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The mathematics education department students' ability in mathematical literacy for the change and relationship problems on the PISA adaptation test

Antonius Yudhi Anggoro, Hongki Julie, Febi Sanjaya, M Andy Rudhito, and Dewa Putu Wiadnyana

Sanata Dharma University, Jl. Affandi Tromol Pos 29, Sleman, Yogyakarta 55002 Indonesia

E-mail: hongkijulie@yahoo.co.id

Abstract. One of goals of this research was to describe the mathematics education department students' ability in mathematics literacy for change and relationship problem on Programme for International Students Assessment (PISA) test. The procedures of this research were (1) adapt the PISA test, (2) validate the PISA adaptation test, (3) ask seven students from mathematics education department to solve PISA adaptation test, and (4) describe bachelor students' solution profile. There were (1) three change and relationship problems, (2) four space and shape problems, (3) two uncertainty problems, and (4) four quantity problems. The type of this research is a design research. Subjects of this research were seven bachelor students of mathematics education department. The research results were as follows: (1) level four achieved by one student (14.29%) in problem number 2b.4; (2) level three achieved by (a) six students at problem number 2a, (b) five students at problem number 2b.2; and (c) three students at number 2b.3 and 3; and (3) level two achieved by three students at number 3.

1. Introduction

In the 21st century, human needs 21st century skills for survive. Those skills include critical thinking and problem solving, creativity and innovation, communication and collaboration, flexibility and adaptability, initiative and self-direction, social and cross-cultural, productivity and accountability, leadership and responsibility, and information literacy [1, 2, 3, 4]. One of components that needed to build 21st century skills is mathematical literacy [5]. Mathematical literacy is an individual's ability to identify and understand mathematics role in the world, to make an accurate assessment, use and involves mathematics in various ways to fulfill the individual needs as a reflective, constructive and filial citizen [2, 6].

Unfortunately, mathematical literacy of Indonesian students was not good as expected. It could be seen from Indonesian ranking in PISA test. In 2015, Indonesia achieved ranking 63 from 70 countries and the average score for mathematics is 386. In 2012, Indonesia achieved ranking 65 from 65 countries, and the average score for mathematics is 375 [7, 8].



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PISA test consist of four contents namely (1) the quantity, (2) space and shape, (3) change and relationship, and (4) uncertainty and data [5, 6, 9]. In the PISA test, there are six levels related to mathematical literacy of students [5, 6, 9].

According to Campbell et al., mathematical abilities of primary teachers who teach in the elementary and junior high school are related directly and positively with the students' achievement [10]. It means that a teacher who has good mathematical literacy will impact positively on improving student's mathematical literacy. This result gave idea to us how to improve our students' mathematics ability. If the schools want to improve students' mathematical literacy, they need to improve their teachers' mathematical literacy. It means universities who produced the teacher candidates has an obligation to improve the quality of prospective teachers it produced. How is our teacher's and teacher candidates' mathematical literacy? Do their mathematical literacy is good or not? Unfortunately, research in this area is still limited. So that's why this research is important to do. Because our university as one of universities producing candidate of teachers, we had obligation to know about the students' mathematics literacy and improve it. The one of research aims was to describe mathematics education department students' ability in mathematics literacy for change and relationship problem on PISA adaptation test.

2. Research Methodology

The type of this research was design research. Subjects of this research were seven mathematics education department students. They were chosen randomly from mathematics education department students in one of private university. The goal of this study was achieved by using Akker's design research procedure [11]. There were three steps in the design research, i.e. (1) construct the design, in this research, the researchers constructed the PISA adaptation test, (2) try out the design, in this case, the researchers asked seven mathematics education students to do the test, and (3) do a retrospective analyze, in this case, the researchers analyze the test result base on the three qualitative data analyze steps developed by Miles and Huberman [12]. This procedures was described in the following diagram.

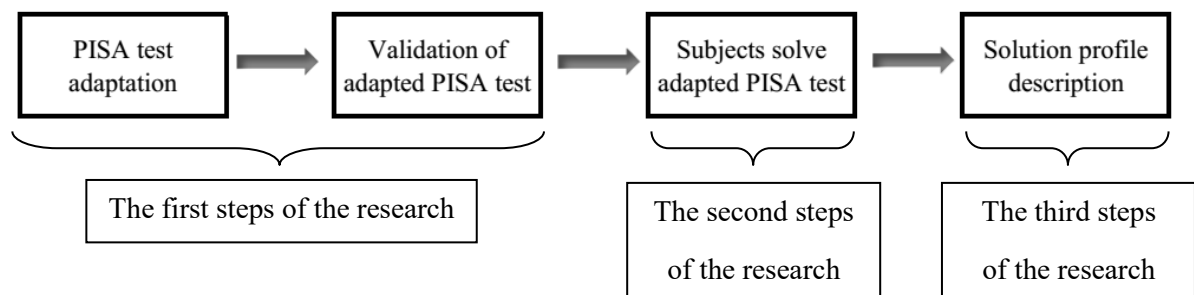


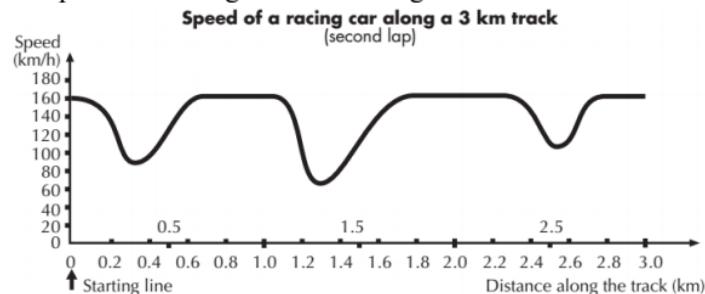
Figure 1. The research procedures

There were four types of the problems in the PISA adaptation test which resulted from this research, i.e. (1) three change and relationship problems, (2) four space and shape problems, (3) two uncertainty problems, and (4) four quantity problems. The language that used in the test is Indonesian, but for the benefit of scientific publications, the test was translated into English.

3. Result and Discussion

Problem 1

This graph shows how the speed of a racing car varies along a flat 3 kilometer track during its second lap.



- a. Where was the lowest speed recorded during the second lap?
 - A. at the starting line.
 - B. at about 0.8 km.
 - C. at about 1.3 km.
 - D. halfway around the track.
- b. What can you say about the speed of the car between the 2.6 km and 2.8 km marks?
 - A. The speed of the car remains constant.
 - B. The speed of the car is increasing.
 - C. The speed of the car is decreasing.
 - D. The speed of the car cannot be determined from the graph.

Figure 2. The problem 1 in the PISA adaptation test

In the graph, the vertical axes represent car's speed and the horizontal axes represent distance along the track. The deepest valley in the graph indicated the lowest car's speed. In this case, it happened at about 1.3 km. So, the answer of problem 1a is C. At interval (2.6, 2.8), the graph was increasing monotone. It indicated that car's speed increase at that interval. Thus, the answer of problem 1.b is B. Note that all relevant information was given in the problem, and the questions were defined clearly. All subjects could answer both problems correctly. It means, the subjects could answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. Thus, base on the PISA classification [5, 6, 9], the students' mathematics literacy were classified in the level 1.

1. C. Di sekitar jarak 1,3 km dari titik awal.
 Karena pada grafik sewaktu menunjukkan pada 1,3 km dari titik awal, grafiknya lebih melengkung kebawah dari pada lengkungan yang lainnya. Diketahui bahwa semakin rendah lengkungannya semakin rendah pula kecepatannya.
2. B. Kecepatan mobil meningkat.
 Karena terlihat pada grafik yang cenderung naik atau meningkat kecepatannya. Diketahui bahwa semakin tinggi grafik semakin cepat pula kecepatannya.

Figure 3. The one example of subjects answer for problem 1

Problem 2

People living in an apartment building decide to buy the building. They will put their money together in such a way that each will pay an amount that is proportional to the size of their apartment. For example, a man living in an apartment that occupies one fifth of the floor area of all apartments will pay one fifth of the total price of the building.

- There were three apartments in the building. The largest, apartment 1, has a total area of 95 m². Apartments 2 and 3 have areas of 85 m² and 70 m² respectively. The selling price for the building is 30 billion rupiah. How much should the owner of apartment 2 pay? Show your work.
- Circle Correct or Incorrect for each of the following statements:

Statement	Correct / Incorrect
A person living in the largest apartment will pay more money for each square meter of his apartment than the person living in the smallest apartment.	Correct / Incorrect
If we know the areas of two apartments and the price of one of them we can calculate the price of the second.	Correct / Incorrect
If we know the price of the building and how much each owner will pay, then the total area of all apartments can be calculated.	Correct / Incorrect
If the total price of the building were reduced by 10%, each of the owners would pay 10% less.	Correct / Incorrect

Figure 4. The problem 2 in the PISA adaptation test

Generally, all subjects used the same technique using ratio concept to solve this problem. First technique, they counted the total area of the apartment, that is $95 \text{ m}^2 + 85 \text{ m}^2 + 70 \text{ m}^2 = 250 \text{ m}^2$. After that, they used ratio to count the price of apartment 2. They used ratio because the price of the apartment is proportional to the size of the apartment according to the problem. There were five subjects who use this technique.

a) Apartemen I luasnya 95 m²
 II luasnya 85 m²
 III luasnya 70 m²
 Luas total apartemen = 250 m²

Harga gedung = 30 Miliar rupiah
 Yang harus dibayar pemilik apartemen II :
 $\frac{85}{250} \times 30 \text{ M} = \frac{85}{250} \times 30.000 \text{ juta}$
 $= 85 \times 120 = 1020 \text{ juta}$
 Jadi yang harus dibayarkan adalah 1020 juta rupiah atau 1,02 miliar rupiah.

Figure 5. One of subject's answer for problem 2a using the first technique

Let us pay attention to the answer in figure 5. Subjects wrote $\frac{85}{250} \times 30 \text{ M} = \frac{85}{250} \times 30000 \text{ juta}$

.The letter M represents billions in Indonesian. To simplify calculation, subject converted "30 billion" to "30000 juta" and then divided 30000 with 250. "30.000 juta" was not common way to represent 30 billion, but mathematically it is true.

The second technique to solve problem 2a is the subject simplified 95:85:70 by divided it with five. The subject got 19:17:14. After that, subject counted the sum of $19+17+14 = 50$ and counted the price of the apartment by using ratio. From the subject's answer, it can say that the subject can interpret agreement between apartment buyer and seller and represent it by using ratio. Thus, six subjects using the first and the second technique were classified by PISA classification [5, 6, 9] in level 3. One another subjects could not solve it.

Subjects answer for problem no 2b.1: All subjects claimed that the statement is correct. This claim is false because everyone would pay the same amount of money for each meter square. This was a consequence of the rule that payment was proportional to the size of apartment. Thus, all students were classified by PISA classification [5, 6, 9] in level 1, because they used relevant information but not in the true way.

Subjects answer for problem no 2b.2: Five subjects claimed that the statement is correct. Thus 71.43% subjects were classified by PISA classification [5, 6, 9] in level three because they could communicate their interpretation of given information in the problem, the result of their thinking, and the reason of their answer. Two subjects did not answer the question.

Subjects answer for problem no 2b.3: Three subjects answered “incorrect” for this question. It showed that subjects could communicate their interpretation of given information in the problem, the result of their thinking, and the reason of their answer. Thus, they were classified by PISA classification [5, 6, 9] in level three. Three subjects answered “correct” for this problem. Thus, these students were classified by PISA classification [5, 6, 9] in level 1, because they used relevant information but not in the true way. One subject didn’t answer the question.

Subjects answer for problem 2b.4: Only one student answered “correct” for this problem. This answer is true. Thus, she was classified by PISA classification [5, 6, 9] in level 4, because she could construct and communicate the reasons why they answer “correct” based on their interpretation of proportional understanding. Four subjects answered “incorrect” and they were classified by PISA classification [5, 6, 9] in level 1, because they used relevant information but not in the true way. Two subjects did not answer the question.

Problem 3

In 1998 the average height of both young males and young females in the Netherlands is represented in this graph. According to this graph, on average, during which period in their life are females taller than males of the same age?

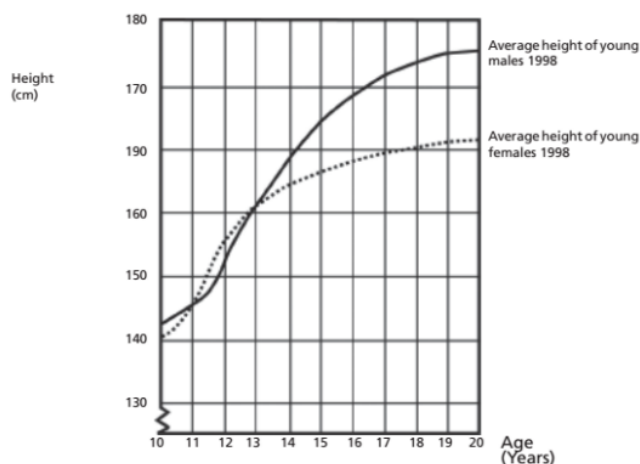


Figure 6. The problem 3 in the PISA adaptation test

In above graph, the vertical axis represent high, horizontal axis represent age, the dash line represent average high of young females and straight line represent average high of young males. Three students answered that young females were taller than young males during age period 11 – 13 year. These students were able to execute clearly described procedures, including those that require sequential decisions. They also were able to interpret and use representations based on different information sources and reason directly from them. Thus, they were classified by PISA classification [5, 6, 9] in level three. One student answered that young females were taller than young males during age period 11 – 12 year. One student answered that young females were taller than young males during age period 12 – 13 year. One student answered that young females were taller than young males when they are 12 year old. These three students were able to extract relevant information from a

single source and make use of a single representational mode. Thus, they were classified by PISA classification [5, 6, 9] in level two. One student answered that young females were taller than young males during age period 11 – 14 year. This student was not able to extract relevant information from a single source and make use of a single representational mode, so this student was classified by PISA classification [5, 6, 9] in level 1.

The following table is the summary of subject's level

Table 1. the summary of subject's level

Problem	Subject's Achievement Level	Reason	The number of subject	Percentage
1a	Level 1	Subjects could answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined.	7	100 %
1b	Level 1	Subjects could answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined.	7	100 %
2a	Level 3	Subjects could interpret agreement between apartment buyer and seller and represent it by using worth comparison.	6	85,71 %
	Didn't answer the question	-	1	14.29 %
2b.1	Level 1	-	7	100 %
2b.2	Level 3	they can communicate their interpretation of given information in the problem, the result of their thinking, and the reason of their answer	5	71.43 %
	Didn't answer the question	-	2	28.57 %
2b.3	Level 3	Subjects can communicate their interpretation of given information in the problem, the result of their thinking, and the reason of their answer.	3	42.86 %
	Level 1	-	3	42.86 %
	Didn't answer the question	-	1	14.29 %
2b.4	Level 4	Subjects could construct and communicate the reasons why they answer "correct" based on their interpretation of proportional understanding.	1	14.29 %
	Level 1	-	4	57.14 %
	Didn't answer the question	-	2	28.57 %
3	Level 3	Subjects were able to execute clearly described procedures, including those that require sequential decisions. They also were able to interpret and use representations based on different information sources and reason directly from them.	3	42.86 %
	Level 2	Subjects able to extract relevant information from a single source and make use of a single representational mode	3	42.86 %
	Level 1	-	1	14.28 %

4. Conclusion

According to above results and discussion, we can take some conclusion. Only one or 14.29% subject achieved level four in problem number 2b.4. Six or 85.71 % subjects achieved level three at problem number 2a. Five students or 71.43 % achieved level three at problem number 2b.2. Three subjects achieved level three in the problem 2b.3 and 3. Three subjects achieved level two in the problem three.

From the results of this study, researchers suggest that there needs to be concrete steps from the mathematics education department, to improve mathematical literacy skills of the students. One of steps that can be taken is to change the learning method and evaluation system in the mathematics education department. Learning methods that should be used are no lecturer-centered, but student-centered. The evaluation system with the non-test method in the lecture needs to be increased in frequency of use. If the evaluation system uses a test method, the evaluation questions in the lecture must begin to be improved in quality to be equivalent to the questions in level four, five, and six in PISA calcification.

Acknowledgments

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