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Exploring Primary Student's Problem-Solving Ability by Doing Tasks Like PISA's Question

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Abstract

Problem solving plays an important role in mathematics and should have a prominent role in the mathematics education. The term "problem solving" refers to mathematics tasks that have the potential to provide intellectual challenges for enhancing students' mathematical understanding and development. In addition, the contextual problem that requires students to connect their mathematical knowledge in solving mathematical situational problem is believed to be an impact on the development students' problem-solving ability. The tasks that have been developed by PISA meet both of these criteria. As stated by the NCTM, that problem-solving skill and ability should be developed to students when they were in primary school (K5-8), therefore, it is important to do an effort to guide students in developing problem-solving ability from primary school such as accustom students to do some mathematical solving-problem tasks. Thus, in this research we tried to investigate how to develop mathematical problem-solving tasks like PISA's question that have potential effect toward students' mathematical problem-solving abilities?. We used a formative evaluation type of development research as an mean to achieve this research goal. This type of research is conducted in two steps, namely preliminary stage and formative evaluation stage covering self evaluation, prototyping (expert reviews, one-to-one, and small group), and field test. This research involve four primary schools in Palembang, there are SD Muhammadiyah 6 Palembang, MIN 1 & MIN 2 Palembang, and SDN 179 Palembang. The result of this research showed that the mathematical problem-solving tasks that have been developed have potential effect in exploring mathematical problem-solving ability of the primary school students. It is shown from their work in solving problem where all of the indicators of problem solving competency have emerged quite well category. In addition, based on interview result from some students, known that they like to do such tasks because can improve their reasoning, creativity and thinking ability.

Keywords*: development research, task of PISA, mathematical problem-solving task, problem solving competency.*

Abstrak

Pemecahan masalah mempunyai peranan yang sangat penting dalam matematika dan harus menjadi tujuan utama dalam pendidikan (pembelajaran) matematika. Istilah "Pemecahan Masalah" berhubungan dengan soal-soal yang memiliki potensi untuk memberikan tantangan yang intelektual untuk meningkatkan perkembangan dan pemahaman

matematika. Selanjutnya, masalah-masalah kontektual yang menuntut siswa untuk menghubungkan pengetahuan matematikanya dalam menyelesaikan masalah yang berhubungan dengan kehidupan sehari-hari juga diyakini memberi pengaruh terhadap perkembangan kemampuan pemecahan masalah siswa. soal-soal yang dikembangkan dalam PISA telah memenuhi kedua criteria di atas. Sebagaimana yang dinyatakan oleh NCTM yaitu kemampuan dan ketrampilan menyelesaikan masalah harus dikembangkan siswa mulai dari sekolah dasar , oleh karena itu adalah sangat penting melakukan suatu usaha untuk membimbing siswa dalam mengembangkan kemampuan pemecahan masalah mulai dari sekolah dasar seperti membiasakan siswa untuk menyelesaikan soal-soal pemecahan masalah. sehingg, dalam penelitian ini kita mencoba untuk menyelidiki bagaimana mengembangkan soal pemecahan masalah matematika model PISA yang memiliki efek potensial terhadap kemampuan pemecahan masalah siswa?. kita menggunakan penelitian pengembangan tipe formative evaluation sebagai alat dalam mencapai tujuan penelitian ini. Jenis penelitian ini dilakukan dalam dua tahap yaitu preliminary (persiapan) dan tahap formatif evaluation yang meliputi self evaluation, prototyping (expert reviews, one-to-one, dan small group), dan field test. Penelitian ini melibatkan empat sekolah dasar di Palembang, yaitu SD Muhammadiyah 6 Palembang, MIN 1 & MIN 2 Palembang, dan SDN 179 Palembang. Hasil penelitian ini menunjukkan bahwa soal-soal pemecahan masalah matematika yang telah dikembangkan memiliki efek potensial dalam menggali kemampuan pemecahan masalah matematis siswa sekolah dasar yang ditunjukkan dengan munculnya indikator kemampuan pemecahan masalah dengan kategori cukup baik dalam menyelesaikan soal-soal yang telah dikembangkan. Selain itu, berdasarkan hasil wawancara diperoleh bahwa dengan mengerjakan soal-soal model PISA ini dapat melatih penalaran, kreatifitas serta berpikir siswa

***Kata kunci**: penelitian pengembangan (development research), soal PISA, soal-soal pemecahan masalah, kemampuan pemecahan masalah.*

Introduction

Problem-solving is one of five standard mathematical competence that is the prominen object in learning mathematics conducted by the National Council of Teachers of Mathematics (NCTM) (NCTM, 2000b) and mathematics education curriculum in Indonesia (Depdiknas, 2006).

However, students' problem-solving abilities still require attention. Several research and international evaluation such as the Program for International Student Assessment (PISA) and The Third International Mathematics and Science Study (TIMSS)

mentions that the level of Indonesian students' problem-solving ability still weak in solving non-routine or high level problems (Mulis et al, 2000; Stacey, 2010). The low scores are caused by factors such mathematical learning, in which the international standard test material are given in various studies of evaluation has not been though, so when the test, they have failed. A further factor is the evaluation process, where most of the item tests in evaluation process still at low level. For example is the result of the research from Sampoerna Foundation Team (2008) toward the National Examination (UN)'s item test stating that the tasks in UN is not yet cover all cognitive aspect as expected by the curriculum. Therefore, it is necessary the effort to improve both mathematics learning and evaluation process, so that the quality of Indonesian education which oriented on problem-solving ability will be better.

Referring to the second attempt, then the development of the questions that focus on problem-solving abilities need to perceived as media in mathematics evaluation and learning process. Research recommends that students should be exposed to truly problematic tasks so that mathematical sense making is practiced (Marcus & Fey, 2003; NCTM, 1991; van de Walle, 2003). Mathematical problems that are truly problematic and involve significant mathematics have the potential to provide the intellectual contexts for students' mathematical development. So, not all problems can be a task in improving student mathematical problem-solving ability. According Zulkardi and Ilma (2006), Sumarmo (2010), and Sumardyono (2011), the development of problems with open type and contextual nature of non-routine can be used as means of improving the quality of the learning process, especially to improve problem solving skills and also as mean of assessment in mathematics.

Along with the times and reforms in education, the problem-solving ability that must be mastered by students is no longer limited to the ability in solve challenging mathematical problems but rather than how students can use math skills as a tool in solving daily problems as preparation to face knowledge society (knowledge society) (Hayat and Joseph, 2010). Therefore, the questions that were developed besides challenging (non-routine) also should reflect the problems commonly encountered by students in daily life to give an opportunity for students to apply their mathematics knowledge. The mathematics problem-solving tasks formulated in PISA test is one of alternative tasks which can be used to develop students 'problem-solving abilities, because the questions are given in this test are the contextual and non-routine

problem that measure students' mathematical literacy. The definition of *mathematical literacy* for PISA is:

> *Mathematical literacy is an individual's capacity to identify, and understand, the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned, and reflective citizen.*
> *(OECD 2009a)*

This report discuses a development research which have purpose to generate mathematical problem-solving task like PISA that have potential effect toward students' mathematical problem-solving ability. The central issue of this research is formulated into a research question: how to develop mathematical problem-solving tasks like PISA's question that have potential effect toward students' mathematical problem-solving abilities?.

***Programme for International Student Assessment* (PISA)**

PISA is a project of the Organisation for Economi Co-operation and Development (OECD). PISA involve testing of literacy in reading, mathematics, and science in samples of 15-year-olds draw from each participating country. The aim in focusing on students of this age is the generation of a summative, comparative, international report on *mathematical literacy* for students nearing the end of their period of compulsory schooling. The tests are designed to generate measures of the extent to which students can make effective use of what they have learned in school to deal with various problems and challenges they are likely to experience in everyday life (OECD, 2009a).

Test formulated in PISA are always based on real situations that contain problems that must be solved because the PISA assessment focuses on the mastery of processes, understanding of concepts and ability to apply it. So that the assessment conducted by PISA is more oriented to what students can do based on what they have learned in school, than just pay attention to whether students have mastered certain material. A student considered to have high levels of mathematical literacy if he is capable of analyzing, reasoning and communicating mathematical knowledge and skills effectively, and able to solve and interpret mathematical problems in various situations.

The structure of the PISA mathematics framework can be characterized by the mathematical representation: ML + 3Cs. ML stands for *mathematical literacy*, and the three Cs stand for content (includes four main overarching ideas, namely the space and shape, change and relationships, quantity, and uncertainty), contexts (set in four different context: making decisions in one's personal life, or understand the various events in the world) and competencies (PISA groups mathematical skills into three competency: reproduction cluster, cluster connections, reflection cluster). Suppose a problem occurs in a situation in the real world; this situation provides a context for the mathematical task. In order to use mathematics to solve the problem, a student must have a degree of mastery over relevant mathematical content. And in order to solve the problem a solution process has to be developed and followed. To successfully execute these processes, a student needs certain competencies, which the framework discusses in three competency clusters.

Student performance through these score levels helps illustrate the full range of PISA mathematics proficiency (Levels 1 to 6, where Level 1 is the simplest and Level 6 the hardest). Questions are presented in three distinct sections: the easiest questions in PISA 2003 mathematics illustrating PISA proficiency at Levels 1 and 2 (in fact the two easiest questions in the test lie below Level 1) which are found on the PISA scale from 358 to 482 points; questions of moderate difficulty in PISA 2003 mathematics illustrating proficiency at Levels 3 and 4, which are found on the PISA scale from 482 to 607 points; and the most difficult questions in PISA 2003 mathematics illustrating proficiency at Levels 5 and 6 which are found on the PISA scale from 607 and above (OECD, 2009b). In this study, which was developed is a matter of the questions at the level of moderate and most Difficult because of the problems that developed at this level are the questions that are non-routine (OECD, 2009b).

Problem Solving

Problem in mathematics is not just a task or question to be answered by the students but has a special meaning as well as involve two requirements: (i) must be understood by students and challenging, (ii) task can not be solved by a procedure already knew (non-routine) (Hudoyo, 2001: Gani 2003). In addition, Sakshaug et al. (Fox & surtees, 2010) also state that problem is task that required the learner to reason through a situation that will be challenging but not impossible. With the problem there is a

hurdle that the learner cannot immediately see how to get over or round. In order to solve a problem a child must be challenged to make decision about strategies to use. Basically the problem for someone not necessarily be a problem for others, but depending on the situation and also who is the problem solver. Bell (in Hartatiana, 2010) state that:

> "*Something called the problem is determined by the attitude of a person through a situation that may or may not be a problem for them. For example the question: "specify the number that can be placed at points to make 3 + ...= 12 the statement is true", is for students in grade 1 can be a problem but for sixth grade students this is not a problem. So a math problem is not necessarily a problem for every student, but depending on the situation"*

Progression within the problem-solving theme highlights the 'increasing complexity of the problems the children tackle as they move from one-step to multi-step problems and begin to meet those problems that are more complex and where less routine approaches are needed to solve them

Problem solving includes the skills of identifying and understanding the problem, planning ways to solve a problem, monitoring progress as the problem is tackled and then reviewing a solution to a problem. There could also be the potential for the child thinking about 'what next?'. Sakshaug et al. (2002, p.vi) describe the mathematical problem-solving experience as something that 'encompasses the acts of exploring, reasoning, strategizing, estimating, conjecturing, testing, explaining and proving. It is a very active process for those involved. Through the problem solving, we are challenged to think beyond the point where we were when we started, we are challenged to think differently. We are challenged to extend our thinking about a situation in a way that is new or different.'

In general, when researchers use the term *problem solving* they are referring to mathematical tasks that have the potential to provide intellectual challenges that can enhance students' mathematical development. Such tasks—that is, problems—can promote students' conceptual understanding, foster their ability to reason and communicate mathematically, and capture their interests and curiosity (NCTM, 2010). Research recommends that students should be exposed to truly problematic tasks so that mathematical sense making is practiced (Marcus & Fey, 2003; NCTM, 1991; van de Walle, 2003). Mathematical problems that are truly problematic and involve

significant mathematics have the potential to provide the intellectual contexts for students' mathematical development

In addition, task in mathematics is divided into two namely routine and non-routine problem. Routine problem is task of common practice that can be solved by the same or similar procedures with the new students learned in class (Aisyah, 2007). While the problem non-routine defined as a task that required thinking further because the procedure (algorithm) is not clear enough. While, non-routine matters are difficult and complicated matter, and there is no standard method to solve it.

The Prosess of Problem Solving

Problem solving is an essential part of mathematics, yet many students spend much of their mathematics career copying and reproducing algorithms. According to Shulman and Armitage (in Ohnemus, 2010), many students lack the ability, interest, and motivation to solve authentic and involved problems. Problem solving is an attempts to find way of difficult situation for achieving a goal that is not immediately achievable (Polya, 1985). From this definition seem that the problem-solving process need more than usual, it means we need a combination of prior knowledge.

The process of problem solving when student confront problem situation is by understanding information that is given, identifying critical features and any relationships in a situation, constructing or applying one or more external representations, resolving ensuing questions and, finally, evaluating, justifying and communicating results as a means to further understanding the situation. Polya (P4TK, 2010) state that: basically the process in solving problem can divide into for stage, namely understanding the problem, devising plan, carrying out the plan, and looking back.

The PISA 2003 Assessment Framework: Mathematics, Reading, Science and Problem Solving Knowledge and Skills (OECD, 2003b) through which OECD countries established the guiding principles for comparing problem-solving performance across countries in PISA, defines problem competencies as: *"… an individual's capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious and where the content areas or curricular areas that might be applicable are not within a single subject area of mathematics, science or reading."*

Research Methodology

This research conducted in first semester of Indonesian curriculum in 2011/2012. There are four primary school was involved in this research, they are SD Muhammadiyah 6 Palembang, MIN 1 & MIN 2 Palembang, and SDN 179 Palembang. We used a formative evaluation type of development research as a mean to achieve this research goal. This type of research is conducted in two steps, namely preliminary stage and formative evaluation stage covering self evaluation, prototyping (expert reviews, one-to-one, and small group), and field test.

The basic research methodology that will be discussed is:

- *Self Evaluation*

  At this stage, the initial steps undertaken by the researchers are analyzing the students characteristic, analyzing the curriculum and conducting cooperate with the school. Then, researcher tries to design mathematics tasks according to PISA's characteristics of mathematical problem-solving. Product in this stage is called prototype I.

- *Prototyping*

  At this stage, prototype I have been evaluated by giving it to the expert (expert reviews) and to three students (one to one) in SD Muhammadiyah 6 who have different mathematics ability. Experts are required to validate construct, content and language of the product qualitatively. The result from this revision called prototype II. Then, this prototype II was tested in small group consisting of 5-6 students in MIN 2 Palembang to observe the practicality of the product. Quantitatively validation process was also performed to determine validity of item tests (task) on prototype II, this process conducted to 19 sixth grade students at MIN 1 Palembang. Finding or suggestions from students and result of validity item tests used to revise the prototype II becomes prototype III.

- *Field Test*

  Field tests carried out in the sixth grade students of SDN 179 Palembang to determine the potential effect of tasks toward students' problem-solving abilities. The tasks given in field test are task in prototype III that has been qualified (validity, practically (easy use), and effective)

Data Collection

We use some instruments to collect data in this research that are the interview sheet, advice or comments sheet, student answer sheets and the set of mathematics problem-solving task like PISA. The data is collected through: (i) Walkthrough, it is conducted on experts to obtain information about validity of task qualitatively based on its construct, content and language; (ii) documents, is used to obtain data about the practicality of task (clarity and legibility); (iii) test, it is conducted to obtain data about potential effects of task that have been developed toward students' mathematical problem-solving ability.

Data Analysis

We use descriptive and document analysis to analyst the data. Descriptive analysis was used to analyze data from experts related to discussion, interview or their comment. Then, descriptive analyst was also used to analyst data about practicality of task based on observation and interview with students during one-to-one and small group process. Then, the document analysis was used to analyze students' suggestion or comment sheet on one-to-one or small group process. In addition, researcher also conducted an analysis using software of SPSS-12 to calculate the validity and reliability of each item test. This analysis conducted on students' score at MIN 1 Palembang using correlation of Karl Pearson and Cronbach-Alpha.

In the field test stage, data analysis of students' answer used to view potential effect of task which has been developed to explore students 'problem-solving abilities. The potential effect of tasks toward students' problem-solving abilities can be shown from their work and strategies used in solving the problem.

Result and Discussion

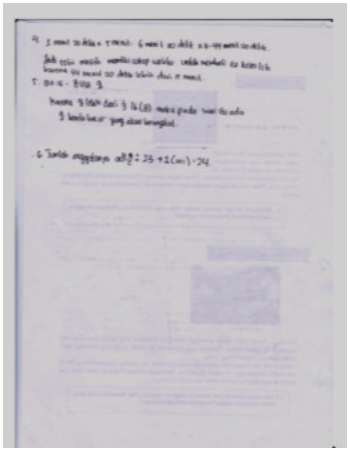
Expert Review dan One-to-one

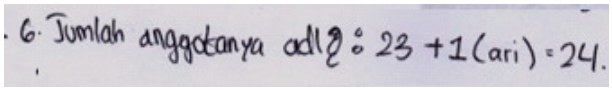
In the prototype I, research conducted 15 item problem-solving tasks like PISA's question including four contents, two-component process, three contexts, and four levels of PISA. Then, this prototype was validated by experts based on its construct, content and language. Suggestion and comment from experts were analyzed in determining the revised decision will be made. In the same period, prototype I also

was given to students in one-to-one process and ask their comment and suggestion about practicability of the task.

In one-to-one process, researcher found a few things that can support and contribute to the development of next stage in this research. The first finding relates to indicators of problem-solving ability which is the understanding the problem. Average students in one-to-one process tend not to write their understanding of the problem but directly solve the problem. Students who are in learning mathematics use to write their understanding can do it when they solve task in prototype I.

The second finding related to other problem-solving indicator that is the devising plan, where most of student not write down how process to solve the problem on their answer sheet but they prefer to write it in another sheet (Figure 1). This condition draw the situation of students in learning mathematics process, where teacher don't give more attention to process that his students done when they solve the mathematics problem. The teacher more stressed student to give the short or final answer. If this happened constantly then the students will be not creative and they will assume that process in mathematic is not important.





Devising plan written by students in other place

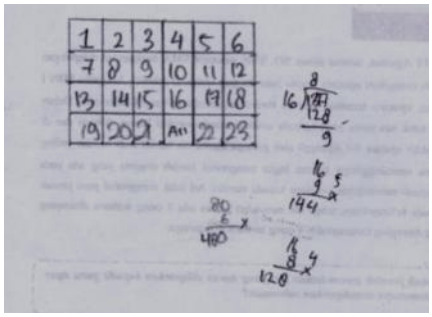


Figure 1: Student's answer of Task 1 in one-to-one process

Small Group and Validation test

In small group process, research conducted test to 6 students at MIN 2 Palembang by giving them the tasks in prototype II. Comment and suggestion from student also used to revise this prototype. Beside that, researcher also conducted test to 19 sixth grade students at MIN 1 Palembang to determine the validity test item and reliability of the

tasks. The analysis result of this test shows us that one of 15 tasks was not valid, whereas the value of reliability of this test is 0,737 (high reliability).

Furthermore, researcher makes the decision to still maintain the invalid task because based on analysis of students answer was found that students still have difficulty to using mathematical concept that needed in solving the task. There were 12 from 19 student in that test were failed where 60% of them make mistake in calculating and lack understanding about concept decimal (the concept which is needed to solve this task). In other side, there were 70% of all student in the test understand that task well.

The task below is the invalid task in validity test:

Parking Area

A rectangular-shaped parking area will be built in front of the shopping center. The size of parking area is 10,25m x 6m. In the floor of that parking is planned to be fitted with array of paving \block like shown in the picture in the right side. It takes 50 paving blocs for each 1m^2. How many paving blocks required to make that parking area?

In Figure 2, we can see some of students' mistake:

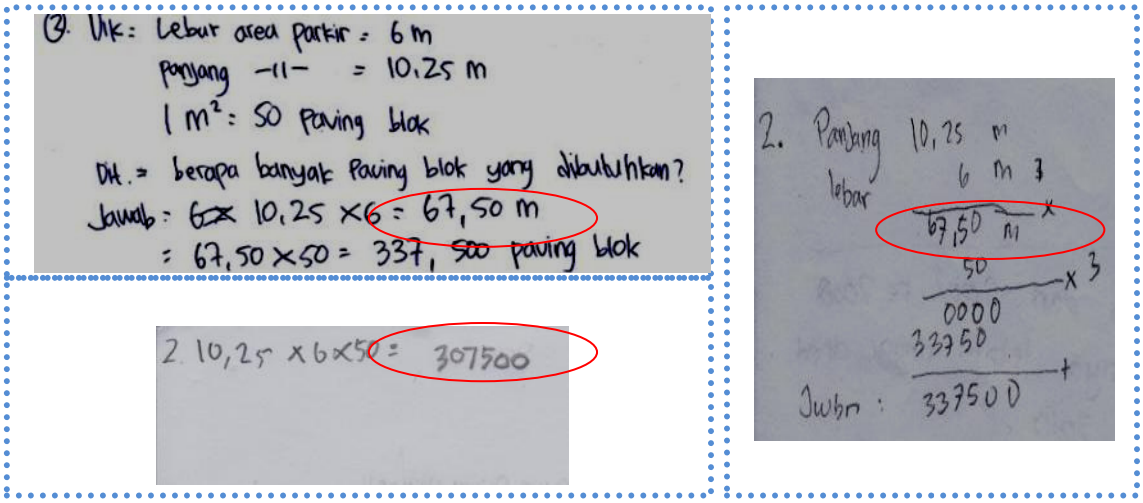


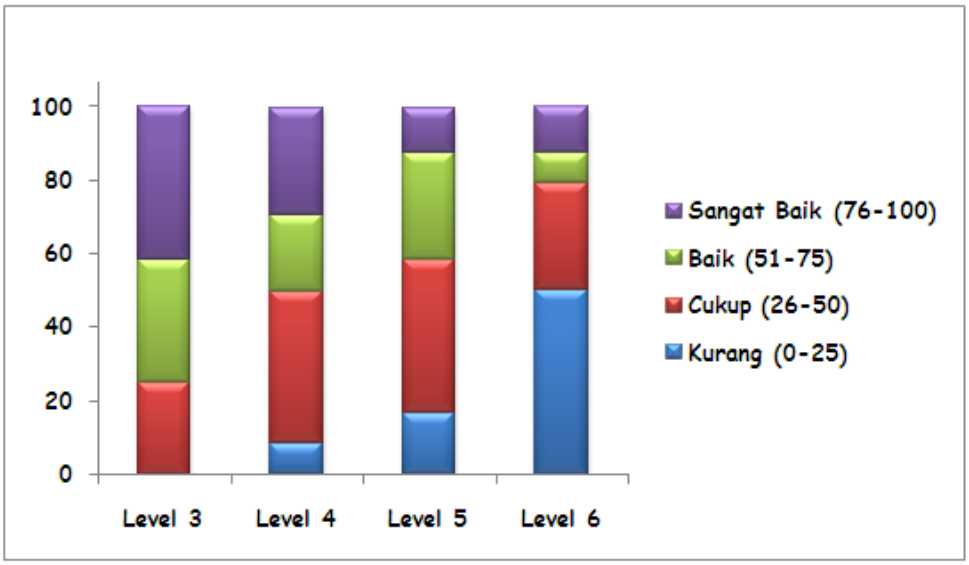
Figure 2: students' answer of Task 2 in validation test process

Field Test

The Graph 1 shows us the distribution of student scores on problem solving ability in solving mathematics problem solving task like PISA's question based on level of PISA. From the Graph, we can see that the task items at level 5 and 6 (most difficult level) are still hard for student compared to the task items at level 3 and 4 (moderate

difficult level) where the average of students' score in level 3 and 4 are 67, 5 and 54,25, whereas in level 5 and 6 are 48,47 and 35.

Grafik 1. Distribution of students' average score in mathematics problem-solving based on level



In addition based on analysis result of students' score, we found that more that 54% of students in the field test class show the mathematical problem-solving ability in good category in solving mathematical problem-solving task like PISA's question that have been developed. Then there are 8,33% of students (2 person) who have mathematical problem-solving in very good category.

The potential effect of the tasks like PISA's question can bee seen from students' strategy in solving the task. There are many strategies that students emerged in their solution. It shows that students are challenged to answer the task have been developed by using their own strategy. Following, we will discus about one of tasks like PISA's question that have been developed along with some students' answer. We choice task number 1.

Task 1

Context: Personal

Content: *Quantity*

Competency Cluster: Connection

Level: 3, the problem can be solved by using simple strategy; the problem deal with only a single data source containing discrete, well-defined information; the problems need requiring decision making skills.

Car from Lemon Skin

Car from lemon skin is one of traditional toy of Indonesian children. Mr.Saleh would like to make some of cars for children around of his house. To make this car, he needs some material and certain number of material as mentioned in the table below:

Bahan	Lidi	Kulit untuk Badan	Ban mobil
Jumlah yang diperlukan untuk membuat sebuah mobil	3	2	4
Jumlah yang tersedia	52	27	60

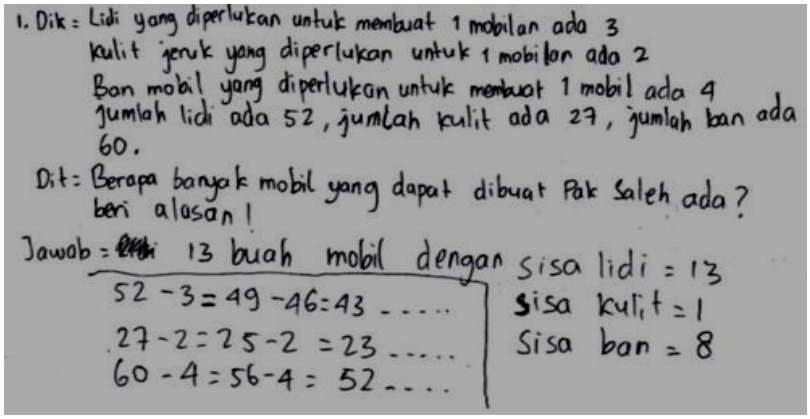
How many cars can be made by Mr.Saleh from material are available in the table? Prove your answer and give your reasons!

Problem in the task 1 was developed based on the characteristic mathematical problem-solving of PISA which consists of three aspects namely: *first* is that the settings for the problems should be real, they should draw on situations that represent contexts that could conceivably occur in a student's life or, at least, be situations the student can identify as being important to society, if not directly applicable to his or her personal life; *second*, is that they are not immediately resolvable through the application of some defined process that the student has studied, and probably practised, at school. The problems should present new types of questions requiring the student to work out what to do. This is what causes the item really to be a problem-solving item; *Finally*, the problems used should not be limited to a single content area that students would have studied and practised as part of their study of a single school subject in school.

To answer this task, there are some mathematics knowledge or concepts that students can be used, they are factors and multiple of integer and integer aritmatic operations. There are five student's strategies in solving this task. Figure 2(i) and Figure 3 show students' strategies where both of them are same basically. Both of students use subtracting strategy repeatedly until one of available material not enough to make the

new car. The student A who have answer in Figure 3 do his strategy more clear than what the student B who have answer in Figure 2(i) because have done.

(i)



(ii)

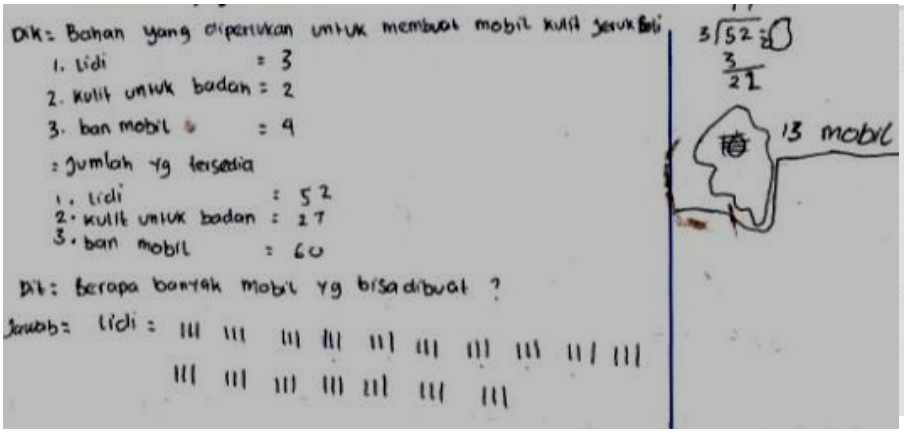


Figure 2: student' answers of Task 1 in validation test process

Figure 2(ii) show very interesting strategy where the student uses simple strategy without involving mathematical operation. Student tries to solve by understanding the problem well and connect it with simple mathematical concept. While the student C who has answer in Figure 5(i) understand well the problem and can make connection with his mathematical knowledge to solve the problem by using multiplication and division directly to the number of each car's material. Then, the Figure 5(ii) is also very interesting strategy, student try using easy mathematical calculation to find the task solution. He start his solution by using grouping of ten to find the number of material will be needed if they make ten of car then he count the remains of that material, is it enough or not to make next car.

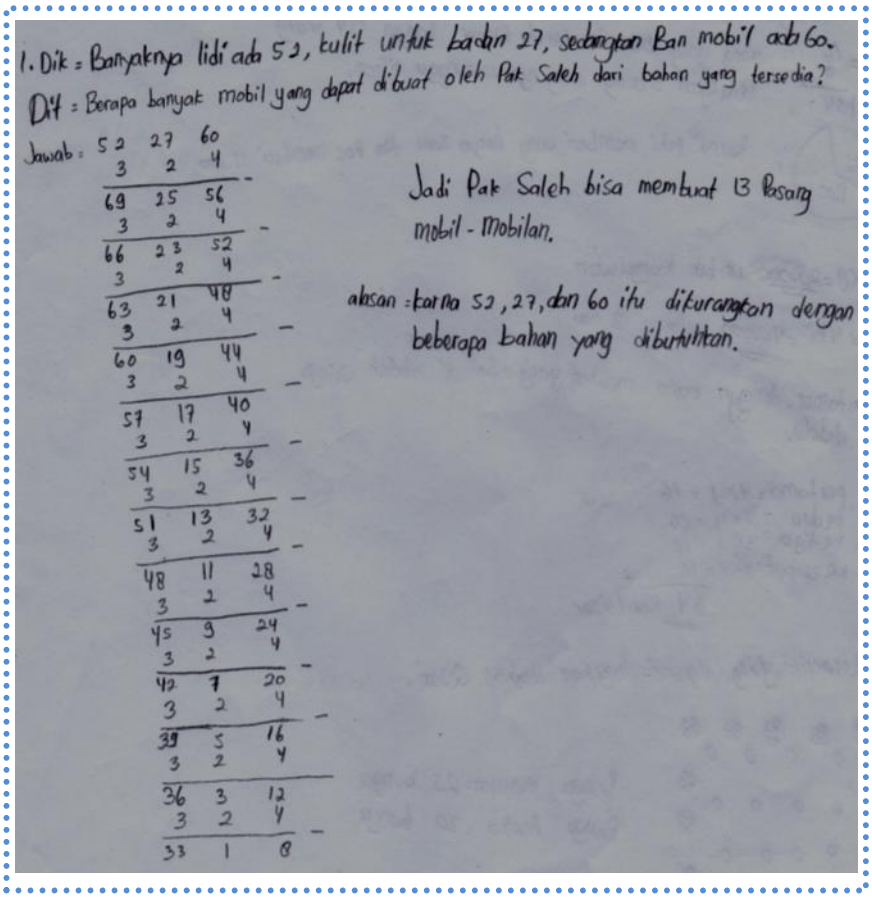


Figure 3: student' answers of Task 1 in validation test

There are also some mistake that have been done by students, for instant is in Figure 4. Most of students still have lack understanding of the problem. Students are not able to connect the problem in the task to real world situation. The mindset of students still focus on mathematics calculation and algorithms without meaningful.

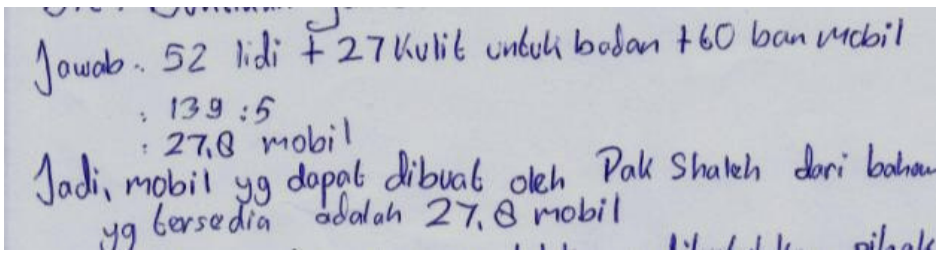
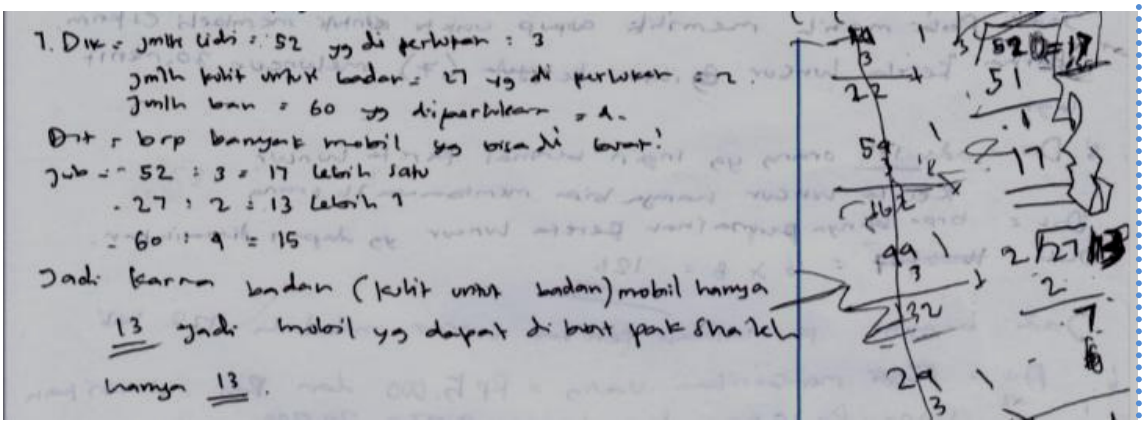


Figure 4: student' answers of Task 1 in validation test

(i)



(ii)

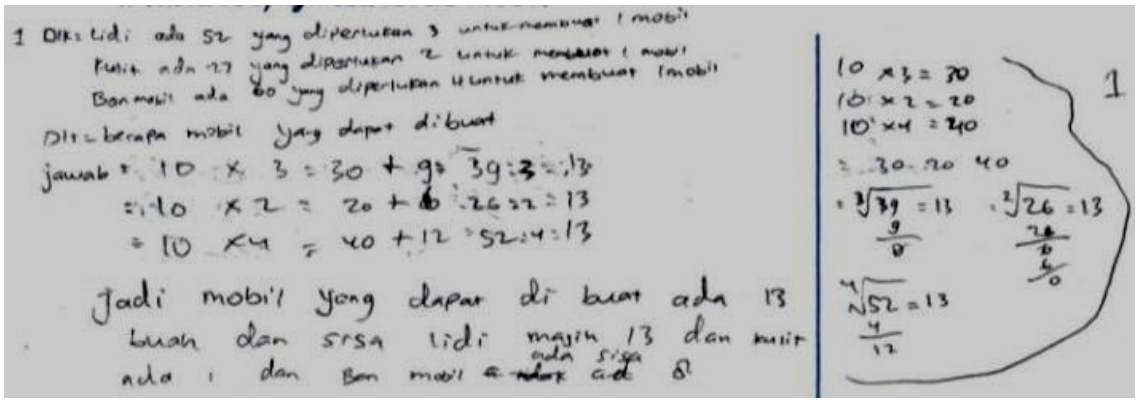


Figure 5: student' answers of Task 1 in validation test

Conclusion

This research has produced a set of valid and practical mathematical problem-solving tasks like PISA on moderate and most difficult level. The validity is reflected from the result of the experts' assessment which states that over all of the tasks have been good in content, construct, and language. The validity of the product can also be seen quantitatively from score test analysis result of the task using product-moment correlation algorithm of non-research subject students. The practicality of the product has been shown from test result analysis of one-to-one and small group students, where most of students can use and understand the task well. The mathematical problem-solving tasks that have been developed have potential effect in exploring mathematical problem solving competency of the elementary school students. It is shown from their work in solving problem where all the indicators of problem solving competency have emerged quite well category. In addition, based on interview result from some students, known that they like to do such tasks because can improve their reasoning, and thinking ability, and can explore their creativity.

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