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# The mathematics education department students' ability in mathematical literacy for uncertainty problems on PISA adaptation test

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**Abstract.** The Programme for International Student Assessment (PISA) is a triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students who are nearing the end of their compulsory education. In most of the PISA-related studies, more students as subjects than teachers. Even mathematics education students who are prospective teachers have not got a place in this PISA research. One of goals of this research was to describe mathematics education students' ability on PISA adaptation test. In this research, there were several steps to achieve the goal, that is (1) creating test questions by adapting PISA test, (2) validating test questions using expert validation, (3) asking the students to do the test, and (4) describing the students' solution test. The mathematics PISA adaptation test consist of 4 scopes, that is quantity, space and shape, change and relationship, and uncertainty. The test contained 13 questions, three quantity problems, three uncertainty problems, three change and relationship problems, and four space and shape problems. This research used 7 students of Mathematics Education Department of Sanata Dharma University as subject research. This research was a design research which developed by Cobb and Koeno. In the uncertainty area, all students answer correctly at the level 1 problem, six students answer correctly at the level 4 problem, two students answer correctly at the level 5 problem, two students answer correctly at the level 5 second problem, one student answers correctly at the level 6 problem. Therefore, the quality of mathematics education students' needs to be improved to reach the maximum level in PISA.

## 1. Introduction

Student achievement is closely related to the teacher's mathematical and pedagogical skills [1, 2]. In addition, teacher knowledge achieved by students has a significant relationship with teachers' perceptions [1, 2]. In this case, teachers' perceptions are defined as (1) teacher paradigms in the learning process of mathematics, and (2) teacher attention to students' math skills [1, 2]. Furthermore, mathematical knowledge of teachers is the main factor of teachers in giving attention to students' math skills [1, 2]. The Programme for International Student Assessment (PISA) is a triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students who are nearing the end of their compulsory education. Based on the opinion, the ability of teachers in managing the process of learning to teach mathematics and solve mathematics

problems is one of the determinants of student success in completing the PISA test. Most of the PISA-related studies, more students as subjects than teachers. Even mathematics education students who are prospective teachers have not got a place in this PISA research.

Therefore, this study aims to describe the solution of mathematics education students on PISA adaptation tests. This PISA adaptation test contains 4 topics, namely quantity, space and form, change and relationship, and area of uncertainty. However, in this paper the researcher will only explain the results of research for mathematics student education solution PISA adaptation test on the topic of uncertainty [3, 4, 5].

Mathematical literacy is the understanding of individual mathematics in applying it in everyday life [6]. Using mathematical literacy, students can understand and apply the role of mathematics in a real-life context. [2, 7, 8]. According to [3], mathematical literacy is the ability of a person to identify and understand the role of mathematics in real life, to make accurate judgments, use and involve mathematics in various ways to meet the needs of individuals as reflective, constructive and devoted citizens. The things that affect the ability of mathematical literacy are: (1) mathematical thinking and reasoning, (2) argument of logical ability, (3) mathematical communication ability, (4) problem modeling ability, (5) proposing and problem solving ability, (6) the ability to represent ideas, and (7) using symbols and formal language skills [7, 9].

In PISA, the problem of students' mathematical literacy is divided into 6 levels [3, 10]. Based on Julie's research [10], 83.33% of students reach level 4 and 38.89% of students reach level 5. Furthermore, this study will also look at the comparison of the results of students' ability to do the test with mathematics education students who are prospective teachers.

## 2. The research methodology

Design research has two characteristics that are process-oriented and oriented to usability [11]. One of the stages in this study, researchers developed a design of a test adapted from PISA. Researchers also described the mathematics education student's solution for the test. These results will be the basis for creating modules that contains a learning process that can be used to improve PISA competencies. Therefore, this research may be classified in the design research.

One of the study aims was to describe mathematics education student's solution on PISA adaptation test. The steps for research can be seen figure 1. In this paper, the researcher limited the discussion of the results of the study only to the subjects of research in mathematics education students and for uncertainty problems.



**Figure 1**. Research steps.

This test contained 13 questions, which consists of three quantity problems, three uncertainty problems, three for change and relationship problems, and four for space and shape problems. The test was done by students within 90 minutes.

This research used 7 students of Sanata Dharma University's Mathematics Education Departments as the subject of the research. The selection of students as the subjects of this study was conducted randomly proportional, then the best 7 student were selected as research subjects. The results will be presented qualitatively.

## 3. The Results and discussion

In this paper, the research results present the result of the PISA adaptation test on the uncertainty area [3, 4, 5]. The result were described as follow:

**Problem 1.** The Figure 2 shows information about exports from Zedland, a country that uses zeds as its currency. (see figure 2)
   a.   What is the total value (in million zeds) of exports from Zedland in 1998?
   b.   What is the value of fruit exported from Zedland in 2000?
        A.  1.8 million zeds.              D. 3.4 million zeds.
        B.  2.3 million zeds.              E. 3.8 million zeds.
        C.  2.4 million zeds.
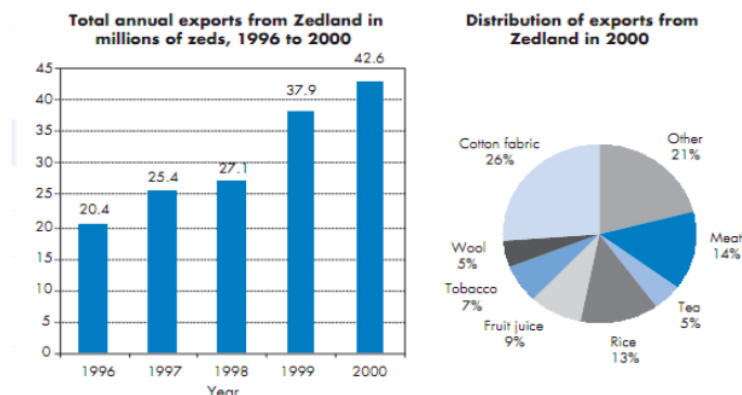


**Figure 2**. Distribution of exports from Zedland.

**Student's answer for problem 1a**:
The total value (in million zeds) of exports from Zedland in 1998 was 27.1. The solution was made by all students. Students' answer as above could be categorized as level 4 because the question is explicit and only needs to select relevant information from the chart.

**Students' answer for problem 1b**:

1.   The value of the fruit is exported from Zedland in the year 2000 $= \frac{9}{100} \times 42.6 = 3.834$ million zeds$\approx 3{,}8$ million zeds. The answer was E. The solution was made by six students. Students' answer as above could be categorized as level 4 because they must understand the data on Figure 2 along with the relationship the two charts. In addition, they must also understand the representation associated with the topic of fractions, especially percent.

2.   A. 1.8 juta zeds

$$\frac{1{,}8}{42{,}6} \times 100 = 4{,}1\%$$

The solution was made by one student.

a. Nilai total ekspor dari zedland pada tahun 1998 adalah 27,1 juta zeds

b. Nilai buah yang diekspor dari zedland pada tahun 2000

$$= \frac{9}{100} \times 42.600.000 = 3.834.000$$
$$= 3,834 \text{ juta zeds}$$
$$\approx 3,8 \text{ juta zeds} \quad (E).$$

**Figure 3**. Example of students' solution of problem 1.

**Problem 2.** Many scientists fear the increasing levels of $CO_2$ gas in Earth's atmosphere caused by climate change. The Figure 4 shows that the level of $CO_2$ emissions in 1990 (see bright bars) in some countries (or territories), emissions levels in 1998 (see dark bars), and percentage changes in emission levels between 1990 and 1998 (indicated by arrows and percentage).
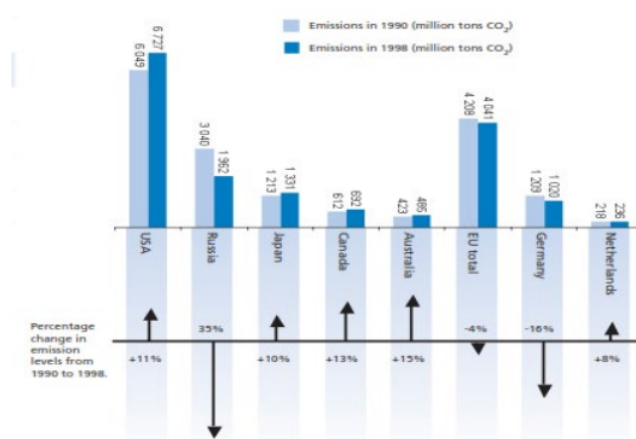


**Figure 4**. The level of CO2 emissions in 1990.

a. In the diagram you can read that in the USA, the increase in $CO_2$ emission level from 1990 to 1998 was 11%. Show the calculation to demonstrate how the 11% is obtained.

b. Mandy analyzed Figure 4 and claimed she discovered a mistake in the percentage change in emission levels: "The percentage decrease in Germany (16%) is bigger than the percentage decrease in the whole European Union (EU total, 4%). This is not possible, since Germany is part of the EU." Do you agree with Mandy when she says this is not possible? Give an explanation to support your answer.

**Students' answer for problem 2a:**
The increased CO2 emission levels from 1990 to 1998 is
$$\frac{(6727-6049)}{6049} \times 100\% = \frac{678}{6045} \times 100\% = \frac{67800}{6045}\% \approx 11\%.$$
The solution was made by two students.
Students' answer as above could be categorized as level 5 because they must did some following action:

1) Choose correctly the required data, i.e. emission of $CO_2$ in 1990 in the USA was 6049 and emission of $CO_2$ in 1998 in the USA was 6727,
2) Choose a formula that suits the real situation, the percentage changing was

$$\frac{new\ data - old\ data}{old\ data} \times 100\%.$$

3) Compare and evaluate the result with 11%.

There were five students who didn't solve the problem.

**Students' answer for problem 2b:**

1. No, because EU is a union of many countries and every country has their enhancement or decline and if we calculate, the answer can be lower than one country (Germany).

   The solution was made by one student.

   Students' answer as above could be categorized as level 6 because:

   a. they should be able to read data from a graph
   b. they can interpret that the percentage of emission reduction data in Germany is 16% while in the EU is 4%
   c. Understand the reality that Germany is part of the EU
   d. They can also formulate and communicate their thoughts appropriately and in accordance with the real situation that the percentage decrease in the EU is 4% does not mean that all percentage declines in the EU state are 4%.

2. The student agrees with Mandy opinion because the percentage is calculated based on the region.

   The solution was made by one student.

3. There were five students who did not solve the problem.



**Figure 5**. Example of students' solution of problem 2.

**Problem 3.** In a country, a number of polls are conducted to find out much support for an upcoming presidential candidate. Four newspapers conducted a poll with the following results in table 1:

**Table 1.** Vote result of some newspaper.

| Newspaper Name | Vote Result | Information |
|---|---|---|
| Newspaper 1 | 36.5 % | The poll was conducted on January 6th to 500 randomly selected people from voting citizens. |
| Newspaper 2 | 41.0 % | The poll was conducted on January 20th to 500 randomly selected people from voting citizens. |
| Newspaper 3 | 39.0 % | The poll was conducted on January 20th to 1000 randomly selected people from voting citizens. |
| Newspaper 4 | 44.5 % | The poll was conducted on January 20th to 1000 readers by phone |

Which newspaper gave the best predictions about the number of voters, if the elections take place on 25 January? Give three reasons to support your answer!

**Students' answer for problem 3:**
1. The best predictions is Newspaper 3. The reason was: (a) the poll was conducted five days before the election time, so the owner have had a plan to choose, (b) the samples is 1000 people, so more samples can reduce errors, and (c) randomly choose. The solution was made by one student. Students' answer as above could be categorized as level 6, because the students:
   a. must be able to understand complex problems in the problem associated with the real situation
   b. filter information that is relevant to the real situation
   c. could compare and evaluate existing data to solve the problem
2. The best predictions was Newspaper 2. The reason was: (a) for 500 people, (b) if using 500 people the result is 41% then more people can make the result increase, and (c) respondents were selected randomly from citizens who have voting rights. The solution was made by one student.
3. The best predictions was Newspaper 4 because the newspaper call the reader of their newspaper so this will make more effective. The solution was made by one student.
4. The best predictions is Newspaper 3.
   The reason was: (a) the poll was conducted before the election time, (b) get support from 390 people, and (c) selected from citizens who have voting rights. The solution was made by one student.
5. The best predictions was Newspaper 2 because from 500 people, 205 people give the support, it's mean more than half. The solution was made by one student.
6. The best predictions is Newspaper 3. The reason was: (a) much samples, (b) the result is not far from newspaper 1 and newspaper 2 which get vote from phone, and (c) randomly selected. The solution was made by one student.
7. The best predictions is Newspaper 4. The reason was: (a) the poll was conducted five days before the election time, (b) more samples, that is 1000 people, and (c) call the readers directly so they can find the another reason. The solution was made by one student.

**Figure 6**. Example of students' solution of problem 3

The following table summarize the results obtained by the student. Information in each level can be seen in Julie [10].

**Table 2.** The students' ability in the uncertainty area for the PISA adaptation test.

| Problem | Student's Achievement Level | The number of student | Percentage |
|---|---|---|---|
| 1a | Level 2 | 7 | 100,00% |
| 1b | Level 4 | 6 | 85.71% |
|  | Could not be leveled | 1 | 14.29% |
| 2a | Level 5 | 2 | 28.57% |
|  | Could not answer | 5 | 71.43% |
| 2b | Level 6 | 1 | 14.29% |
|  | Could not be leveled | 1 | 14.29% |
|  | Could not answer | 5 | 71.43% |
| 3 | Level 5 | 1 | 14.29% |
|  | Level 4 | 2 | 28.57% |
|  | Could not be leveled | 4 | 57,14% |

From table 2, it can be seen that the mathematics education students' have been able to reach level 2 and level 4. This means that students of mathematics education students' have been able to solve complex mathematical problems that are sufficient to relate them to mathematical concepts they have understood. On the other hand, they are still struggling with level 5 and 6 problems. They have not been able to solve complex mathematical problems that contain deep thinking about mathematical concepts, filtering information, and connecting with reality.

The results above also indicate that the suitability of research conducted by Julie [10] related to PISA ability of students in uncertainty area, that is 83.33% of students achieved level 4 and 38.89% of

students achieved level 5. Therefore, it is necessary to improve the quality of mathematics education students' to be able to solve the PISA problem level 5 and 6 so that when they become a teacher, they can guide students in improving quality on problems related to PISA overall.

## 4. Conclusions

Based on Section 4, it can be concluded that almost all students could solve level 2 and level 4 uncertainty problem. Five of seven students has not been able to complete a first level 5 uncertainty problem. Six of seven students have not been able to complete a second level 5 uncertainty problem. Six of seven students have not been able to complete an uncertainty problem for level 6. This means the students were still having difficulties with the PISA problems level 5 and level 6. Therefore, the quality of mathematics education students' needs to be improved to reach the maximum level in PISA.

Based on our research in 2018, learning approaches that might improve mathematical literacy skills were realistic mathematical approaches and reflective pedagogy. The study related to the influence of realistic mathematical approaches and reflective pedagogies on mathematical literacy skills was being conducted by us.

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