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Developing a Model for Teaching Indonesian Primary Level Mathematics Olympiads: Applied Linguistics

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The relation between linguistics element and mathematics problem tasks is robust to make the students able to solve the mathematics problems. Low linguistics comprehension may lead to the failure of understanding mathematics problems given. This paper reports the development of teaching models for the International Mathematics Olympiads. From classroom observation and mathematic problem tasks, it is revealed that students' failure to answer Olympiads' questions during the class session was due to their low linguistics elements, which influence their comprehension of an understanding math problem. Among the ten problems, only one problem could be understood by half of the total students. It indicates that if students fail to understand linguistic elements at any level, the overall comprehension of the math problem will also fail. It is essential to improve the students' linguistics elements to enhance the students' problem-solving skills. A significant role is given to the teachers/instructors to expand the students' knowledge and skills. The process of helping students to understand the problems must be carried in various ways—the importance of interactive communication between teachers and students or among students also supporting the teaching process. Therefore, two teaching models have been developed from the students' problems. In the present paper, the first teaching model is expected to improve the students with vocabulary to solve the problem. Meanwhile, the second teaching model gives the students to figure out the mathematical problem.

Keywords: *Mathematics Olympiad, Linguistics Elements, Comprehension, Teaching Models*

Introduction

One of the activities that mathematics talented children engaged in are the mathematic Olympiad (Choi, 2013; Astawa, 2007). The signs of special talent in mathematics appear during children's development period at primary schools (Campbell et al., 2000). Campbell et al. (2000) also explained that various activities are taken to improve children's mathematics skills, including after school extra-curriculum courses by specialised math teachers, or other specialised training programs for such purpose.

During the period of training, students encouraged to participate in mathematic competitions or Olympiad, either in the national scope or even international. There is no exception for elementary students. There are some international mathematic Olympiads in which these groups regularly participate, including IMAS, head-quartered in Taiwan, AIMO, the final round of which was held in China, IMC in Singapore, and AMC centred in Australia or the United States (Djukić et al., 2011). These competitions are attended by junior high school students as well as elementary school students. In all of these Olympiads, the elementary school category is divided into Middle Primary (3rd and 4th grade) and Upper Primary (5th and 6th grade).

Nevertheless, Indonesian elementary students Olympiads' potentials are often hindered by their English capacity. The linguistics obstacle is a crucial point to improve the student's understanding of mathematics capability (Fraser et al., 2015; Zazkis & Leikin, 2010). Stated by Barwell (2018), an essential point to students who speak different languages at home, which become their dominant language, will be less effective for doing mathematics in their non-dominant language. Besides the dominant language they use at home, casual evaluation by Carr et al. (2019), the pre-school program can have positive-short term impacts on their academic skills that follow the students into elementary school. It means that both linguistics and mathematics capability should be developed from an early age. Supported by Foster et al. (2018), an exploration of cross-domain predictive relations between mathematics and cognitive and linguistics skills is essential, informing the understanding of how these skills develop simultaneously. Such an exploration may also provide knowledge of the cognitive and linguistic mechanisms that support the learning of mathematics (KÖVECSES & RADDEN, 1998; Perlovsky, 2011).

According to prior observation, the obstacle in the training of solving problems from the international mathematic Olympiad is the problem of understanding the language, not the mathematics capabilities. It could be seen as the questions are translated into Bahasa Indonesia.

The average rate of the correct answer to the explained problems is 90%, while the average rate of correct answers if the problems are still in English, is 50-70%. The points are deducted from students' weekly exercises. It could also be seen from other data of the average point of MNR Competition (Indonesian Mathematics Competition) and the average point of IMAS of the students in Surabaya. The data shows that students who participated in IMAS have a success rate of 70%, while in other Olympiad competitions, their success rates are below 60%.

The current development of teaching models of mathematic Olympiad is still limited to national scope (using Bahasa Indonesia), such as the one conducted by Astawa (2007). There is still no teaching model of mathematical Olympiad specially tailored for the international level. With the current status that English is not taught at the elementary level, and there is a lack of English enrichment for technical mathematical terms. Therefore, a specific teaching model created for the international mathematic Olympiad using English is needed for the elementary level (Nurillah, 2017). This paper reports how such a model has been developed. It starts with descriptions of problems in learning mathematics in other languages and their solutions, which are then followed by an elaboration of the research methods in developing the model. It ends by describing findings as to the bases for model development, and two models are proposed.

Literature Review

The mathematics issues in elementary grades have been going around in many countries. In the US, for example, many immigrants of elementary level in the US use their native languages, which are mostly Latin (Spain), and Asian (Abedi & Lord, 2001; Fuchs et al., 2006; Martiniello, 2008; Ma, 2010). Abedi and Lord (2001) researched the differences in mathematic abilities of elementary students whose native language is English and those whose native languages are non-English. The results show that the students whose native languages are non-English have lower competences as compared to those who are native English speakers. Abedi and Lord (2001) claimed that the students whose backgrounds are non-English speakers are more unlucky in their mathematics school tests.

Another country having a mathematics problem of its students with a non-English native speaking background is New Zealand (Huang, 2000). The case study of Neville-Barton and Barton (2005) in New Zealand shows that high school students whose native languages are non-English have a 15% lower score than that of the native language is English. Their problems lie in the mathematical concepts, not on their English vocabulary. Another finding by Neville-Barton and Barton is that in a school where the non-English native students have a good average mark for English, they still have a problem in their mathematics technical terms (Neville-Barton & Barton, 2005). In the third school, the major problem of the non-English native students is their low capacity of English. From these three case-studies performed, Neville-Barton and Barton concluded that the low mathematic competence of the non-English students is related to the problem of their general English capacity and the technical vocabulary or terms of mathematics. In solving mathematical problems, they tend to memorise the mathematics procedure without taking severe attention to the vocabularies and context of the maths (Neville-Barton & Barton, 2005).

Abedi et al. (2004) have reviewed various efforts of the states in the US to minimise those language obstacles of students who learn by their non-native languages. Several solutions have been tried, namely: using a bilingual dictionary or word list of translated English, direct interpretation, two versions of the language (English and native), and simplified English. One of the suggestions to improve the result of the mathematic test is to conduct the test using the language they used in learning maths. It means that if they learn maths using their first language (e.g., Bahasa Indonesia), it should be tested using their first language (Bahasa Indonesia).

English modification training by Abedi et al. (2004) should focus on: 'low-frequency vocabulary' and 'passive voice construction.' Both are specific characteristics of mathematical problems. They maintained that the use of a commercial dictionary could not help the students to understand the mathematical concepts of the English maths problem. Also, the list of words or glossary has proven to help students understand mathematical problems successfully. Alongside the training of English modification of mathematical problems, another research by Mueller and Maher (2009) shows that an excellent communication of maths teachers and students in building the comprehension of mathematical concepts is needed. This communication is delivered in the language that the students understand.

Adler has been done other researches about mathematics teaching in multilingual South Africa in classrooms in which the students regularly use more than one language, and sometimes teachers, during classroom interaction (Adler, 1997, 1998, 1999, 2002). Adler (2000) proposes a framework in of different kinds of resources available in mathematics classrooms: (1) primary resources, such as buildings and teachers; (2) material resources, such as books or calculators; (3) social and cultural resources, including language; and (4) other resources, such as teachers' knowledge.

Another method to help non-English students to solve mathematical words problem is by using digital media, such as the educational software of the VETA learning game by Lantz-Andersson et al. (2009). Lantz-Andersson et al. (2009) have successfully shown that the use of math software in the class, together with student-teacher communication, could build an understanding of the mathematic concept. As Mueller and Maher (2009) have discovered, the key is the interaction of teachers and students while using the software.

In reviewing automatic item generation, Deane and Sheehan (2003) explain that one of the software that can be used to generate similarly structured math words problems with similar difficulty levels by standard language (not algorithmic language) is Math Test Creation Assistant (MTCA). The main point of Deane and Sheehan's (2003) suggestion is to generate English words for similar problems, such as in (01) below.

(01) A ____ travelled ___ miles in ___ hours. On average, how fast did the ____ move during this time period?
(Deane and Sheehan, 2003:8)

This problem could be substituted with other words or structures (02).

(02) It took ___ hours for a ____ to go ____ miles. What was the _____'s average speed?
(Deane & Sheehan, 2003, p. 8)

This pattern could be applied to teach math using English for math-focused to Olympiad of elementary students in Indonesia and other countries where English is not their first language. Mathematic technical terms discovered by Deane and Sheehan include motion, current, age, coin, work, part, dry mixture, wet mixture, percentage, ratio, unit cost, mark-up/discount/profit, interest, direct variation, inverse variation, digit, rectangle, circle, triangle, series, consecutive integer, physics, probability, arithmetic, and word (Deane & Sheehan, 2003).

There has been researched on the mathematic Olympiad teaching model for elementary students in Bali by Astawa (2007). It was an experiment in a course that consists of 30% of theory improvement, 50% of problem exercise, and 20% of moderation. These treatments could boost the academic ability of the Olympiad candidates in the sampled school. Although the language used in the math word problem in his research is Bahasa Indonesia, Astawa (2007) claimed that his teaching model could significantly improve the academic capacity of the participants of the national science Olympiad. Besides, he also tested whether two teaching models of "continued block" and "discrete block" produce different results.

In the continued block teaching model, the participants of the Olympiad were quarantined for two weeks, so they were physically and mentally separated from their parents or guardian. In a discrete block model, the participants were engaged in a weekly course, so they were not physically and mentally isolated from their parents or guardian for a long time. Astawa (2007) concluded that there is no significant difference between the two models in improving the logical mathematics capacity of the Olympiad candidates. It should be noted that both models improved the logical mathematic ability of the Olympiad candidates. Astawa (2007) suggested that the critical factors in improv the mathematic capacity of the elementary mathematic Olympiad are the improvement of basic mathematics concepts and the exercises of math word problems.

Despite Astawa's study, there seems to be a lack of research on mathematics Olympiad teaching procedures, particularly technical mathematics terms for elementary students for international level Olympiads (Astawa, 2007). Astawa's study is only at a national level, which uses Bahasa Indonesia, in contrast to the international mathematic Olympiad, which uses English as the medium of communication (Astawa, 2007). There is only research in the US by Fuchs et al. (2006), which shows that mathematic words problem is strongly related to the students' capacity in solving the non-verbal problem, concept-building, efficiency in reading words, and the student's language. Therefore, this research will develop a model for teaching mathematics so that these factors could be maximised for use in preparing Indonesian students to face international mathematic Olympiads.

Methods

This research used a qualitative approach (Miles et al., 2014; Merriam, 1988). It is relevant to the purpose, data collection method, and data analysis technique in this research (Ary et al., 2010). This research aim is to develop a model for teaching mathematics in preparing Indonesian students to face international mathematic Olympiads. The data are students' written responses to mathematics problems in the classes of Olympiads preparation in one mathematic Olympiads preparation group in Surabaya. Students' reactions to the competency test of English mathematic word problems set to gauge for the problem with the English language are also the data for this research. The question consists of 10 math problems, and each is given direction like this: *Tulis kembali soal di atas dalam Bahasa Indonesia* (Rewrite the question in Bahasa Indonesia) and *Selesaikan soal di atas* (Solve the problem).

1. Participants

The subjects of the research are one class of 5th-grade elementary students who are members of *Klinik Pendidikan Matematika* (Mathematics Education Clinic or KPM) Surabaya and their math teacher of KPM. They were involved in the observation process. The observation was focused on the problems that occurred in the learning process. The aspects of the observation are the teacher-student interaction, the question asked by the students to the teacher, the situation.

In contrast, students tried solving problems, and the students' answers, either spoken or written, including math test result. Also, the students took a maths competency test to determine their competence in linguistic elements and the overall math problems. The data were analysed qualitatively, focusing on the aim of the research, i.e., to develop a model of teaching mathematic Olympiads based on the revealed students' problems.

Results and Discussion

1. Understanding Linguistic Elements and Math Problems

The competence of linguistic elements influences the comprehension of the math problem. The context of the comprehension of math problems, in this case, is the student's overall comprehension of math problems in English (Pape, 2004). The indicator of student's comprehension is the accuracy of the answers to the math problems (Nurkaeti, 2018). As indicated in Table 1, the students' comprehension level of the mathematical problems is very low. Among the ten problems, only one problem (question 1) could be understood by half of the total students (53.7%). It proves that if students fail to understand linguistic elements at any level, the overall comprehension of the math problem will also fail.

Table 1 shows that out of 41 students, only 14 students or 34.1% could understand these technical terms. In a more detailed view of Table 1, students' language comprehension level is higher than the math problem comprehension. It is expected that the students' problem comprehension rate is at least at the same level as the language comprehension rate. However, the result is different from the expectation. The students' problem comprehension is lower than their language comprehension. Although the students could understand the linguistic elements, they failed to comprehend the overall math problem, for instance, problem numbers 5 and 9. Two students could understand the language in problem 5. However, both failed to understand global math problems. Similar phenomena could be seen in questions 9; three students understand the word, but they were unable to understand the overall math problems. From this evidence, it could be concluded that the comprehension of linguistic elements does not ensure an understanding of global math problems.

Technical terms are found in almost every mathematical technical word problems. The understanding of these terms is strictly required to get the correct answer. Take a look at following problem 2.

Problem 2

Find the **sum** of all **multiples** of 5 from 5 to 200.

This question contains the technical term; 'sum,' which means *jumlah* in Bahasa Indonesia and 'multiples,' which means *kelipatan* in Bahasa Indonesia. Failing to understand either name would result in a wrong answer, the students then interpreted this problem in several ways.

(1) Students only write a row of numbers, which are multiples of 5 in the range of 5 to 200.
(2) Students only write the sum of the multiple of 5 numbers.
(3) Students write a row of numbers, which are multiples of 5 in the range of 5 to 200, then sum them all.

2. Transformation of Verbal Language to Mathematical Notation

Ability to transform verbal language into mathematical notation English math problem comprehension is very crucial in solving mathematic Olympiads problems. All ten kinds of given Olympiad problems use verbal language, and six of them are mathematical word problems, which are: problems 1, 3, 6, 7, 8, and 10. None of them is mathematic notation model, such as (10 + 3) – 4 =........, and its similar kind. The following problem 5 is an example of the verbal mathematic problem.

Problem 5

How many positive whole numbers less than 2005 can be found, if the number is equal to the sum of two consecutive **whole numbers** and also equal to the amount of three consecutive whole numbers?

There is no hint of the mathematic operational symbol in the problem; therefore, a meticulous skill of transforming verbal language to mathematical notation is essential. The following is the mathematical notation of the problem 5. None of the students could answer this kind of math problem.

The previous data indicate that KPM participants have difficulties in solving a math problem because most of them did not understand the technical mathematical terms. Most of the students do not understand the words *remaining*, *intersection point*, *two-third the height*, and so on. The fact is that many of the English to Bahasa Indonesia translated math problems are incomplete; not translated into Bahasa Indonesia; not using equivalent terms, and many of the students unable to explain. Therefore, a strategy to overcome language issues in a mathematical word problem is needed.

3. The Proposed Teaching Models

From the findings of students understanding of linguistic elements in English and math problems previously presented, teaching models made especially for international mathematic Olympiad at the elementary level have been developed. It is an essential process in improving the students' problem-solving skills. Teachers/instructors need to conduct the class by maximising their role as the facilitator of knowledge and skills. It should be noted that there is a difference between teaching and assessment. Teaching is the process of helping students in various ways to understand problems. This process is marked by the interactive communication between teachers and students, and also communication among students, while assessment is a process to determine the success rate of the teaching. This process is marked by the absence of interaction found in the teaching process. The second process is a follow up of the first process. For example: after the students prepared, the teachers distribute the question sheets, then wait for the students to finish their work. After the works have been collected, the teachers discuss the problems with the students and give necessary reviews.

To help improve the English mathematics course, there are two suggested models: 'pre working' and 'while working.' The first model is shown in Figure 1, after the opening, the difficult words or the mathematic technical words are introduced to students. This model is aimed to prepare the students with the vocabulary needed to solve the problems. It is expected that the students will not face any difficulties in the level of phrases or sentences in solving the problems. The teachers could ask students who know the particular meaning in order not to give just random meaning. This method could provide the chance for teachers to use *prior knowledge* of the students.

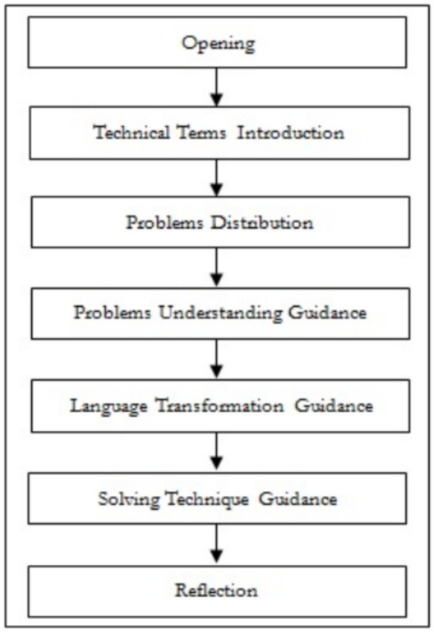

Figure 1. Teaching Model 1: Pre-Working Model

In the problem understanding phase, teachers/instructors guide the students step by step until the students understand the problem. Various techniques could be implemented in this phase. For example, teachers could ask students about the meaning of the words, phrases, and sentences; guide students to find keywords of the problems; ask the students to translate part of the problems; ask the students the overall meaning of the problems; ask the students to explain the contents of the problems; etc. The way the teachers asking the students should be arranged systematically to get the students accustom to think systematically. This phase aims to guide the students in understanding the whole meaning and context of the mathematical word problem.

The next phase is the verbal language transformation to mathematical notation. There are many mathematical word problems which, at first glance, seem to do not contain any mathematics operational words. The mathematic operation is expressed in another kind of words such as in problem 6.

Problem 6

Aisyah has some candies. Every day, she **eats** one half remaining candies from the previous day.

The word 'eats' means subtraction. Discussion about the importance of this phase and examples are provided in Teaching Model Improvement. Another crucial point is the patient of the teachers to guide the students in finding the ultimate methods of solving the problems. The students have limited ability and experience in solving mathematical problems due to their age. Therefore, they usually need a long time just to solve one mathematical problem. It will not occur in students who already know the solving technique of the problem. The example is in problem 2.

Problem 2

Find the sum of all multiples of 5 from 5 to 200.

In solving this problem, teachers should guide students to use the ultimate technique so that they could solve the problems quickly. However, what happened is much time wasted because the students do not know how to solve the problem. It is one topic of a problem in sequential sum or arithmetic. In other words, this phase is about the understanding of the mathematic concept. As shown in Table 1, some students understand the language aspect of the problem but do not understand the mathematical theory, so they fail to solve the problem. It could be seen in problem 5 and 9. Language understanding does not assure the knowledge of the mathematic concept. Therefore, teachers should guide the students with the ultimate technique of solving the problem.

The last phase is the reflection. This activity is conducted at the end of the class. Teachers ask students to tell what they have gained during the class that day. It was useful to strengthen the materials that have been presented and to measure the learning capacity of the students. In this occasion, teachers could inform the topic of the next meeting, also explain what students can do and prepare in their home.

The second suggested teaching model is similar to Model 1. The difference is only in the phase of Technical Terms Introduction. In Model 2, this phase is conducted after distributing the math problems, as shown in Figure 2. As can be seen in Figure 2, the while working model gives the students chances to figure out the mathematical problems by themselves first. Then, language assistance in the form of technical terms introduction comes later. It provides more independence on the part of students. This model might well be implemented for students who have mastered the English language or having little problems with language elements.

Figure 2. Teaching Model 2 (*While Working)*

Table 1. Summary of competency test of English mathematic word problem

Problem Number	1	2	3	4	5	6	7	8	9	10
Language	26	22	3	4	2	17	13	3	3	2
%	63.4	53.7	7.3	9.8	4.9	41.5	31.7	7.3	7.3	4.9
Material	22	14	1	2	0	3	1	3	0	1
%	53.7	34.1	2.4	4.9	0	7.3	2.4	7.3	0	2.4

Conclusion

From the findings and discussions above, it can be concluded that the development of models for teaching mathematic Olympiads for Indonesian students was based on the revealed problems in understanding English language elements and mathematical terms. By arguing for the teachers' roles in the proposed model, teachers are suggested to apply one of the models: pre-working and while working. Both teaching models are conducted by using the steps of opening, key terms introduction, problem distribution, understanding guidance, language transformation guidance, solving technique guidance, and reflection.

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