning outcomes on the topic of polyhedrons (Yanni, 2018). They learned to get used to utilizing their mathematical knowledge to solve real-life problems. Therefore, both their learning activities and their learning outcomes could experience an enhancement.

The result of this study revealed that students with a low level of conceptual understanding benefited greatly due to the integration of Ethno-STEM in mathematics learning. Their initial lack of understanding of concept improved, and some of them even experience a 100% enhancement in their score. Similar findings were also reported that the integration of STEM into learning was very beneficial for the low-achievers (Han et al., 2015)ha. The study even revealed that it shortened the gap between their achievement with other students.

Through STEM, students were engaged in an active and creative learning environment that involves teamwork, project, presentation, hands-on activities, and other activities so that they could discover the concept to develop their procedural and conceptual understanding (Heryuriani & Musdayati, 2020; Farmer et al., 2015; Lee et al., 2019). Through their involvement in naturally exploring and constructing their knowledge, they developed their curiosity, interest to learn various things, critical thinking skills, and problem-solving. They received feedback from their peers, teachers, or the use of technology (Stohlmann, 2019). In line with the findings of a study that showed that STEM-based learning could increase their motivation and present them with experience with engineering (Stohlmann, 2019). Moreover, this learning also could support the development of their achievement in the school final exams. In terms of ethnomathematics, similar findings were also reported by some researchers. A study about the application of ethnomathematics in elementary school revealed that it supported the enhancement of students' conceptual understanding of geometry (Nugroho et al., 2018). Additionally, the conceptual understanding of students' taught by ethnomathematics-based material is better than the one participating in conventional learning (Utama et al., 2019)f. There are several factors affecting students' conceptual comprehension in the implementation of ethnomathematics. Firstly, it is very much following constructivism theory because the students build their knowledge and understanding of a concept by relating it to their environment, experience, or previous knowledge. The integration of ethnomathematics provides them with a meaningful and realistic learning environment so that they can comprehend the concept better. Therefore, the instruction could support the development of students' conceptual understanding.

The integration of Ethno-STEM as a learning approach was very influential in students' conceptual understanding. It does not only facilitate the students to understand the application of the concept in other fields (Science, Technology, Engineering, and Mathematics) but also allows them to be aware of the use of mathematics near their environment, especially the culture. They realized that mathematics is essential in every aspect of our life, and it leads to more meaningful learning and an increase in conceptual understanding.

The differences in students' answers on every indicator between the pretest and posttest showed that the Ethnomathematics-based STEM learning successfully enhanced students' conceptual understanding. They gave better responses, and the description of their answers is as follows. *First,* Restate the concept, Most of the students could restate the concept of a cuboid. The item question on this indicator was to write down the properties of the three-dimensional shape shown in the figure. In this item, students could mention that the number of edges is 12, the number of faces is six, and the number of vertices is 8. Additionally, they were also able to write down the properties of a cylinder where the number of edges is 2, the number of faces is 3, and it does not have any vertice. *Second,* Classifying objects based on specific properties according to the concepts. In this indicator, the majority of the students could classify an object according to specific properties. Students mentioned the name of the three-dimensional shape shown in the figure given. The results revealed that they could categorize that the three-dimensional figures shown are cuboid and cylinder. *Third,* Given examples and non-examples of a concept, Most of the students in this indicator were already able to present examples and non-examples of the concepts of cylinder and cuboids. Their task was to write down three objects which have the same shape as the figures given. Based on students' responses, they could present examples of cuboids and cylinders. The eraser was the most common answer given by the students as the example of cuboid, while the board marker was what most of the students mentioned as the example of a cylinder.

Fourth, Present concepts in various mathematical representations, In this indicator, several students could present concepts in many mathematical representations. In one of the problems, the teachers asked them to draw a three-dimensional shape similar to the figures given. The conditions are that the length is twice the width, and the width is twice the height. Additionally, their other task was to draw a cylinder on the condition that the cylinder height is the same as its diameter. According to students' responses, several students could draw the cylinder and cuboid with the predetermined criteria. *Fifth,* Develop the necessary conditions for a certain concept, most of the students could develop the necessary conditions for a concept. It was evident in their skill in analyzing the figures, whether it is the same as the figure in the first indicator, by explaining their reasoning. The teachers presented a three-dimensional shape in the form of a cube, and they were asked by the teachers to determine whether it is a cuboid or not. The majority of them responded that it is a cuboid because of its properties (the number of edges, faces, and vertices). Besides, they were given the figure of bamboo with one pointed end. They classified it as the non-example of the cylinder because the top part is not circle-shaped.

Sixth, Employ, make use of, and choose certain procedures or operations. In this indicator, the majority of the students could utilize and choose specific procedures. The teacher told them to write down the formula to determine the volume of the figures presented. They were able to answer that the formula to calculate the cuboid volume is by multiplying the length, width, and height. Additionally, they could write down the formula of cylinder volume, which is by multiplying the base area (circle-shaped) of the cylinder with its height. *The last, a*pplying the concept to problem-solving, most of the students in this indicator could apply the concept they learned to problem-solving. They were asked by the teacher to solve real-life problems about cuboids and cylinders, which is by calculating the volume of the two three-dimensional shapes. They answer the questions by utilizing the formula to determine the cuboid and cylinder volumes. Table 5 and Table 6 shows that the Ethno-STEM learning approach satisfies the influence criteria in terms of inferential and descriptive statistics. Therefore, the learning approach influenced the conceptual understanding of the fifth-grade student.

CONCLUSIONS

Results and discussion revealed that the ethnomathematics-based STEM approach was effective in enhancing the conceptual understanding of the fifth-grade students. Their concept comprehension before the instruction improved from the low category to the very high one. Therefore, Ethno-STEM learning affected the increase in the conceptual understanding of the students. Ethnomathematics-based STEM learning is one of the learning alternatives to enhance students' conceptual understanding. Further research should be considered on another topic of mathematics.

AUTHOR CONTRIBUTIONS STATEMENT

Marufi is the main author who has the research concept. while MIl, W and MIk are the makers of the research instruments and data collectors.

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