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Development of Mathematical Literacy Problems using East Kalimantan Context

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Abstract

A deep understanding of advanced mathematics is essential. This is without doubt. However, mathematics that is applicable on daily life is deemed more important. At least for the ones that does not belong to pure mathemacs field. One des not need to be a mathematics professor to be able to predict commute time to their work or to decide which clothes to buy with given amount of discount. This is also known as mathematical literacy. One of the key features of mathematical literacy is the integration of context. Developing or designing mathematical literacy task with local context is one of efforts to promote students' mathematical literacy. This is because students are already familiar with the context hence they cam understand the problem statement better. The current study is design research aiming to develop mathematical literacy problems with East Kalimantan context. There are two phases in this research. The first phase is the preliminary phase. Here, PISA 2012 mathematics problems are reviewed and then researchers developed prototype problems with equal level but based on East Kalimantan context. There were nine mathematical literacy problems were developed in this phase. The second phase is the formative evaluation which consists of self evaluation, expert review and field test. From the process, nine valid items of problems with local context for measuring students' mathematical literacy are obtained.
Keywords: Mathematical literacy, Local Context, East Kalimantan

Abstrak

Pemahaman yang mendalam akan matematika tingkat tinggi adalah hal yang sangat penting. Akan tetapi, matematika yang dapat diterapkan dalam kehidupan sehari-hari dipandang lebih penting. Setidaknya bagi orang-orang yang tidak mendalami matematika murni. Seseorang tidak perlu menjadi guru besar dalam bidang matematika untuk memperkirakan waktu yang ia butuhkan untuk berangkat kerja atau memutuskan baju mana yag dibeli berdasarkan persentase potongan harga. Hal ini juga dikenal sebagai literasi matematika. Salah satu ciri utama dari literasi matematika adalah penggunaan konteks. Membuat soal literasi matematika yang berkonteks lokal adalah salah satu upaya untuk meningkatkan literasi matematika siswa. Hal ini dikarenakan siswa dapat lebih mudah memahami dan sudah terbiasa dengan konteks soal. Penelitian ini adalah penelitian desain yang bertujuan untuk menghasilkan soal literasi matematika dengan konteks Kalimantan Timur. Ada dua tahap utama dalam penelitian ini. Tahap pertama adalah *preliminary phase* (mengkaji soal PISA 2012 serta mengembangkan soal dengan level PISA yang setara tetapi dengan konteks Kalimantan Timur) Pada tahap ini, 9 butir soal telah dihasilkan. Tahap kedua adalah *formative evaluation,* yaitu evaluasi atau penilaian soal yang telah dikembangkan pada tahap pertama. Proses ini terdiri atas *self evaluation*, expert *review*, serta uji coba Berdasarkan ketiga proses tersebut, revisi telah dilakukan dan akhirnya diperoleh soal literasi matematika berkonteks lokal yang valid serta layak untuk digunakan.
Kata kunci: Literasi matematika, Konteks Lokal, Kalimantan Timur

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INTRODUCTION

The definition of mathematical literacy introduced by the OECD through PISA is the ability to formulate, employ, and interpret mathematics in real life problems. Mathematically literate people are able to recognize the role of mathematics in decision making or problem solving (Hattori, Fukuda, & Baba, 2021; OECD, 2019). This is not to say that mathematical literacy is more essential than mathematical procedural knowledge. Since mathematical procedural knowledge is needed to recognize and employ mathematical concept and procedure and interpret the result to the various context (Hwang & Ham, 2021). Kolar & Hodnik (2021) even suggested that mathematical literacy and mathematical procedural knowledge are interdependent. Strengthen one component will influence the progress of the other.

The significance of solving real life problems does not come with convenience. The ‘real’ nature of real life problems does not really match with the idea of pure mathematics which is exact and abstract. However context can connect these two. The use of context in problems is very important because context can bring the mathematical concepts that students learn to life. Contextual problem-based learning, especially with contexts that familiar to students, can help them build meaning for the mathematical content they are studying (Walle, Karp, & Bay-Williams, 2013). In line with the previous statements, the importance of context in learning has been expressed by many researchers before (Kohar, Zulkardi, & Darmawijoyo, 2014; Paraol & Stormowski, 2022; Rejeki, Meidina, Hapsari, Setyaningsih, & Azura, 2021). Developing context-based or mathematical literacy problems can be a starting point to get students familiar with contextual problems. Therefore, the current study aims to develop mathematical literacy problems based on PISA 2012 Items for Release (OECD, 2013b) which then were modified using local context.

A large number of research has been conducted on mathematical literacy problems. While some of them closely or loosely based on PISA (Wijaya, Heuvel-panhuizen, Doorman, & Robitzch, 2014), others have their own framework (Edo, Hartono, & Putri, 2014). Some of them developed problems on certain level (Kamaliyah, Zulkardi, & Darmawijoyo, 2013) and domain (Afkhami, Alamolhodaei, & Radmehr, 2012; Dewantara, Zulkardi, & Darmawijoyo, 2015). Recently, numbers of research to develop mathematical literacy problems with local context are increasing. Using local context in mathematics problems is recommended since students are already familiar with the context, thus they can make less effort to mathematizing process. Majority of the problem items developed focused on local context of western Indonesia (Charmila, Zulkardi, & Darmawijoyo, 2016; Pratiwi, Effendi, & Ummah, 2020; Putra, Zulkardi, & Hartono, 2016). For some extent, it can be unfavorable for students in other region. For instance, students in Kalimantan might not be familiar with context of paradigling spot in Malang.

Several other research that developed PISA-like problems were conducted by (Fadlila, Wijaya, & Hilmi, 2022; Marwanda, Yusrizal, & Johar, 2021; Sulistiani & Zulkardi, 2019; Yansen, Putri, Zulkardi, & Fatimah, 2019). The first, and third paper developed problems in a certain PISA content. The second paper developer problems for all PISA contents. All papers developed PISA-like problems in more general Indonesian context. To conlude, prior researches that developed PISA-like or mathematical literacy problems mostly referred to PISA framework in certain domain (process, content, context) and in general Indonesian context. For local context-based problems, mostly researches were from western Indonesia. Among researches that developed PISA-like problems using Kalimantan, especially East Kalimantan context is that of (Prastyo & Salman, 2020). The authors developed several items and classified them based on PISA 2003 framework. The difference between PISA 2003 and 2012 framework is that the former employed the term 'competency clusters' to classify problems according to their routinity nature, the later introduced mathemtical process that emphasizes mathematical modelling process (OECD, 2013a). Another research related to matheatical literacy in East Kalimantan is that of Hamidy & Jailani (2019). It closely based on PISA 2012 framework. The difference is that the current study used local context for all the developed problems. The current research tried to close the gap from prior researches in a way that it made attempt to produce mathematical literacy problems with well-distributed level based on PISA 2012 framework with East Kalimantan context for all problems.

Theoretical Review

Mathematical literacy based on PISA 2012 framework is centered on three domains: a) processes through which contextual problems solved (formulate, employ, and interpret); b) mathematical contents (uncertainty & data, quantity, change & relationship, and space & shape); and c) context (personal, social, occupation, and scientific). The four categories of context reflect the wide spectrum of real world problems that can be solved mathematically. Although PISA does not report students' mathematical literacy based on context, it is still taken into account when developing question items.

The context used in problems should be authentic. According to Vos (2018) any education aspect, included task design, can be considered to be authentic if it is an out-of-school origin and can be certified by experts. For instance, students were asked to calculate the amount of paint needed by a car with specific model. The measurement and sketch of the car were provided by a real car factory. However, teachers or task designers may reduce the degree of authenticity to which students are familiar with as well as the question is one that the people within context would ask. In addition, Kolar & Hodnik (2021) stated the need for considering the level of difficulty of the non-contextual version of the question as well as the recognisability of the connection between mathematical contexts in non-contextual and contextual tasks. These points were taken into account when developing mathematical literacy problem. Name of place or things used in the context are authenthic. However the dimension used, e.g. length of a river or distance between two places, can be different, if not approximated.

PISA also reported participants' level of mathematics literacy. Participants' proficiency are categorized into six levels which are hierarchical (OECD, 2013c). These levels serve as token of students' of mathematical literacy level. Therefore, if students can solve a task in a certain level, they are presumed to be able to solve tasks in lower level(s). The levels also serve as guide to design mathematical literacy problems or tasks. Based on PISA framework (OECD, 2013c), problems belong to level 1 are clearly stated with all relevant information available and can be solved with routine procedures. At level 2, students can interpret and recognise situation in contexts that require no more than direct inference. They can employ basic mathematical procedure and make literal interpretation of the results. Problems at level 3 allow students to execute procedures that require sequential desicions. They also can handle calculation with decimal, fraction and percentage. At level 4, students can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. Problems at level 5 demand studnts to develop and work with models for complex situations, identifying constraints nd specifying assumptions. Finally problems at level 6 consist with complex problem situation and relatively non-standard contexts.

METHOD

This study aims to create mathematical literacy problems that are modified from PISA problems with East Kalimantan context. The process followed those of Zulkardi & Putri (2020) which consists of preliminary phase and formative evaluation. The preliminary phase mainly consisted to develop prototype problems while the second phase was conducted to assess the validity and the reliability of the problems created. Subjects, instruments, and detailed process for both phases are described in the following parit.

Preliminary Phase

This phase focused on reviewing literature and designing problem prototype. The main literature was PISA Mathematics 2012 (OECD, 2013b) since its main theme was mathematics.

Formative Evaluation Phase

The formative evaluation consisted of self evaluation, expert review, one-to-one, small group, and field test. Self-evaluation was conducted after the prototype was finalised. In this process, all research team members sit together to revisit the problems and check for typing errors as well as to conjecture students' possible answers. The revision directly done to the prototype problems. The next step is validation process consisting of expert review, one-to-one and small group. Expert review and one-to-one were conducted around same time. There were two experts and five students participated in expert review and one-to-one process respectively. For one-to-one, students were asked to work on the problems and were interviewed about the readibility of the prototype problems. Reviewers were asked to fill the validation sheet after studying the problems. Revision was done based on students and experts' comments and recommendation. The next step is small group in which 30 students were administered to the problems and their answers were reviewed whether There were misunderstading about the problems. The last step in formatve evaluation phase is field test which was conducted online by administering the test using google form. 92 ninth grade students accross the province were voluntarily participated at this phase. Students' answers were then coded by three raters using 4 scales (3 = correct and complete answer; 2 = reasonable process but there is miscalculation; 1 = wrong or irrelevant reason; 0 = wrong answer/not answering). The interrater reliability using interclass correlation (ICC) coefficient (Koo & Li, 2016) were measured to assure the consistency of the raters in coding students' answers using given scales. Cronbach Alpha was also employed to provide information about the consistency within each level of developed problem.

RESULTS AND DISCUSSION

Results of Preliminary Phase

Nine items have been developed which are grouped into 5 units. Since the developed problems is PISA-adopted, the current study adopted 6 levels of mathematical literacy ability based on PISA as well. For convenience, the six levels are summarized into three levels (basic, intermediate, advance) for this study. The classification of mathematical literacy levels can be seen on Table 1.

Table 1. PISA problems modification framework

PISA Unit/Context	PISA Level	Level of Modified Problems	Unit/Context of Modified Problems
Which Car?	3	Intermediate	Buying Amplang
Which Car?	4	Intermediate	Buying Amplang
Charts	1	Basic	Souvenir Store
Charts	1	Basic	Souvenir Store
Charts	2	Basic	Souvenir Store
Climbing Mount Fuji	5	Advance	Mahakam Tourist Ship
Helen The Cyclist	3	Intermediate	Cyclist
Helen The Cyclist	6	Advance	Cyclist
Garage	6	Advance	Lamin Traditional House

The following is examples of problems representing the three levels (basic, intermediate, and advance) as well as the elaboration of the process of developing the problems, their cognitive demand as well as their relation and modification of their corresponding PISA problems.

Example of problem in basic level

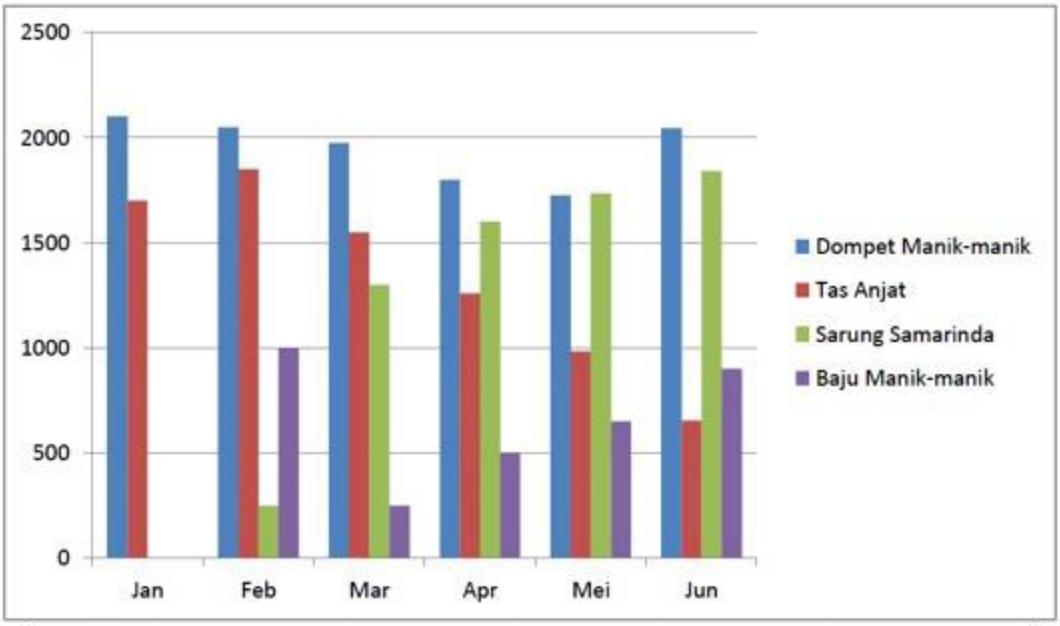
Students who are at basic levels are able to solve problems with information that are all explicitly given and to perform simple calculations or estimates involving integers (not decimals or fractions). Problem 2c is included in the basic level which is a modification of the PISA problem unit ‘Charts’ (OECD, 2013b). The unit is presented in the context of album sale for four group bands from January to June. The modification was done in the context. Instead of using unfamiliar group band name, the problem context was changed to local context, namely the sale of ethnic souvenirs of Samarinda. The problem is shown in Figure 1.

Example of problem in intermediate level

Students in intermediate level are able to solve problems that have certain limits and require assumptions. They are starting to be able to reason in a simple context. Moreover, students are also able to calculate and reason with fractions or decimals. Problem 1b is classified into the intermediate level which is a modification of the PISA problem unit ' Which Car?’(OECD, 2013b). This unit is presented in the context of cars along with their respective specifications at a car dealer. The car sales context then was changed into Amplang sales. Amplang is traditional snacks in Samarinda. In addition, while in the original PISA problem, students need to calculate the tax on the cars, now they need to calculate the discount when buying amplang. However, the concept used is similar, which is to calculate the percentage. The problem is shown in Figure 2.

Toko Cinderamata

Sebuah toko ekspor cinderamata Kaltim mengekspor dompet manik-manik dan tas anjat yang dimulai pada bulan Januari. Lalu pada bulan Februari, toko tersebut juga mulai mengekspor sarung samarinda dan baju manik-manik. Berikut ini adalah grafik batang yang menunjukan kuantitas ekspor cinderamata tersebut dari bulan Januari sampai bulan Juni.



Pemilik toko merasa khawatir karena tas anjat mengalami penurunan permintaan ekspor dari bulan Februari sampai bulan Juni. Apabila tren penurunan ekspor terus berlanjut, perkirakan berapa buah tas anjat yang diekspor pada bulan Juli? (Pilih salah satu jawaban!)

(A) 70 buah
(B) 370 buah
(C) 670 buah
(D) 1340 buah

Jelaskan mengapa memilih jawaban tersebut?

Figure 1. Example of Problem in Basic Level

1. Memilih Amplang?

Ucup hendak membeli amplang di sebuah toko di Jl. Slamet Riyadi, Samarinda.
Tabel dibawah ini secara detail menunjukan kualitas dan harga amplang dalam kemasan di toko tersebut.

Merek Amplang	A	B	C	D
Stok (bungkus)	50	70	40	100
Harga (Rupiah)	70.000,-	100.000,-	71.000,-	130.000,-
Waktu Simpan (bulan)	12	10	6	9
Komposisi Ikan	30,79%	30,796%	30,82%	30,783%

b. Berapakah potongan harga yang diperoleh Ucup untuk membeli amplang merek C jika toko tersebut memberikan diskon 2,5%? (Tuliskan langkah-langkah penyelesaiannya)

Figure 2. Example of problem in intermediate problem

Example of problem in advance level

Students in advance levels are able to solve problems in complex situations. They have good reasoning skills and are able to use and translate mathematical representations in problems in a flexible manner. Problem 5 is classified into the advance level which is a modification of the PISA problem unit 'Garage'(OECD, 2013b). The unit is presented in the context of a garage sketch. The garage context of the problem is changed into a local context, namely a sketch of Lamin House, East Kalimantan traditional house, which is shown in Figure 3.

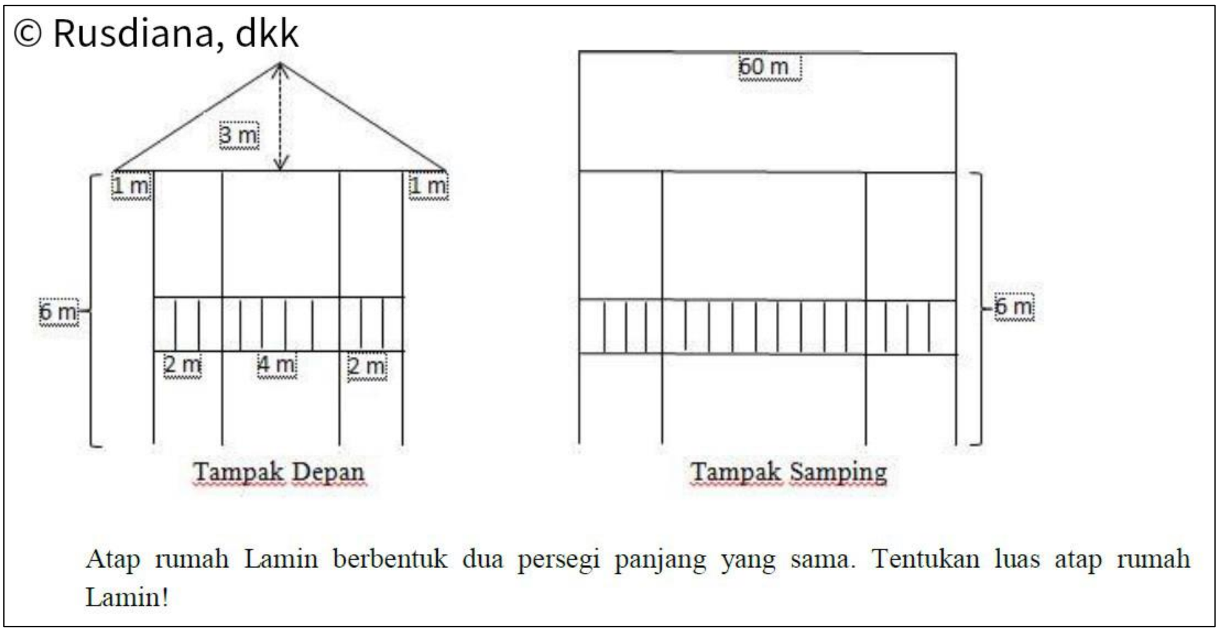


Figure 3. Example of problem in advance level

Results of Formative Evaluation

The first step of formative evaluation after the protype problems have been self-evaluated was expert review. Experts commented that in Problem 1a (Figure 2) where the students were given information about Amplang, one of which is the weights of each package should be changed to number of stok. This was due to minimalize the confusion students might have about composition that they might multiply the percentage of composition with the weight. The second comment was to add sentence which asks students to elaborate their reasoning or explanation about their answer. This was done to evaluate students' thinking process when solving the problems. The last comment from expert was to make the sketch of Lamin House in Problem 5 (Figure 3) clearer. This was in line with the interview result from students in one-to-one step where they commented that they do not really comprehend the sketch.

After being revised, the prototype problems were administered to 30 students or small group. After students' answered were coded, it was found that most students did not understand the term 'trend' in Problem 1c. The problem asked students to estimate the sale next month based on the decreasing trend of previous sales. Based on this, the term 'trend' was changed to more straightforward phrase, which is "if the sales keep decreasing,....". Feedbacks from the validation process is shown in Table 2.

Table 2. Feedbacks from the validation process

Validation process	**Feedback**
Expert-review	• Problem 1a: weight should be changed to stock • Add sentence to demand students' reason or explanation for their answer • Sketch of Lamin House need to be more clear
One-to-one	• Sketch of Lamin House is not clear
Small Group	• Students did not understand the term "trend" in Problem 1c

The final step for formative evaluation is the field test. Result from this step was used to measure the reliability of the instruments developed. Reliability here are the consistency of all raters in coding students' answers for each problem items as well as the consistency of each mathematical literacy level. The result is shown in Table 3.

Table 3. Reliability measurement

Level	**Problem**	**ICC coefficient**
Basic (Cronbach's alpha = 0.706)	2a	0.865
	2b	0.927
	2c	0.877
Intermediate (Cronbach's alpha = 0.626)	1a	0.719
	1b	0.936
	4a	0.838
Advance (Cronbach's alpha = 0.643)	3	0.924
	4b	0.921
	5	0.786

Table 3 implies that the nine items developed are reliable in way that it is consistent within level and for each items. Cronbach's alpha coefficient of the three levels are in a medium to good category. It implies that the items belong to each level are consistent measuring the same level. Meanwhile the ICC coefficient for nine items which in good to very good category implies that raters are consistent in coding students' answer.

Discussion

The results above implies the validity and reliability of problems developer to measure mathematical literacy of students with East Kalimantan context. Problem (Figure 1) requires students to estimate the sale of an ethnic souvenir in July by taking sales in previous months into account. Students do not need to perform complex calculations. They only need to consider that sales of Anjat bags in February were about 1800 pieces, about 1550 pieces in March, about 1250 pieces in April, about 1000 pieces in May, and about 700 pieces in June. By doing so, they are expected to realize that there is a decrease in bag sales about 200-300 pieces per month, hence to estimate that sales in July are approximately 370 pieces (Option C). Option D is wrong because it indicates an increase in the number of sales. Option A and B defy the downward trend of 200-300 pieces earlier (selling 70 pieces indicates a decline that is too large while 670 pieces indicates a decline in sales that is too small). This is shown in Figure 4.

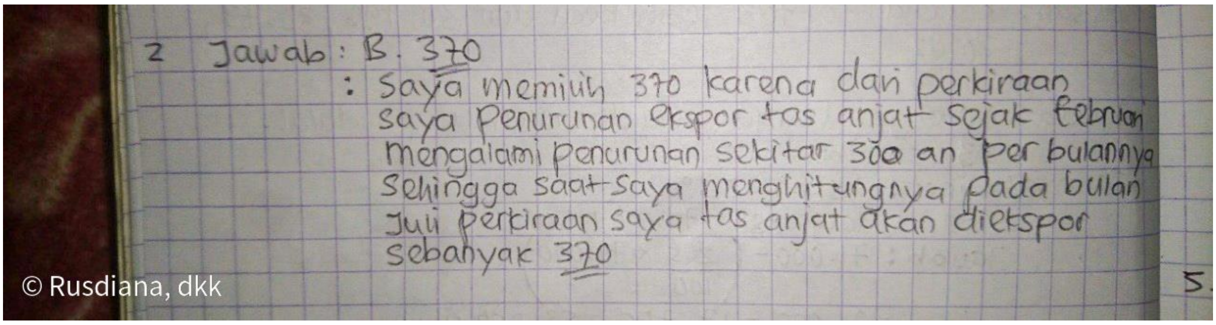

2 Jawab : B. 370
: Saya memilih 370 karena dari perkiraan saya penurunan ekspor tas anjat sejak februari mengalami penurunan sekitar 30a an per bulannya sehingga saat saya menghitungnya pada bulan Juli perkiraan saya tas anjat akan diekspor sebanyak 370

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Figure 4. Sample of students' answer of basic problem

While students are expected to do estimation process in the previous example, the problem (Figure 2) requires them to calculate the discount they will get by buying one of the amplang brands when the discount percentage is given. This problem emphasizes the Employ process more, because students do not need to spend time to understand and translate the context of the problem but directly using mathematical procedures that are explicitly stated in the problem which is calculating 2.5% of Rp 71,000,-. This problem is labelled intermediate since students need to work with decimal quantity which is more cognitively demanding than working with whole number like in basic level problem. Students' answer is shown in Figure 5.

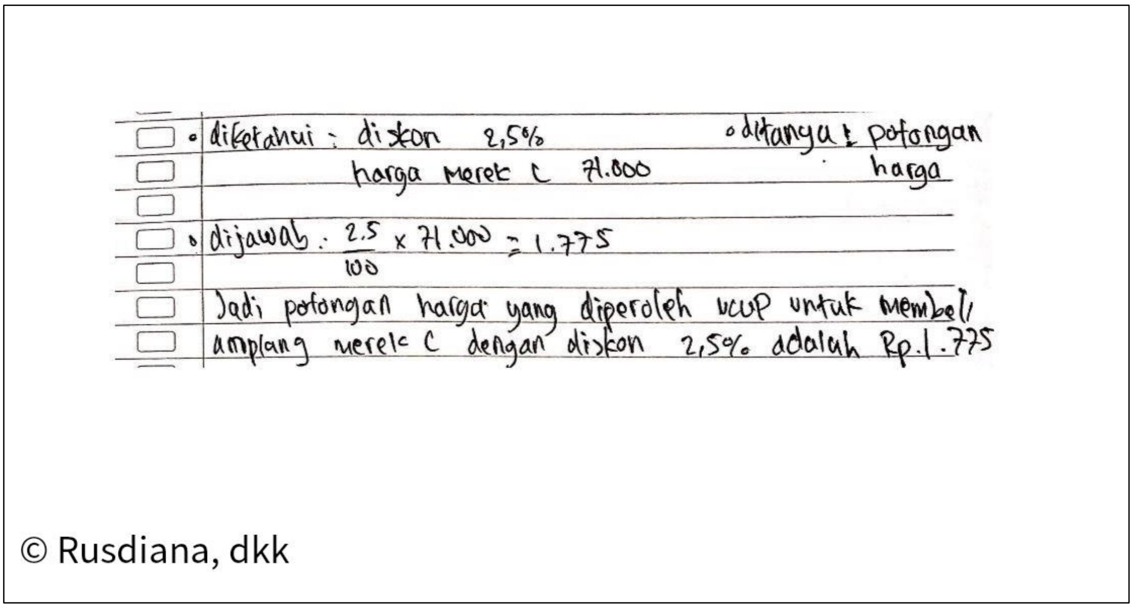
• diketahui : diskon 2,5% • ditanya : potongan harga
harga merek C 71.000
• dijawab : $\frac{2.5}{100}$ x 71.000 = 1.775
Jadi potongan harga yang diperoleh ucup untuk membeli amplang merek C dengan diskon 2,5% adalah Rp.1.775

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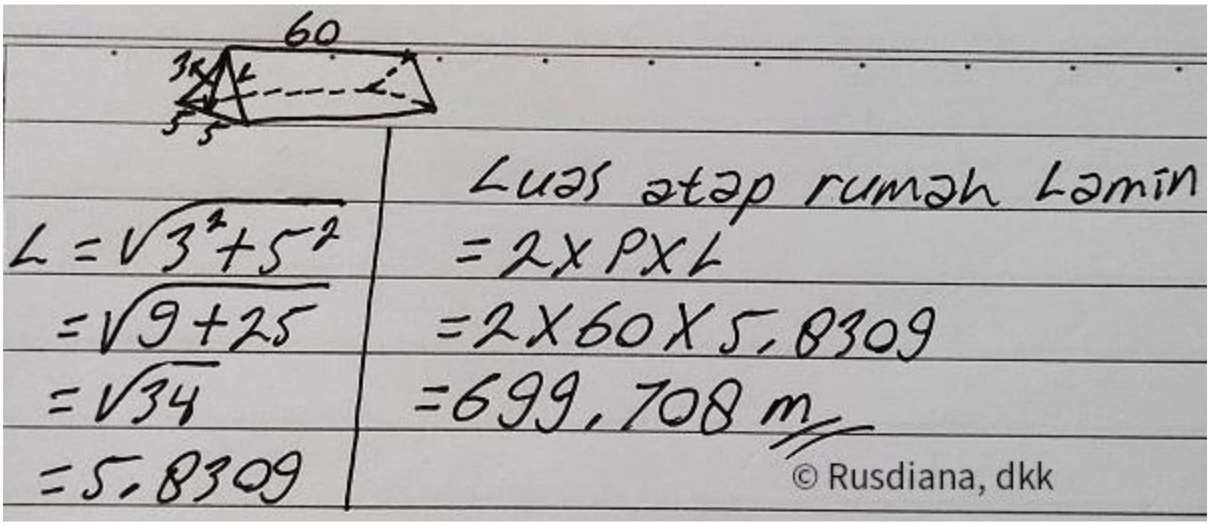
Figure 5. Sample of students' answer for intermediate problem

Problem (Figure 3) requires students to find the roof surface area of Lamin house based on the sketch provided. This problem is classified into advance level because students have to choose the right information from the problem, in this case the students observe that the roof surface area of Lamin house is twice the rectangle measuring 60 meters with a dimension that is not directly obtained from the problem. The answer will be wrong if the student multiplies 60 meters by 3 meters. Students then must employ the Pythagorean theorem to find the dimension intended, that is, the result of $\sqrt{3^2 + (2 + 2 + 1)^2}$. After that, it is multiplied by 60 meters and then multiplied by 2 to obtain the correct answer. Figure 6 is one example of students' answer for advance level problem.



. Figure 6. Sample of students' answer for advance level

Results of PISA survey became an indicator of education quality, especially mathematics, in many countries. Indonesia might be one of those countries. Large numbers of research on mathematical literacy in Indonesia laid their argument on PISA results, mostly stated that mathematical literacy of Indonesian students are far below the PISA average and always ranked within 10 bottom of countries participated (Khaesarani & Ananda, 2022; Putri Hapsari, Victor Didik Saputro, & Damas Sadewo, 2022; Susanta, Sunardi, & Susanto, 2022). This resulted to the effort to design PISA-like problems hoping to familiarize students with context-based problems.

This study is in the same corridor with previous researches that developed mathematical literacy problems (Fadlila et al., 2022; Kamaliyah et al., 2013; Marwanda et al., 2021; Sulistiani & Zulkardi, 2019; Yansen et al., 2019). However, this study have developed mathematical literacy closely based on PISA problems which had been validated with more robust method. Closely here means the content and process of the problems remain unchanged, only the context was changed into local context. This may bring a new light to the prior researches that mostly developed problems in certain domain. Furthermore the difficulty level of problems are in line with that of PISA such that the problems developed are evenly distributed by its difficulty. This is supported by the result of internal consistency of problem items that belong in the same level. Lastly, results of ICC showed the consistency of raters using the 0-3 scales for coding students' answer. This is essential since the sale used was a bit different with PISA which has 0-2 scales.

CONCLUSION

This research has developed mathematical literacy problems with East Kalimantan context. The validity is seen from results of expert review, one-to-one, and small group. Hence, it cam be employed to measure students'mathematical literacy. However, this study has not addressed the implementation of the developer problems to measure mathematical literacy of students in a wider area. This cam be recommendation for the next research .

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