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The students' ability in mathematical literacy for the quantity, and the change and relationship problems on the PISA adaptation test

Julie H. ✉ ,   Sanjaya F. ✉ ,   Anggoro A.Y. ✉

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One of purposes of this study was to describe the solution profile of the junior high school students for the PISA adaptation test. The procedures conducted by researchers to achieve this objective were (1) adapting the PISA test, (2) validating the adapting PISA test, (3) asking junior high school students to do the adapting PISA test, and (4) making the students' solution profile. The PISA problems for

mathematics could be classified into four areas, namely quantity, space and shape, change and relationship, and uncertainty. The research results that would be presented in this paper were the result test for quantity, and change and relationship problems. In the adapting PISA test, there were fifteen questions that consist of two questions for the quantity group, six questions for space and shape group, three questions for the change and relationship group, and four questions for uncertainty. Subjects in this study were 18 students from 11 junior high schools in Yogyakarta, Central Java, and Banten. The type of research that used by the researchers was a qualitative research. For the first quantity problem, there were 38.89 % students who achieved level 3. For the second quantity problem, there were 88.89 % students who achieved level 2. For part a of the first change and relationship problem, there were 55.56 % students who achieved level 5. For part b of the first change and relationship problem, there were 77.78 % students who achieved level 2. For the second change and relationship problem, there were 38.89 % students who achieved level 2. © Published under licence by IOP Publishing Ltd.

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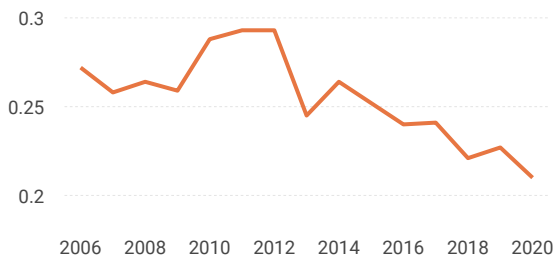
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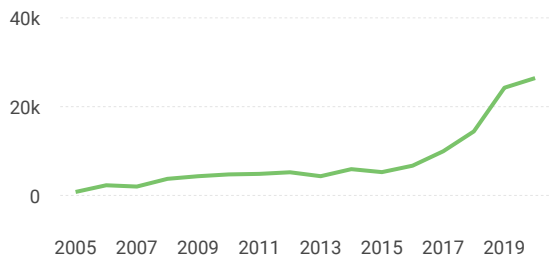
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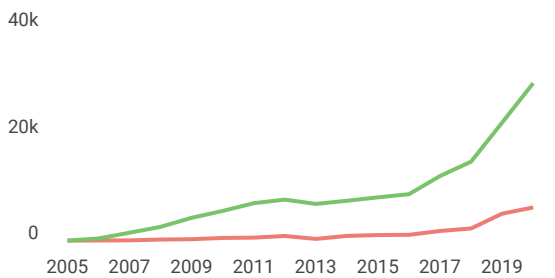
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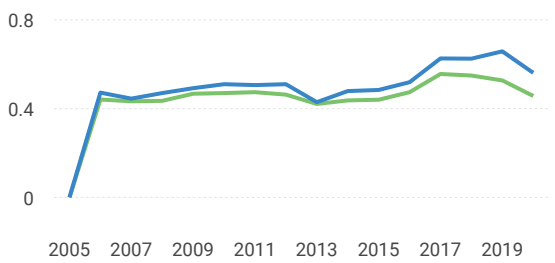
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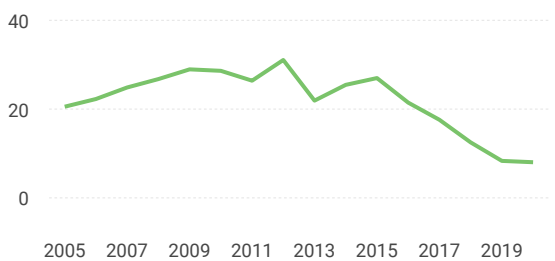
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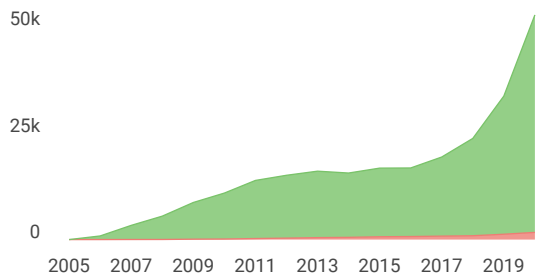
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1st International Conference on Applied & Industrial Mathematics and Statistics 2017 (ICoAIMS 2017) is organised by Faculty of Industrial Sciences & Technology, Universiti Malaysia Pahang, Malaysia. Our co-organisers are Institut Teknologi Sepuluh (ITS) Nopember, Surabaya, Indonesia, Society of Industrial and Applied Mathematics (SIAM), Malaysian Mathematical Sciences Society (PERSAMA) and Malaysian Institute of Statistics (ISM). This international conference is a biannual conference, started in 2017. The main topics of the conference is divided into six categories; Pure Mathematics, Applied Mathematics, Computational Mathematics, Statistics & Applied Statistics, Operational Research and Mathematics Education including Engineering & Industrial Applications.

The keynote presentations are provided especially to show the contribution of Mathematician and Statistician in engineering and industrial application towards research and knowledge sharing where our conference theme for this year is 'Bridging Mathematics & Industry'. We have five keynote speakers which from Department of Statistics Malaysia, Creative Vision Sdn. Bhd., Malaysia, Universiti Pertahanan Nasional, Malaysia and Institut Teknologi Sepuluh Nopember (ITS), Indonesia.

ICoAIMS 2017 was an overwhelming success, attracting the delegates, speakers and sponsors from many countries and provided great intellectual and social interaction for the participants. Without their support, the conference would not have been the success that it was. I trust that all the participants found their involvement in the Conference both valuable and rewarding. Once again, I would like to convey my deepest appreciation for all contributions and wish you success in the years ahead. Hope to see you again at ICoAIMS 2019.

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The students' ability in mathematical literacy for the quantity, and the change and relationship problems on the PISA adaptation test

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The students' ability in mathematical literacy for the quantity, and the change and relationship problems on the PISA adaptation test

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Abstract. One of purposes of this study was to describe the solution profile of the junior high school students for the PISA adaptation test. The procedures conducted by researchers to achieve this objective were (1) adapting the PISA test, (2) validating the adapting PISA test, (3) asking junior high school students to do the adapting PISA test, and (4) making the students' solution profile. The PISA problems for mathematics could be classified into four areas, namely quantity, space and shape, change and relationship, and uncertainty. The research results that would be presented in this paper were the result test for quantity, and change and relationship problems. In the adapting PISA test, there were fifteen questions that consist of two questions for the quantity group, six questions for space and shape group, three questions for the change and relationship group, and four questions for uncertainty. Subjects in this study were 18 students from 11 junior high schools in Yogyakarta, Central Java, and Banten. The type of research that used by the researchers was a qualitative research. For the first quantity problem, there were 38.89 % students who achieved level 3. For the second quantity problem, there were 88.89 % students who achieved level 2. For part a of the first change and relationship problem, there were 55.56 % students who achieved level 5. For part b of the first change and relationship problem, there were 77.78 % students who achieved level 2. For the second change and relationship problem, there were 38.89 % students who achieved level 2.

1. Introduction

The Program for International Student Assessment (PISA) test was an international program sponsored by the OECD to evaluate the literacy skills in reading, mathematics, and science of students aged about 15 years. In the PISA test, the purpose of the mathematical literacy test was to measure how students apply mathematical knowledge that they had to solve a set of problems in a variety of real context. PISA defines mathematics literacy was an individual's ability to identify and understand the role of mathematics in the world, to make an accurate assessment, to use and involve mathematics in various ways to meet the needs of individuals as reflective, constructive and filial citizens [8].

From several studies reported that in a modern society at the 21st century that humans not only required a content knowledge, but they also required skills that called as 21st century skills that 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 [2, 8]. Mathematical literacy became one of the components necessary to build 21st century skills.

In 2015, Indonesia followed the PISA test for the fifth time. In the 2015, the ranking and the average score of Indonesia for PISA tests were 63 and 386 for mathematics, 62 and 403 for science, and 64 and 397 for reading from 70 countries. In the 2012, the ranking and the average score of Indonesia for PISA tests were 65 and 375 for mathematics, 64 and 382 for science, and 61 and 396 for reading from 65 countries (source: www.oecd .org /pisa). The material of the PISA tests in mathematical literacy can be grouped into four classes, namely (1) the quantity, (2) space and shape, (3) change and relationship, and (4) uncertainty [1]. There were six levels in the PISA questions related to mathematical literacy of students and the deep explanation about these levels could read in [6]. One of the research questions that would be answered by researchers in this paper was how were the solution profiles of junior high school students for the adapting PISA test for quantity, and change and relationship problems.

2. The PISA Test
Jan de Lange said mathematical literacy was an individual's ability to identify and understand the role of mathematics 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 [3]. Jan De Lange said the following competencies would form the mathematical literacy skills, namely: (1) the thinking and reasoning mathematically competence, (2) the argument logically competence, (3) the communicating mathematically competence, (4) the problem modelling competence, (5) the proposing and solving problem competence, (6) the representing idea competence, and (7) the using symbol and formal language competence [3].

3. The Research Methodology
In a qualitative study, the researcher sought to describe a phenomenon that occurred in a natural situation and not make a quantification of the phenomenon [4, 5]. This research was classified in the qualitative research, because in this study the researchers sought to describe a phenomenon that occurred in a natural situation and did not make a quantification of the phenomenon. A natural phenomenon that was described in this study was how the junior high school students solved the adapting PISA test.

One of purposes of this study was to describe the solution profile of junior high school students for the adapting PISA test. The processes conducted by researchers to achieve this objective were as follows: (a) adapting the PISA test, (b) validating the adapting PISA test, (c) asking junior high school students to solve the adapting PISA test, and (d) describing the junior high school student solution profiles for the adapting PISA test. In the adapting PISA test, there were fifteen questions that consist of two questions for quantity, six questions for space and shape, two questions for change and relationship, four questions for uncertainty, and one question for the argument logically. The time given to students to take the test was 90 minutes.

There were 18 junior high school students who had 14 – 15 years old as the subject of this study. They came from 11 junior high schools in Yogyakarta, Central Java, and Banten. The steps to choose subjects were the researchers chose the schools proportional randomly and then the researchers chose the best students in those schools to become our research subjects.

4. The Results and Discussion
The research results that would be presented in this paper were the result test for quantity, and change and relationship problems. In the following section, researchers would present the solution profile of the junior high school students for the uncertainty problems.
1. **The first problem for quantity**: at 18 grams of water there were $6{,}02 \times 10^{23}$ molecules. If a bath contained 400 liters of water, how many molecules were there in the bath?
   The solution profile of the junior high school students for this problem was as follows:
   a. The first strategy, i. e. students used the worth comparison concept between the water mass and the number of the water molecules (the student 'answer example can see in figure 1). Students
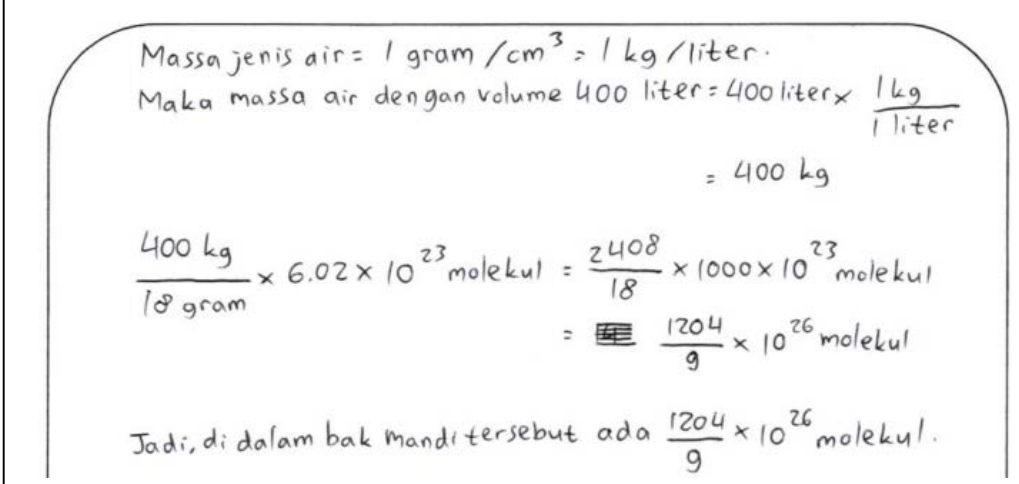
used their knowledge about the water mass which was unknown in the problem. Students found water masses for 400 liters of water. After that, the students used the worth comparison concept between the water mass and the number of the water molecules to find the number of water molecules in 400 liters of water. There were seven students used this strategy to solve this problem. The student thinking process of these seven students could be classified at level 3, because students could select and apply simple problem solving strategies and could interpret and use representations based on different information sources and reason directly from them.

Figure 1. The example of the student answer for the first quantity problem.

    b. Eight students used the comparison concept between the volume of water and the number of the water molecules, but students have not been able to relate this problem to the water density concept. Since students could not relate this problem to the water mass concept, students used the comparison concept between the volume of water and the number of the water molecules by converting 18 grams of water to 18 cm^3.

    c. Three subjects did not answer this question.

2. The second problem for quantity:

Mr. Toni wanted to make the Indonesian children's toys made from the skin of a Balinese orange for the kids around his house. The table 1 showed the materials needed and the number of material available to make the toy. How many toys could be made by Mr. Toni?

Table 1. The materials needed and the number of material available to make the toy.

The Material	The Stick	The orange peel for the body of the car	The orange peel for wheels of the car
The number of materials were needed to make one car	4	2	4
The number of materials were available	33	27	36

The solution profile of the junior high school students for this problem was as follows:

    a. The first strategy, namely fifteen subjects did by dividing the number of stick, orange peel for the body of the car, and orange peel for wheels of the car available in succession with the

number of stick, orange peel for the body of the car, and orange peel for wheels of the car which were required to make one toy. The division result was rounded down. The smallest rounding result was the number of toys that could be made by Mr. Toni. The results obtained were 8.

b. The second strategy, i. e. one student divided the number of stick available with the number of stick which was needed to make a toy. The results were rounded down. Furthermore, he counted the number of the orange peels used to make the bodies and wheels of eight toys. From the calculations obtained were 16 and 32 respectively. Since all materials were enough to make eight toys, he concluded that the toys that could be made by Mr. Toni were eight.

c. Two subjects did not answer this question.

The students' thinking process in the first and second strategy could be classified on level 2, because students could interpret and recognize situations in contexts that require no more than direct inference, and could extract relevant information from a single source and make use of a single representational mode.

3. The first problem for change and relationship:

Based on the graph shown in figure 2, estimate:

a. The distance from the starting point of the starting line to the starting point of the longest straight line of the race path.

b. Determine the smallest speed during the second lap!
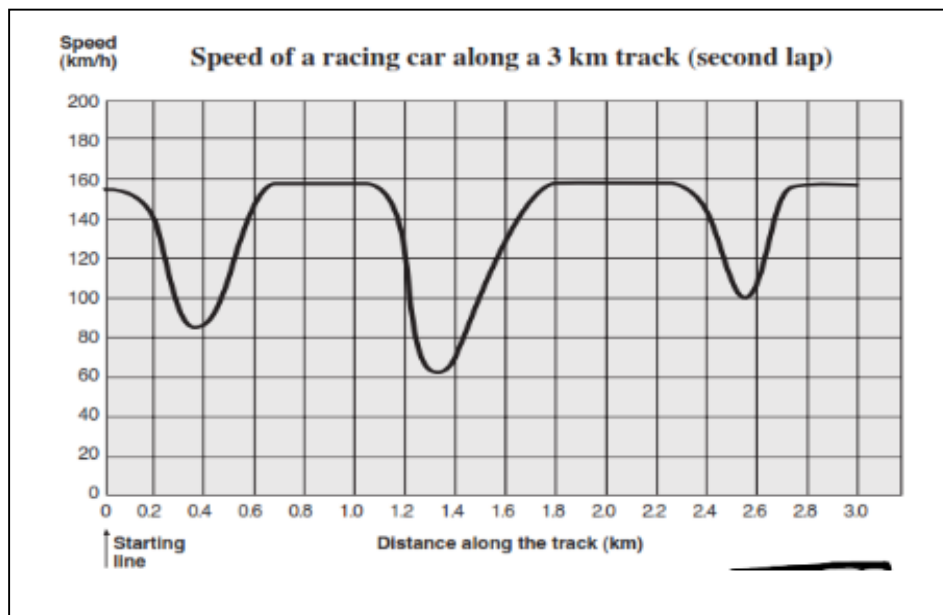
Figure 2. The graph connected between the distance in km and the speed in km/h.

The solution profile of the junior high school students for part a of this problem was as follows:

a. The first strategy, namely seven students answered 1.8 km. Because in general for a straight line, the car speed would reach maximum after it was stable. The longest stable velocity contained in the charts starts from 1.8 km from the starting line. So, 1.8 km was the distance from the starting line up to starting point of the longest straight line. The student has not been able to implement on the available graphs in the problem the explanation that he made, namely in general for the straight line, the car's speed would reach its maximum after it was stable, so it has not been precise in determining the distance from the starting point to the starting point of the straight line.

b. The second strategy, i. e. two students answered 1.3 km. Because in general for a straight line, the speed of the car would go up. From the chart above, the speed of the car would go up the longest

starting from 1.3 km to 1.8 km. Thus, the distance from the starting line up to the longest straight line was 1.3 km.

c. The third strategy, i. e. one student answered 2.3 km. Because the longest straight line starts from km 1.7 to 2.3 km. Thus, the distance from the starting line up to the longest straight line was 2.3 km. Students were not careful in reading the question, which was at the "starting point of the longest straight line of the race track".

d. Eight students did not answer the question.

The student's thinking process in the first, second, and third strategy could be classified at level 5, because students could develop and work with models for complex situations, identifying constraints and specifying assumptions, could select, compare, and evaluate appropriate problem solving strategies for dealing with complex problems related to these models, and could work strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characters, and insight pertaining to these situations.

The solution profile of the junior high school students for part b of this problem was as follows:

a. 14 students answered the smallest speed achieved between at 1.3 km and 1.35 km, i.e. between 60 km/h and 64 km/h. The student's thinking process in the first until fourth strategy could be classified on 2 because students could already extract information and communicate it.

b. Four students did not answer the question.

4. The second problem for change and relationship:

The figure 3 illustrates the relationship between the length and height of coral reefs:
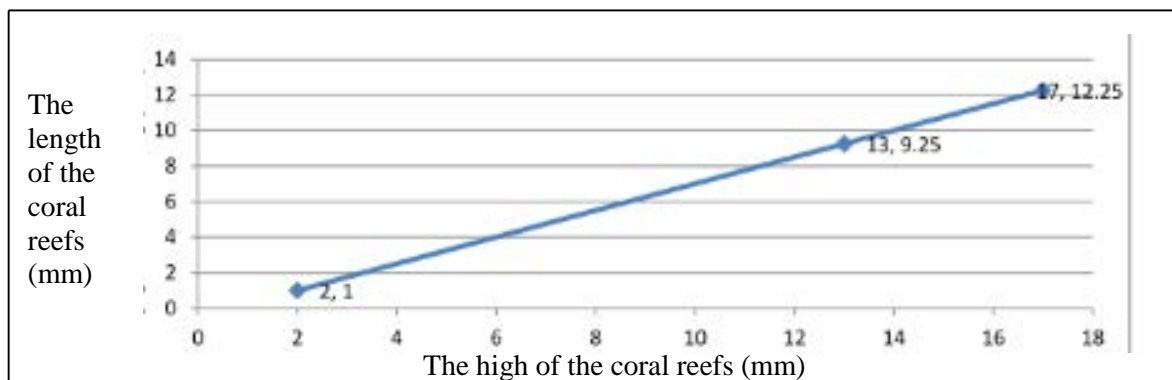
Figure 3. The graph connected between the high of the coral reefs and the long of the coral reefs.

Determine the function that stated the relationship between the height of the coral reef and the length of the coral reefs!

The solution profile of the junior high school students for this problem was as follows:

a. The first strategy. i.e.: two students determined the function formula by using the formula $y - y_1 = m(x - x_1)$. To use the formula, students look for a line gradient that passes through two given points. After that, the students substituted the values of m, y_1, and x_1 to the formula, so that the equation of the line through the two points known was $y = \frac{3}{4}x - \frac{1}{2}$.

b. The second strategy, namely: a student determined the formula of the function by using the formula $y = mx + c$. Then the student substituted the three known coordinates in the problem into the function formula to obtain three linear equations with two variables. After that the student used the elimination and substitution method to find the value of m and c until finally the student could find the function formula.

c. The third strategy, namely: three students determined the formula of the function by using the formula $\frac{x-x_1}{y-y_1} = \frac{x-x_1}{y-y_1}$. Then students took the coordinates of two points, namely (2, 1) and (13, 9.25) from three known points in the problem to be substituted to the function formula.

d. The fourth strategy, namely: a student tried to determine the function formula from the known point coordinates on the problem so that students found the function formula of the line through the three points.

e. The fifth strategy, namely: three students determined the formula of the function by using the formula $y = mx + c$. To find m in the function formula, students used the formula $m = \frac{y_2 - y_1}{x_1 - x_1}$. Then the students took the two-point coordinates, namely (0, 0) and (17, 12.25) from three known points in the problem to be substituted to the gradient formula so that the student obtained the m value. To find the value of c, the student assumed the line through the coordinate center point and substituted the coordinate of the center point into the function formula that has been substituted by the m value so that the student obtained the function formula. The mistake of students in solving this problem was that the student assumed the line through the coordinate center point.

f. Eight students did not answer the question.

The students' thinking process in the first until fourth strategy could be classified at level 2, because students could interpret and recognize situations in contexts that require no more than direct inference, and could extract relevant information from a single source and make use of a single representational mode.

5. Conclusions

For the first quantity problem, there were 7 of 18 students who achieved level 3 and 3 of 18 students who did not solve the problem. For the second quantity problem, there were 16 of 18 students who achieved level 2 and 2 of 18 students who did not solve the problem. For part a of the first change and relationship problem, there were 10 of 18 students who achieved level 5 and 8 of 18 students who did not solve the problem. For part b of the first change and relationship problem, there were 14 of 18 students who achieved level 2 and 4 of 18 students who did not solve the problem. For the second change and relationship problem, there were 7 of 18 students who achieved level 2 and 8 of 18 students who did not solve the problem.

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