PISA-like problems using Indonesian contexts

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Abstract. This study aims at developing Program for International Students Assessment (PISA)-like problems which are valid, practical, and have potential effect. The contexts used for this problems are Indonesian contexts involving traditional games, traditional clothes, tourist attractions, social lives. This is a development research which are analysed descriptively. Based on the analysis, it has been concluded that there have been eight PISA like problems consisting problems with quantity content category, problems with uncertainty and data category, problems with change and relationship content category, and problems with space and shape content category which are valid, practical, and have potential effect. The categories are also covering context and process categories in PISA framework. Those problems are valid according to judgment from experts based on the content, construct, and language aspects. Those problems are practical based on the results of the test to small groups of students. Moreover, those problems have potential effect on students’ critical thinking skill.

1. Introduction
As the demand of globalization era, Indonesian people, including students, must be prepared to participate in international competition. Various kinds of competition are held to map the quality of education in many countries all over the words. However, the results suggested that Indonesia was still on the bottom of the ranking lists.

Based on the survey conducted by Trend in International Mathematics and Science Study (TIMSS) in 2015, the Indonesian students’ achievement in mathematics was on the 45th position from 50 participating countries [1]. The TIMMS survey conducted every four year focusing on the domain of mathematics and science contents, particularly on students’ cognitive skills. Besides that, Indonesian students’ performance was on the 65th position out of 72 countries participated in PISA-Program for International Students Assessment [2]. PISA study conducted every three years is focus on assessing students’ skills in identifying, understanding, and applying mathematics in daily life.

There might be many factors causing the results of the low of students’ performances on both TIMMS and PISA. A possible reason might because Indonesian students rarely face and solve problems with the characteristic of TIMMS or PISA. This study will focus on the case of PISA.

There are three components examined by PISA. The components are content, context, and process. The content is divided into four categories namely change and relationship, space and shape, quantity, and uncertainty and data [3]. The context is divided into three categories which are personal, occupational, public, and scientific. The process is divided into three categories namely formulating, employing, and interpreting. This study used those three components and its categories to design PISA-like problems using Indonesian contexts.
There have been several studies about Indonesian students’ errors in solving PISA problems [4–6]. The studies found that Indonesian students mostly experienced difficulties in the early stages (comprehending and transforming) at solving context-based task. Moreover, [7] claimed that the low level of students’ reasoning and creativity could be the main factors of their difficulties. Besides that, gender and mathematics textbook could be the factors influencing Indonesian students’ performances in PISA [8]. Furthermore, a study about mathematics textbook for 8th graders in Indonesia showed that the percentage of mathematics problems in line with PISA problems is still low with about 33.40% [9].

As the mathematics textbooks could be the factors of the low level of students’ skills in solving PISA problems, this study aims at developing PISA-like problems which are valid, practical, and have potential effect. The problems developed are expected to enrich learning resources used for 8th graders’ classroom mathematics.

2. Research Method
This is a design research using the type of development study with formative evaluation consisting two stages; preliminary and prototyping stages. The preliminary stage is involving an analysis of students’ background knowledge, PISA problems, and curriculum. The prototyping stage includes self-evaluation, expert review, one-to-one, small group and field test [10]. The subjects were 8th graders of a private school in Surakarta, Indonesia. The data collection was conducted using walkthrough, documentation, tests and interviews.

The preliminary stage was started by an analysis of students’ background knowledge. This would be the consideration of the difficulty level of problems designed. Afterwards, PISA problems and curriculum analysis were conducted to map and match the problems designed with the content of mathematics for 8th graders based on the characteristics of PISA problems and the Indonesian curriculum. Lastly, the draft of the first prototype was designed based on the results of the analysis.

The prototyping stages begun with self-evaluation yielded the first prototype. Afterwards, walkthrough and one-to-one were conducted simultaneously to test the first prototype. In the walkthrough phase, the content, construct, and language of the first prototype are validated by experts. The researcher conducted one-to-one test to one student. The results of expert review and one-to-one produces the second prototype that will be tested at the small group phase. Six students from low, moderate, and high level of achievement in mathematics involved in this phase. Students are required to solve the problems and then provide suggestions or comments to know about the practicality of the problems that has been solved. The researcher carried out validity and reliability analysis of each items as well. The revision based on the result of small group phase produced the third prototype which will be tested in the field test. In the field test phase, thirty students worked on the third prototype.

3. Result and Discussion
This study was conducted for students who are at the first semester of 8th grade of junior high school. The preliminary stage involving an analysis of students’ background knowledge, PISA problems, and curriculum and the prototyping stage including self-evaluation, expert review, one-to-one, small group and field test will be described in the following paragraphs.

3.1. Preliminary Stages
The preliminary stages was conducted by firstly analyzing students’ preliminary knowledge. This study was conducted in the second half of the first semester of 8th graders. Therefore, the problems designed would be involving topics they have learned previously, either in the elementary school or in the 7th grade and the first half of the first semester of 8th grade in junior high school. Afterwards, an analysis of the characteristic of PISA problems and the Indonesian curriculum were conducted consecutively.

The analysis of the PISA problems was focus on the components and the categories of each component of the PISA frameworks. Whereas, the analysis of the Indonesian curriculum was focus on
the basic competent of mathematics learned in the 7th and 8th grade of junior high school. Based on the analysis, the draft of the prototype was designed. It is involving four themes namely “Prambanan Temple” which is one of Indonesian Tourism Attractions, “Batik” which is one of Indonesian traditional clothes, “Ojek Online” which is one of Indonesian social life, and “Playing Kites” which is one of Indonesian traditional games. The problems of each theme have to fulfill the requirements of PISA-like problems. In other words, each problem was designed based on the categories of all components of PISA frameworks, namely content, context, and process. The map of the categories of the problems for each themes are described on Table 1. Whereas, the description about the map of problems of each theme based on the Indonesian curriculum will be described in the prototyping stage.

Table 1. Test Blue Print of The Prototype of PISA-like Problems

| Theme                          | Unit            | Content Categories | Context Categories | Process Categories | Item Type   | Item No |
|-------------------------------|-----------------|--------------------|--------------------|-------------------|-------------|---------|
| Tourismattraction             | Prambanan Temple| Quantity           | Scientific         | Formulate         | Essay       | 1       |
| Traditional clothes           | Batik           | Uncertainty and Data| Societal           | Interpret         | Essay       | 2       |
| Social Life                   | Ojek Online     | Change and Relationship| Societal           | Employ            | Essay       | 3       |
| Traditional games             | Playing Kites   | Shape and Space    | Societal           | Interpret         | Essay       | 4       |

3.2. Prototyping Stage

The draft of the prototype was evaluated by three researchers conducted this study and yielded the first prototype. Afterwards, in the walkthrough phase, an expert on PISA problems and an expert of Indonesian curriculum reviewed the prototype. The review related to the content, construct, and language of the problems designed. The one-to-one phase was conducted with one student to test the first prototype. The results of walkthrough and one-to-one phases were used to revise the first prototype and become the second prototype that will be tested at the small group phase.

In the small group phase, six students from low, moderate, and high level of achievement in mathematics were participated. Students are required to solve the problems and then provide suggestions or comments to know about the practicality of the problems that has been solved. The researcher carried out validity and reliability analysis of each items as well. To increase the level of validity and reliability, a focus group discussion involving mathematics educators (teachers and lecturers) was conducted. The revision based on the result of the small group phase and the focus group discussion produced the third prototype which will be tested in the field test. In the field test, thirty students worked on the third prototype. The prototyping stage will be described in detail based on each theme on these following paragraphs.

3.2.1. Prambanan Temple. The first theme is about one of Indonesian tourism attractions, Prambanan Temple. There are two problems designed for this theme which is related to numbers. As mentioned in Table 1, based on PISA frameworks, it is related to quantity. In the prototyping stage, there was no significant revision on the problems of this theme. One of the two figures is shown on Figure 1. Whereas, the description about the Indonesian curriculum is on Table 2.

Table 2. The Map of The First and The Second Problems

| Indonesian Curriculum |
|-----------------------|
| Grade VIII            |

3
Basic Competence:

3.1 Making generalizations of the patterns of the sequence of numbers and of the sequence of object configurations.
4.1 Solving problems related to the patterns of the sequence of numbers and of the sequence of object configurations.

![Figure 1. Prambanan Temple](image)

In the field test, all students gave correct answers on the first and the second problems provided in this theme. The question is mainly about prediction about the number of all small temples (candi perwara) surrounded the main temples. However, students found difficulties to explain the steps to get the answers. Figure 2 shows one example of students’ written works.

![Figure 2. An Example of Students’ Written Works on the Second Problem](image)

The students said, “If you want to know the steps to get the answers, just see my calculation”. It shows that the students found difficulty in communicate their thinking. However, by the mathematical discourse, students could step by step explain the way to get the answer. As [11] said that students had a better mathematical communication when they were asked more open-ended questions. However, to enhance students’ performance, practicing writing about mathematics regularly and routinely are needed to gain experience with writing about mathematics [12].

3.2.2. Batik. The second theme is about one of Indonesian traditional clothes, Batik. There are two problems designed for this theme which is related to statistics. As mentioned in Table 1, based on PISA frameworks, it is related to uncertainty and data. In the prototyping stage, there was significant revision on the problems of this theme. It was about the term “respondent” which was unfamiliar for students. One of the two figures is shown on Figure 3. Moreover, the description about the Indonesian curriculum is on Table 3.
Table 3. The Map of The Third and The Fourth Problems Based on Indonesian Curriculum

| Indonesian Curriculum |
|-----------------------|
| Grade VII             |
| Basic Competence:     |
| 3.12 Analysing the relationship between data and the way to present the data (table, line diagram, bar chart, and pie chart. |
| 4.12 Presenting and Interpreting data in the form of table, line diagram, bar chart, and pie chart. |

![Figure 3. The Data of Batik Ownership of the Respondents.](image)

In the field test, all students gave incorrect answers on the third and the fourth problems provided in this theme. The question is mainly about the number people having batik as shown in the pie chart. Based on the classroom discussion, students were careless in understanding the problems. Figure 4 shows one example of students’ written works.

![Figure 4. An Example of Students’ Written Works on the Fourth Problem](image)

The students answered that 47% means 47 people, 26% means 26 people, 14% means 14 people, and 13% means 13 people. Carelessness were usually become the main factor in translating mathematics word problems [7], [13], [14]. However, by the mathematical discourse, students could step by step understand the problem and find the correct answer.

3.2.3. Ojek Online. The third theme is about one of Indonesian typical social life, Ojek Online, a mean of transportation commonly used by people in town. There are two problems designed for this theme which is related to algebra. As mentioned in Table 1, based on PISA frameworks, it is related to change and relationship. In the prototyping stage, there was no significant revision on the problems of this theme. One of the two figures is shown on Figure 5. Whereas, the description about the Indonesian curriculum is on Table 4.
### Table 4. The Map of The Fifth and The Sixth Problems Based on Indonesian Curriculum

| Indonesian Curriculum |
|-----------------------|
| Grade VII             |
| Basic Competence:     |
| 3.6 Explaining linear equation and linear inequalities with one variable and its solutions. |
| 4.6 Solving problems related to linear equation and linear inequalities with one variable. |

![Figure 5. Ojek Online.](image)

The question is mainly about choosing the cheapest fare of two different corporate of ojek online. In the field test, all students gave correct answers on the fifth and the sixth problems provided in this theme although they just found one possibilities of two possible answers. However, students found difficulties to explain the steps to get the answers. Figure 6 shows one example of students’ written works.

![Figure 6. An Example of Students’ Written Works on the Sixth Problem](image)

The students just answering that A is cheaper than B without giving any explanation. Based on the classroom discourse, students did not really understand the problem and just guessing. As [15] stated that error in formulating mathematical model is the main difficulty of solving algebraic problems. Therefore, students tend to use trial and error in solving algebraic word problems [16].

### 3.2.4. Playing Kites

The fourth theme is about one of Indonesian traditional games, Playing Kites. There are two problems designed for this theme which is related to geometry. As mentioned in Table 1, based on PISA frameworks, it is related to space and shape. In the prototyping stage, there was significant revision on the problems of this theme. It was about the problem involving trigonometry which changed into problems about Pythagorean theorems. One of the two figures is shown on Figure 7. Whereas, the description about the Indonesian curriculum is on Table 5.
Table 5. The Map of The Fourth and The Eighth Problems Based on Indonesian Curriculum

| Indonesian Curriculum |
|-----------------------|
| Grade VIII            |
| Basic Competent:      |
| 3.6 Explaining and proving Pythagorean theorem and triple Pythagorean numbers. |
| 4.6 Solving problems related to Pythagorean theorem and triple Pythagorean numbers. |

Figure 7. Playing Kites.

The question is mainly about the relations about the length of the thread, the height of the kite, and the distance of the child and the kite. In the field test, it was only about 25% students gave correct answers on the seventh and the eighth problems provided in this theme. In the classroom discussion, some students said that they forgot the Pythagorean theorems, while some others said that they were unfamiliar with the context. Figure 8 shows one example of students’ written works.

Figure 8. An Example of Students’ Written Works on the Eight Problem

Students forgot the Pythagorean theorems could be because of the negative effect of classroom practices which mainly focus on remembering formulas [17]. Furthermore, realistic context might support students’ understanding, but it must be choose carefully regarding students’ knowledge of the contexts [18].

4. Conclusion and Suggestion
Based on the analysis, it has been concluded that there have been eight PISA like problems consisting problems with quantity content category, problems with uncertainty and data category, problems with change and relationship content category, and problems with space and shape content category which
are valid, practical, and have potential effect. The categories are also covering context and process categories in PISA frameworks. Those problems are valid according to judgment from experts based on the content, construct, and language aspects. Those problems are practical based on the results of the test to small groups of students. Moreover, those problems have potential effect on students’ critical thinking skill.

In addition, the use of PISA-like problems could stimulate students’ critical thinking skills. However, classroom discourse and writing mathematics practices are needed to enhance students’ critical thinking and mathematical communication skills. Furthermore, the use of appropriate contexts is important to avoid students’ difficulties caused by unfamiliar contexts.

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