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SAILING CONTEXT IN PISA-LIKE MATHEMATICS PROBLEMS

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Abstract

Developing PISA like mathematics problems using daily life context helps to improve the quality of learning. This study aimed to generate a valid, practical, and having potential effects on mathematics literacy ability PISA like mathematics problems with the context of sailing in the 2018 Asian Games. This research involved three expert reviews and 32 fifteen-years-old tenth-grade students of SMA N 10 Palembang, a public senior high school in Palembang Indonesia, as the research subjects. This study used the design research method of development studies type. The data were collected through documentation, walkthrough, tests, and interviews. The problem developed in this study is related to the length of wood required to span the sail. The results show that the problems are valid. The validity was viewed from its compatibility with the PISA framework, in which it had related the problems with daily life context of sailing in the 2018 Asian Games and space and shape content. The problems are also practical, viewed from students' understanding of the problem. And, the problems have potential effects when tested in learning issue of mathematical literacy ability. The dominant ability is reasoning and representation ability, while the communication ability is still low because the students do not give detailed answers.

Keywords: Design Research, Mathematics Literacy, PISA, Sailing Context

Abstrak

Mengembangkan soal matematika tipe PISA menggunakan konteks yang berhubungan dengan kehidupan sehari-hari dapat membantu meningkatkan kualitas pembelajaran. Penelitian ini bertujuan untuk menghasilkan soal matematika tipe PISA dengan konteks cabang olahraga layar pada Asian Games 2018 yang valid, praktis dan memiliki efek potensial terhadap kemampuan literasi matematika. Penelitian ini melibatkan 3 *expert review* dan 32 siswa yang berusia 15 tahun kelas X SMA N 10 Palembang sebagai subjek penelitian. Metode penelitian yang digunakan adalah *design research* tipe *development study*. Teknik pengumpulan data terdiri dari dokumentasi, *walkthrough*, tes dan wawancara. Soal yang dikembangkan berhubungan dengan panjang kayu yang dibutuhkan untuk membentangkan layar. Hasil penelitian menyatakan bahwa soal yang dikembangkan telah (1) valid dilihat dari kesesuaiannya dengan *framework* PISA yaitu telah menghubungkan permasalahan dengan kehidupan sehari-hari dengan menggunakan konteks cabang olahraga layar pada Asian Games 2018 dan konten *space and shape*, (2) praktis dilihat dari pemahaman siswa terhadap soal yang dikembangkan, (3) memiliki efek potensial ketika diujicobakan dalam pembelajaran memunculkan kemampuan literasi matematis. Kemampuan dominan yang muncul dari soal yang dikembangkan adalah kemampuan penalaran dan representasi sedangkan kemampuan komunikasi masih rendah disebabkan oleh jawaban yang dituliskan siswa tidak dituliskan secara rinci.

Kata kunci: Desain Research, Literasi Matematika, PISA, Konteks Layar

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Programme for International Student Assessment (PISA) is an international study which is conducted every three years to measure literacy ability of 15 years old students (OECD, 2016). Since 2000, Indonesian students have participated in the PISA test, but they did not get good results. The score obtained by Indonesian students, especially in mathematical literacy is only around 350 - 400, which is still far from 500 as the average international PISA score. It occurs because Indonesian students are only able to answer the problems in the low category, and almost no student can answer the problems that need high levels of thinking (Stacey, 2011; Stacey, 2012). Therefore, the unavailability of problems that measure mathematical literacy ability causes the students not be able to answer the PISA problems (Lutfianto, *et al*. 2013, Pulungan, 2014).

Mathematical literacy is needed by everyone in facing the problems in life because it is mostly used to help people to understand the role and usefulness of mathematics in daily life (Stacey, 2012). Furthermore, literacy ability also presents concepts that can add the mindset of students and teachers (Sturgeon, 2018). The mindset is trained through the process of literacy, especially mathematical literacy by formulating, applying, and interpreting the problems. The mindset is also consistent with the definition of mathematical literacy that "*Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts* ....". Based on this definition, literacy also uses context in its problems. The context used is adapted to the development of the 21st century (OECD, 2015).

Moreover, the NCTM (2014) states that using the context of the real world is expected to be a stepping stone in understanding the concept of mathematics. However, the context used in the PISA problem is still strange to the students because it is still related to the foreign context (Sasongko, 2016). Also, students are also difficult in turning problems into mathematical problems (Wijaya, *et al.* 2014). Contextual learning provides a mindset to the students that mathematics is not only about counting, but what is learned in mathematics can also be useful in life (Widiati, 2015).

The use of context is one of the characteristics of the *Pendekatan Matematika Realistik Indonesia* (PMRI) adopted from the Realistic Mathematics Education (RME) which emphasizes the meaningfulness of mathematical concepts in the form of problem (Prahmana, *et al*. 2012; Zulkardi, 2002; Prahmana & Suwasti, 2014). Context can be applied in the form of a problem that is seen as an important aspect of mathematics learning (Chapman, 2006; Prahmana, *et al*. 2012). The problems can be in the form of the development of a PISA like problem designed by the teacher so that it can be applied in classroom learning (Zulkardi, 2010). Based on the study from Putri (2015), giving problem in the form of test with PMRI approach can make students happy and challenged to answer them so that an optimal learning result of mathematics can be achieved. Clair (2018) and Putri (2015) suggest that the context applied in classroom learning should use the context which is close to the student. Therefore, one of the contexts that can be used is the context of sailing in the 2018 Asian Games.

The 2018 Asian Games is a sports competition held every four years which aims to enhance and strengthen the friendship between Asian countries. The Asian Games is also referred to as the energy of Asia because it shows the spirit of unity and sports achievement in Asia. Jakarta and Palembang will be the host of the 2018 Asian Games. One of the sports is sailing. Sailing is a part of the aquatic sports that contribute a lot of medals so that it becomes a mainstay sports at the 2018 Asian Games (INASGOC, 2018). By using sports as a context of the developed problem will make students prefer mathematics and also remember the event of Asian Games 2018. Many studies developed the design of learning mathematics using sports context in the 2018 Asian Games, using this context can help students understand mathematics (Gunawan, *et al*. 2017; Fajriyah, *et al*. 2017; Rahayu, *et al*. 2017; Roni, *et al*.

2017; Efriani, *et al*. 2018; Nizar, *et al*. 2018). Therefore, this article will discuss the developed problem using the context of sailing in the 2018 Asian Games.

METHOD

This study was design research of development study. The stages conducted in this study were preliminary and prototyping (formative evaluation) which included self-evaluation, expert reviews, one to one, small group, and field test (Tessemer, 1993; Zulkardi, 2002).

In the preliminary stage, the writers determined the subject and the place of the study and analyzed the subject matter, including the curriculum as well as the PISA problems that would be developed to produce the draft. The next stage was the formative evaluation started from the self-evaluation. A draft that had been developed to produce Prototype I was reviewed; then, piloted at the expert reviews and one to one stages.

In the expert review stage, Prototype 1 was validated by experts. The validation process was conducted in three ways, namely face to face review, mails review, and focus group (Tessemer, 1993). Along with the expert review, one to one stage was done with three students having various capabilities. Students were asked to read, examine, and give feedback about the legibility and clarity of the problem. Suggestions and comments from experts and students were taken into consideration to revise Prototype 1 to produce Prototype 2. Then, Prototype 2 was tested in the small group stage.

In the small-group stage, the problem was tested to six students having various abilities. They were asked for their opinions and comments about the problem they had been working. This stage focused on knowing the practicality of the problem. Students' suggestions and comments in the small group stage were taken into consideration to revise the Prototype 2 to produce Prototype 3. Next, Prototype 3 was tested in the field test stage.

In the field test stage, the problem was tested to 32 tenth grade students of class X MIA 1 of SMA N 10 Palembang to see its potential effects on the mathematical literacy ability. The data collection techniques used in this study was: (1) documentation, (2) walkthrough, (3) test, and (4) interview. The data from the expert review, one to one comments, student answers and interviews were analyzed descriptively.

RESULTS AND DISCUSSION

The results of this research are 12 questions of PISA like mathematics problems with the context of sport in Asian Games. This article only discusses one of developed PISA like problems with the context of sailing. In the preliminary stage, the writers determined the 15-year-old students of SMA N 10 Palembang as the research subjects and the content material about space and shape for the problem. The content was based on the 2013 curriculum, and it can be related to the context of sailing in Asian Games. Then, the PISA problems from 2000 to 2012 were collected. The problem was made concerning the existing PISA problems and the developed one.

The reference problem used in this study is the 2012 PISA problem with the context of a sailing ship. The problem asked to determine the length of the rope required when the angle and height of the sail are known. Then, the writers paraphrased the problem by changing this adopted problem from the Bairac method (2005) into determining the height of the wood required to tie the sail in the sailing ship. The purpose of this problem is to make students understand that to span the sail to catch the wind. The sail must be attached to the wooden pole; therefore, they will know how long the wood is needed to tie the sail.

The next stage is the preliminary stage that began with the self-evaluation stage. At this stage, the writers evaluated and examined the draft of the PISA-like problem. The developed problem was related to the context of sailing as a sport. The type of problem was a closed-constructed response. It was predicted to be in Level 4 because it corresponded to the characteristics of the PISA problem shown by making the model implicit in concrete but complex situations, selecting and combining different representations including symbolizing and relating to real situations, as well as using good skill development and presenting flexible reason and perspective according to the context. At this stage, the problem was by the PISA framework, so there was no revision. The problem at this stage was called Prototype 1.

The Prototype 1 validation process was done via mail review. Experts who acted as the validators were (1) Ross Turner (E1), the director of the Australian Council for Educational Research (ACER) and a MEG PISA staff, (2) Kaye Stacey (E2), the Chairman of MEG PISA from University of Melbourne, Australia and (3) Ahmad Fauzan (E3), a lecturer in mathematics at the State University of Padang. Along with the expert review stage, one to one stage was done with students who had various abilities (high (O1), medium (O2), and low (O3)). The comments and suggestions from the experts and the students in Prototype 1 are presented in Table 1.

Table 1. Comments and Suggestions from Experts and Students

Code	Comments and Suggestions
E1	- Describe the situation clearly, maintain the prerequisites for students to interpret and transform information into a mathematical form - Use rubric from PISA assessment by using a range of answers - Add the abilities of mathematizing, using language, formal and technical operational and symbolic language, as well as problem-solving.
E2	- Reasoning and argumentation abilities in the problem are good, in which it has been analyzed carefully - Less information about the length of the base of the ship to the base of the sail
E3	- Revise the spacing in the problems - The problems may raise students' different perceptions related to the sail size
O2	- The student had correctly put the information about the picture, but he was still confused with the phrase “the length side cloth under the pole.” - Students predict the length of the pole from the base only based on the image without thinking about the wood that is plugged in because the information about the problem is not given

These comments were taken into consideration to revise prototype 1. Based on the validation process at the expert review and one to one stages, the problem was maintained with some revisions, namely (1) adding information "to span the sail, a wood is put in the ship pole" which is useful for guidelines for determining the answer, (2) replacing the question “the height of the wood” into “the length of wood needed to span the sail”. This question gave a benefit for students so that they did not only calculate the length of the wood, but they also knew that the sail could not be unfolded if it did not have the crossing wood, (3) changing the scoring rubric based on the PISA assessment rubric by adding a range of answers. Based on experts' suggestion which says that many students would use the right method but would not get the right results indicated the need of the range for various answers, and (4) revising the mathematical literacy ability indicators based on the steps of work. The result of this revision was called Prototype 2.

Furthermore, the problem in Prototype 2 was tested in a small group stage on November 7, 2017. First, students were given the problem to be solved individually. During this process, the students with high, medium, and low abilities had understood the purpose of the problem by trying to find the solution by writing down what was known from the problem. Some students got the answer by using only one step, while others used some steps to get the answers. Next, the students formed small groups to discuss the problem. In the small groups, they determined the solutions based on the answers they got individually. The students got the same answers in various ways. Because the problem can be answered by all students without any obstacles, the writers consulted it with the advisor. The advisor suggested that the information of the problem be changed. The previous problem asked the student to answer the length of the wood needed to span the sail if the height of the wood and the area of sail were known. Meanwhile, the revised problem asked students to answer the length of the wood needed to span the sail if the three sides of the sail were known, as shown in Figure 1.

PERAHU LAYAR

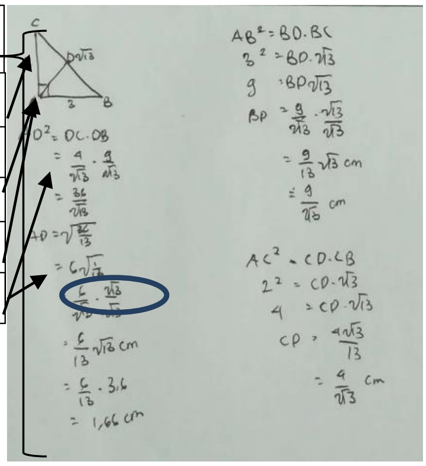
Gambar 1. Perahu Layar
(Sumber : http://www.google.com)

Perahu layar adalah alat transportasi tradisional yang menggunakan layar sebagai penangkap angin untuk berlayar. Perahu di atas dipasang sebuah layar berbentuk segitiga. Sisi layar berturut-turut adalah 2m, 3m dan $\sqrt{13}$m. Untuk membentangkan layar, dipasanglah sebuah kayu pada tiang perahu. Tentukanlah panjang kayu yang dibutuhkan untuk membentangkan layar tersebut !

Figure 1. Prototype 3.

The next stage was the field test held on November 9, 2017. After the students finished with the problem, the writers interviewed them to explore the potential effects of the problem. One of the students' answers is correct, as shown in Figure 2.

Write the process to get solution.
Connection and using various
Using strategic.
Using formal form based on
Connection the information which
Only write the solution.



P: Why did you use this formula?
S: Because, to find the length of this wood I must know the length both of this (student pointed the picture).
P: Where did you get this formula?
S: From the course.
P: Do you know the origin of this formula?
S: I don't know.

Figure 2. Correct student's answer.

From the answers shown in Figure 2, the student wrote the problem into a mathematical statement by imagining the representation from the information given. Using the figure she had made, she symbolized the figure herself to make it easier to find the solutions. As shown in Figure 2, she gave symbols A, B, C, and D. Then, she chose a strategy by relating to the various equations that had been made. Finally, she got the last equation of $AD^2 = DC.DB$, in which the symbol AD was the length of the wood needed to span the sail asked in the problem. Although the students' answer was correct, the writers also interviewed her related to how she got the answer using the formula.

Based on the above interview, the student said she found the solutions using the formula which she got from her course outside the school. However, she did not know the origin of the formula that she used. The literacy ability involved by the student was that she could write the process of achieving the solution completely. She used the image representation by making the figure by herself to make it easier for her to find the solution. Next, she related the previous information about the length of the three sides of the sail consecutively, which is 2, 3, and $\sqrt{13}$ by writing them on the figure she made before. Then, she used the strategy based on the definition and the existing rule of the equation $AD^2 = DC.DB$ to find the solution. However, before getting the length of AD, she found the length of DC and DB from the information that she got before. Once the solution was obtained, she should have been able to conclude the solution, but she only wrote down the solution without any conclusion. The answer was correct with different algorithms, as shown in Figure 3.

Figure 3 shows that the student responded by using the area of the right triangle. The image representation form was divided into two triangles; then, he used the equation of the area of triangle 1 equals the area of triangle 2. However, the writers investigated the reason why the student used the area of right-triangle to find the answer.

Furthermore, Figure 3 also shows the interview results that the student knew that the triangle was a right triangle so that it could be calculated by using the area of a triangle. The triangle was viewed from two different corners so that by using the comparison between the two triangular areas, he got the length of wood needed to span the sail.

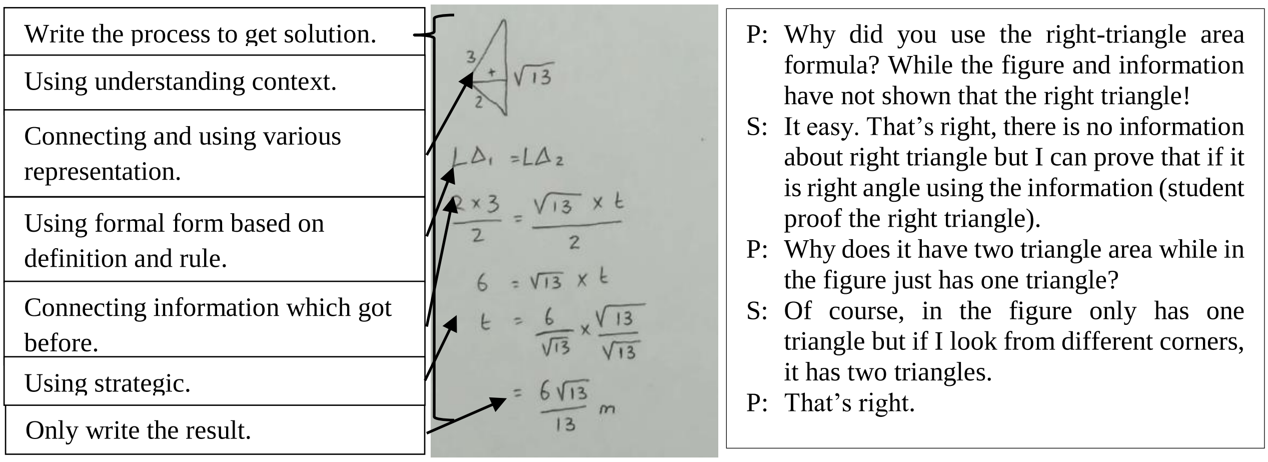


Figure 3. Correct student's answer with different algorithm.

From the mathematical literacy ability involved, students could write down the process of getting a complete solution by relating the previous information about the side of the sail which was 2, 3, and √13 and use various representations namely the image representation by making the figure of the sail and symbol representation by using triangle symbol. Furthermore, he used a strategy based on the existing definitions and rules stated that calculating the area of a triangle can be done with two different corners, but the reason was only found out from the interview. Then, the student got the answer of $\frac{6\sqrt{13}}{13}$. Student only wrote the result without any explanation. This strategy is in line with Hasratuddin's opinion (2010) that students solve a problem only by finding solutions, then operating it, but they do not provide any explanation of the solution. The process often occurs because the learning of mathematics pays less attention to students' mathematical communication ability (Saragih & Rahmiyana, 2013). The student had the potential to explain the reasons why he used the right triangle formula. Moreover, his incorrect answer is shown in Figure 4.

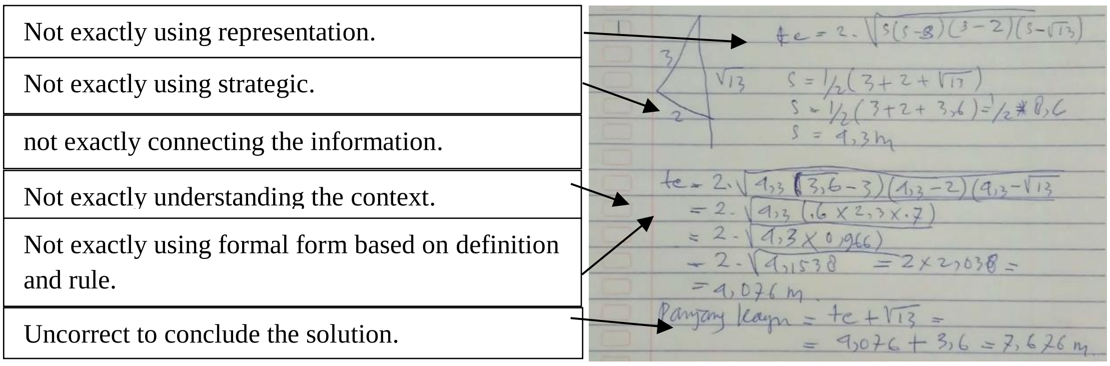


Figure 4. Incorrect student's answer.

From the answer shown in Figure 4, the student used the area of a triangle when the three sides were known. However, this answer did not match with what the question wanted since it asked for the length of wood needed to span the sail, while the student determined the area of the sail. Therefore, his answer did not get any score (no credit). From the answer that he made, the writers interviewed him to find out the reasons why he determined the length of wood needed by using the area formula. The interview between the student and the writers is shown as follows.

P: What is the problem that is asked?
S: The length of wood.
P: Why did you use the area of triangle formula?
S: Because based on the formula area of the triangle, if it is known three sides of the sail, it can use this formula.
P: Is it the length of wood same with the area of the triangle?
S: It's different.
S: Why do you still use this formula.
P: Because I just know the formula of the area if three sides of the sail are known.

Based on the interview above, the student understood what was known in the problem by translating the problem into the mathematical statement using the image representation. However, he was wrong in the use of the information provided. He used the formula of triangle area to calculate the length of the sail due to the lack of prerequisite knowledge about the use of the area formula. From the mathematical literacy ability involved, he had tried to write the process of getting the solution, but the representation of the contextual understanding was not related to the desired question. The strategy used was also not appropriate for the problem which asked to determine the length of wood needed to span the sail instead of determining the area of the triangle. Therefore, he could not relate the information and conclude the solution. The mistake happened when he decided on the strategy to determine the solution. The ability to settle the implementation plan is the core of the problem-solving stage (Hapizah, 2016). Therefore, if the student could not determine the right strategy in planning the settlement, it would cause an error in solving the problem. The field test results showed that out of 32 students, only ten students obtained full credit, 13 students obtained partial credit, and nine students obtained no credit. Furthermore, we could also capture the mathematical literacy ability involving the 32 students.

Communication ability with the indicator to write the process in achieving the solution showed ten students writing it completely and correctly, and five students writing it incorrectly. Whereas, the indicator concludes the mathematical result obtained that none of the students concluded correctly and completely, and nine students did not conclude. The mistake happened because the students did not read the data from the information in the problem carefully, so they were wrong in transforming the information into the calculation. The students placed the order of the sail side size in reverse. Also, the students did not use to writing down the stages, along with the explanations about the process of finding the solutions because they only focused on getting the answer.

The mathematical ability with the indicators of using context comprehension to solve mathematical problems showed ten students could use the understanding of the process to problem-solving appropriately, and nine students could not. This ability is a basic ability that students must have because they must be able to understand the context first before trying to find a solution to get the right solution. This phenomenon is in line with the opinion of Sudarman (2010), who states that students can be said to understand the problem if they can disclose data that are known and asked from the problem given.

Representation ability with the indicator to use and connect various representations in problem-solving showed ten students could use the representation completely and correctly, and five students did not use it correctly. The students' mistake occurred when they represented the figure and wrote the information on the figure. They made a mistake in putting the existing information, which later caused a mistake in the calculation process.

The reasoning and argument ability with the indicator of relating the previously available information to find the solution showed ten students could use reasoning correctly, and nine students did not use reasoning in finding the solution. To get the right solutions, students must be good at relating the previously available information. This phenomenon happened because the problems with the sail context was a high-level problem which needed more reasoning (Sulastri, *et al*. 2014). Also, with good reasoning, students can also solve problems well (Hapizah, 2014).

The ability to choose strategies to solve problems with the indicator of using strategies through various procedures that lead to solutions and conclusions showed nine students could choose the strategy appropriately and nine students did not choose the strategy in problem-solving. There were many strategies to be used for this problem; however, it would only depend on the skills of students to anticipate the relationship. Also, before students determine the suitable strategy, they must first understand the question of the problem, which is the length of the wood needed to span the sail in which the wood is located between the wooden buffers of the sail.

The ability to use language as well as symbolic, formal and technical operations with the indicator of using formal form based on the definition and mathematical rules showed that eight students could use it completely and nine students did not use it correctly.

Based on the above description, the dominant ability arose from the developed problem was the reasoning and representation ability because the students already understood the meaning of the problem well so that students could connect the information of the problem by making the figure repeatedly (Hendroanto, *et al*. 2018; Sukirwan, *et al*. 2018). However, the communication ability was still low because the students only focused on finding the answers, so they were not accustomed to writing answers in detail. Students had potential in developing mathematical literacy ability. However, this ability was not fully appointed but only as a compliment. This ability was needed to train students in solving problems properly (Ahamad, *et al*. 2018). It is also expressed by Sapitri & Hartono (2015) that every student has the potential for the ability of mathematical literacy. However, the students' ability in understanding mathematics is different from one another, so the teacher must train students to optimize their ability. Therefore, mathematical literacy ability of students can be extracted by giving the routine problem for them and asking them to solve it by writing down solutions in detail.

CONCLUSION

The problem was declared to be valid, practical, and had a potential effect on mathematical literacy ability based on the problem development process that had been generated. Valid was assessed from the validator results at the expert review and one to one stage, which stated that the problem was good in terms of content, constructs, and language. Valid was viewed from its compatibility with the PISA framework that had related it to daily life using the context of sailing in the 2018 Asian Games and the content of space and shape. The problem was also considered practical from the small group stage. Practicality was viewed from the students' understanding of the problem. The problem with the context of sailing in the 2018 Asian Games could help students understand the mathematics problems in daily-life contexts. From the problem, students knew that the length of the wood which was used in the sail had the size which could be counted in mathematics. Also, the problem had a potential effect when piloted in the learning of mathematical literacy ability. The dominant ability was reasoning and representation ability because they could understand it well so that they could connect its information by making a figure repeatedly. Whereas, the communication ability was still low because the students only focused on finding the final answer so that they were not accustomed to writing the answers in detail. Therefore, it is suggested to develop a PISA mathematics problem with sailing context on other content and can also use the equipment and rules in the sport. Also, PISA like mathematics problems that have been developed can be given to students regularly to train their mathematical literacy ability.

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