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DEVELOPING PISA-LIKE MATHEMATICS PROBLEM USING THE 2018 ASIAN GAMES FOOTBALL AND TABLE TENNIS CONTEXT

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Abstract

The objective of this study was to produce valid and practical PISA-like mathematics problems on the content of uncertainty and data using football and table tennis contexts in the 2018 Asian Games. This study also aimed to find out the potential effect of the problems on the tenth-grade students' mathematical literacy capability of the senior high school. This study was a design research with the type of development studies consisting of two stages, the preliminary and the formative evaluation. We obtained the data using walk-through, document, observation, interview, and test methods. We assessed the validity of the problems by using the validator assessment results towards the content, constructs, and language of the problems and also from the comments/suggestions of the students in one-to-one phase on the clarity/readability of the problems. The indicator of the problems' practicality was reflected when the students were able to understand the problems well and it was shown in the small group phase. The answers of 33 students involved in the field test showed that the problems had the potential effect, showing the capability of communication and representation. On the problem with football context, six students answered with communication capability and three students with representation capability. On the problem with table tennis context, twenty students answered with communication capability, while five students with representation capability.

Keywords: Design research, PISA-like, 2018 Asian Games, Football, Table tennis.

Abstrak

Penelitian ini bertujuan untuk menghasilkan soal matematika serupa PISA dengan konten *uncertainty and data* menggunakan konteks sepak bola dan tenis meja di Asian Games 2018 yang valid dan praktis. Selain itu, penelitian ini juga bertujuan untuk mengetahui efek potensial soal terhadap kemampuan literasi matematika siswa kelas X SMA. Metodologi yang digunakan dalam penelitian ini adalah *design research* dengan tipe *development studies* dengan dua tahap, *preliminary* dan *formative evaluation*. Teknik pengumpulan data yang digunakan adalah *walk-through*, dokumen, observasi, wawancara, dan tes. Kevalidan soal ditunjukkan dari hasil penilaian validator terhadap soal dari segi konten, konstruk, dan bahasa serta dari komentar/saran siswa di tahap *one-to-one* terhadap kejelasan/keterbacaan soal. Kemudian, kepraktisan soal ditunjukkan pada tahap *small group*, yaitu siswa sudah dapat memahami soal dengan baik. Dari jawaban siswa pada tahap *field test* yang melibatkan 33 siswa, soal memiliki efek potensial yaitu memunculkan kemampuan komunikasi dan representasi. Pada soal dengan konteks sepak bola, enam siswa menjawab dengan kemampuan komunikasi, tiga siswa dengan kemampuan representasi. Pada soal dengan konteks tenis meja, dua puluh siswa menjawab dengan kemampuan komunikasi, sedangkan lima siswa dengan kemampuan representasi.

Kata Kunci: *Design research*, PISA, Asian Games 2018, Sepak bola, Tenis meja.

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Programme for International Student Assessment (PISA) is an international study held every three years to measure the skills and capabilities of students aged 15 years (OECD, 2016a). Mathematical literacy is one of the skills and capabilities assessed in PISA (OECD, 2016a). Indonesia has participated in the PISA program since 2003. However, the results of mathematical literacy are always in a lower rank. In the last two periods, Indonesia was ranked 64 out of 65 participating countries in 2012 (OECD, 2014a), and was then ranked 62 out of 70 participating countries in 2015 (OECD, 2016b).

The low achievement of Indonesian students in PISA mathematical literacy could be caused by various factors. One of the reasons was that the students were not used to solving the PISA problems and were only used to solving the routine ones. As the result, many students made some mistakes when working on PISA problems. This condition is in line with the views of Wijaya *et al.* (2014) that Indonesian students had difficulty in solving PISA-like mathematics problems using context and in transforming them into mathematics problems.

Uncertainty and data contents are important in PISA mathematical literacy because they are the heart of mathematical analysis of many problem situations, and also the theory of probability and statistics as a technique of data representation and description (OECD, 2016b). Students could analyze mathematical problems through understanding the uncertainty and data contents. But in fact, the results of PISA in 2012 showed that Indonesia was ranked 63 out of 65 countries in uncertainty and data contents (OECD, 2014b). Moreover, based on the results of PISA in 2012 on the uncertainty and data content, Indonesian students were only able to solve problems to level 2 out of 6 levels in PISA (Zuhra, 2015). It showed that Indonesian students were still weak in working on PISA problems.

Context is a situation or phenomenon associated with the concept of mathematics, which the students learn (Zulkardi & Putri, 2006; Prahmana, Zulkardi, & Hartono, 2012; Zulkardi & Kohar, 2018). The mathematics learning uses context to build concepts, to give the motivation to learn mathematics, to build models, to provide tools for thinking using procedures, notations, drawings and rules, and to practice specific abilities in specific situations (Shahrill, Putri, Zulkardi, & Prahmana, 2018). In line with the use of context, the Indonesian experts have developed an Indonesian version of Realistic Mathematics Education (RME) which is called Pendidikan Matematika Realistik Indonesia (PMRI). It is an innovative learning adapted from the RME using Indonesian context (Putri, 2011). One of the PMRI characteristics is using a contextual problem. It is important since it could motivate students in learning mathematics (Widjaja, 2013).

The 2018 Asian Games was held in Jakarta and Palembang Indonesia. The Asian Games is a sporting event held every four years by countries in Asia (Wulandari & Atmojo, 2014). According to Wijaya (2008), games have an entertainment aspect that can motivate students in learning such that there is an increase in students' understanding of the concept contained in the game. The sports games at the 2018 Asian Games are familiar sports in the student and community environment because they often play or watch them, like football and table tennis. Therefore, the football and table tennis can be categorized as the real contexts for Indonesian students. In addition, the various studies have used the context of sports games at the 2018 Asian Games to design mathematics learning. Nasution *et al.* (2017) used the rowing context to design mathematics problems, while Roni *et al.* (2017) used sprint context, Putri & Zulkardi (2017) used shot-put context, Gunawan *et al.* (2017) used swimming context, and Rahayu *et al.* (2017) used hurdles context. All the studies show that the mathematics learning within the context of the sports games could help students in understanding mathematics concepts.

Many studies have developed PISA-like mathematics problems with various focus. Oktiningrum *et al.* (2016) developed the PISA-like problems with the context of Indonesian natural and cultural heritage context to measure the students' mathematical literacy. Novita *et al.* (2012) explored the problem-solving capability of students by working on the PISA-like problems. Kamaliyah *et al.* (2013) developed the level 6 problem of PISA. Mardhiyanti *et al.* (2013) developed the PISA problem to measure the students' mathematical communication capability. Silva *et al.* (2013) developed a PISA-like problem on uncertainty content to measure the students' mathematical problem-solving capability. The studies show that the interest to develop PISA-like mathematics problems is high as it highly needed in mathematics learning. Moreover, Zulkardi (2010) suggested to design PISA-like mathematics problems and used it in learning mathematics in the classroom.

Based on the description above, the objectives of this study were to produce valid and practical PISA-like mathematics problems on uncertainty and data content with football and table tennis context and to find out the potential effect of the problems to mathematical literacy capability of the tenth-grade students of the senior high school.

METHOD

The method used in this study is design research with the type of development studies. This study consisted of two stages: preliminary and formative evaluation stages including self-evaluation, expert reviews and one-to-one, small group, and field test (Tessmer, 1993; Zulkardi, 2006). Furthermore, there was also a discussion panel (item paneling) in the expert review phase (Turner, 2000). The subjects of the study were tenth-grade students from senior high school aged 15 years old. The data were collected using walk-through, documentation, observation, interview, and test.

We determined the place and subject of the study, contacted the school, and analyzed the 2013 curriculum in the preliminary stage and designed the problems instrument. We carried out the self-evaluation first in the formative evaluation phase. We evaluated and reviewed the initial prototype in the self-evaluation phase and then analyzed to form Prototype 1.

In the expert review phase, the Prototype 1 was evaluated, reviewed, and rated by the experts to validate it. The expert validation used analysis regarding the content, construct, and language. The Prototype 1 was validated by the expert reviews and was done by sending an e-mail to Ross Turner, Kaye Stacey, and Hongky Julie. The results of expert reviews were used to make product revisions. We conducted a panel discussion (item paneling) in the expert review phase. According to Turner (2000), item paneling (panel discussion) is one of the important step numbers in the development of high-quality test items. The panel discussion was conducted with lecturers and students of mathematics education of Sriwijaya University.

Along with expert reviews, researchers tested students individually (one-to-one). On one-to-one, Prototype 1 was tested towards three students with different abilities, one high ability student, one medium ability student, and one low ability student. The focus of one-to-one was to see the

clarity/readability of the problems. The results were used to revise the product. Prototype 2 was obtained from the phase of expert reviews and one-to-one.

Prototype 2 was tested in a small group phase consisting of six students with different ability, two students with high ability, two students with medium ability, and two students with low ability. Small group phase was used to determine the practicality of the problems that had been developed. The result of the revision of the small group phase was called Prototype 3 and tested in the field test phase.

A field test was conducted in a senior high school. In the field test phase, Prototype 3 was tested in a class consisting of 33 students. Field test phase aimed to determine the potential effects of problems that were developed to mathematical literacy capability of students. To know the capability of mathematical literacy emerged, students' answers were analyzed based on the process of the problem (whether it was a formulation, employing, or interpretation) and then see the indicators and descriptors of the capability of mathematical literacy based on the 2015 PISA framework emerged.

RESULTS AND DISCUSSION

This study had produced ten PISA-like mathematics problems on uncertainty and data contents consisting of 13 questions with the context of sports games at the 2018 Asian Games, namely bridge, martial art, paragliding, football, and table tennis. The thirteen questions consisted of one question for level 1, two questions for level 2, five questions for level 3, two questions for level 4, two questions for level 5, and one question for level 6. But only two units of problems with the context of football and table tennis discussed in this article. The two units are Unit 1 (Men's Football Match) and Unit 2 (The Arrangement of Table Tennis Players). The two units enable many different strategies applied to answer them.

Preliminary Stage

At this stage, we determined senior high school as the location of study and the tenth-grade students aged 15 years old as the subject of study. We contacted the school authorities and mathematics teachers to ask for procedures and research schedule and analyzed the existing PISA mathematics problems, as well as the 2015 PISA framework. Furthermore, we designed the problems based on the existing PISA problems. We designed the problem instrument with football and table tennis contexts in the 2018 Asian Games consisting of problem grids, problem cards, and scoring rubrics. The result of the preliminary stage was the initial prototype. The problems produced on the initial prototype were two units consisting of four questions. The followings were the explanation of two units of the problems at the preliminary stage.

In Unit 1, we developed the PISA-like problem adapting the PISA 2006 problem "Choices". The Choices problem asks many combinations of extra topping pizza. The PISA-like problem in Unit 1 is "Men's Football Match" with the context of football. The problem asks the number of matches in a men's football match until the winner found. To solve the problem, the concept of sample space was used and a matching scheme was created. The sample space is one part of the uncertainty and data contents. The context used in the problem is social, the process used is employing, and the level prediction is level 4.

In Unit 2, we also developed a PISA-like problem from the PISA 2006 problem "Choices" which asked many combinations of extra topping pizza. The PISA-like problem in Unit 2 is "The Arrangement of Table Tennis Players" with the context of table tennis. The Unit 2 problem consisted of three questions. Question 1 asked the number of women's doubles players. To solve the problem, the concept of sample space was used. Question 2 asked the probability of the selection of Ficky Supit and Deepash Anik B in the arrangement of men's doubles player. Question 3 asked the probability of the selection of Habibie Wahid and Indriyani Lilis in the arrangement mixed doubles players. The sample space and probability are parts of the uncertainty and data contents. In Unit 2, the context used is occupational, the process used is employing, and the level prediction is level 3.

Formative Evaluation

The formative evaluation consists of self-evaluation, expert review and one-to-one, small group, and field test.

Self-Evaluation

In this stage, we evaluated and examined the initial prototype that had been made in the preliminary stage based on the characteristics that became the focus of the prototype regarding content, construct, and language. Three characteristics were validated by researchers, peers, and supervisors. The result, Prototype 1, obtained in this stage would be tested at Expert Review and one-to-one phase.

Expert Reviews and One-to-One

In the expert review phase, three validators assessed the problems regarding the content, construct, and language, they are (1) Ross Turner (ACER Australia), (2) Kaye Stacey (University of Melbourne, Australia), and (3) Hongki Julie (Sanata Darma University). In the expert review phase, the researchers also conducted a panel discussion (item paneling). The panel discussion was conducted with nine master students of mathematics education of Sriwijaya, three students of Sriwijaya University mathematics, and three lecturers of mathematics education of Sriwijaya University.

Along with the expert reviews phase, the problems were tested in one-to-one phase. In this phase, we tested the PISA-like mathematics problems developed in Prototype 1 towards three tenth-grade students from the senior high school with different abilities. The three students were FA, AL, and AR. They were asked to work on the problem and then each student asked for opinions, comments, and suggestions on these problems. This aimed to allow researchers to observe the responses and constraints of students when working on the problems and focus on the readability and clarity of the problems. The comments/suggestions from experts and students as well as the revision in Unit 1 and 2 are presented in Table 1 and Table 2.

Table 1. Comments/Suggestions from Experts and Students on Unit 1 Problem

Validation	Comments/Suggestions	Revision
Ross Turner	1. The problem was given an explanation, what was desired on the question; 2. Adding possible ways of answering by other students on the rubric.	1. Repetitive "game" words were made only once; 2. Change the word "then" to "will"; 3. Change the sentence to the question "Give your explanation!" to "Write down the reasons that support your answer"
Hongki Julie	1. The problem was acceptable;	
Panel Discussion	1. The words "then" should be changed to "will";	
Students	1. Students could understand the purpose of the problem and could read table division of men's football group clearly; 2. The "match" words were twice, should be written just once	

Table 2. Comments/Suggestions from Experts and Students on Unit 2 Problem

Validation	Comments / Suggestions	Revision
Ross Turner	1. Answering question 6.1 could use other means example by the formula; 2. Questions 6.2 and 6.3 were not a probability because the team structure had been determined based on the sports factor of table tennis;	1. Question 6.1 was not revised; 2. Questions 6.2 and 6.3 were not used in the next phase because they were not probabilities; 3. The words "coach trained" changed into "formed by coach".
Hongki Julie	1. The problem was acceptable;	
Panel Discussion	1. The words "coach form" changed into "formed by coach";	
Students	1. Students could understand the meaning of the problem and could read the table "the name of the men's table tennis athletes" and "the name of the women's table tennis athletes" clearly.	

Based on suggestions/comments from expert review and one-to-one, the problems on Prototype 1 were then revised again and become validated as Prototype 2. The validity of problems was shown by the validator's assessment of the content, construct, and language as well as the comments/suggestions on the one-to-one phase towards the clarity/readability of the problems. Prototype 2 was tested in the small group phase.

Small Group

In this phase, the problems were tested towards six students with different capabilities. The six students were TM, MF, MRF, AN, AM, and MHD. Based on the small group phase, it could be concluded that the six students already understood the problems, questions, and instructions contained in the problems. Most students had no difficulty in answering the question and able to answer the problems correctly, but there were still students who had not provided a reason with complete evidence.

At the small group phase in Unit 2 problem, it was found that one of the contents of the table was not used in answering the problem, that was the contents of the table "Men's Table Tennis Athlete" so that the problem was revised by eliminating it. Based on the small group phase, the problem was revised and we got a valid and practical Prototype 3. Practicality was seen from the ease of students in understanding the problems. Prototype 3 was then tested in the field test phase. We present the Prototype 3 Unit 1 and Unit 2 in Figure 1 and Figure 2.

Men's Football Match

Source: //img.antaranews.com

In the men's football match in Asian Games 2014 in Incheon, South Korea, there were 29 football teams that follow the match. The twenty-nine teams were grouped into 8 groups just like the table below.

Grup A	Grup B	Grup C	Grup D
Korea Selatan Malaysia Arab Saudi Laos	Uzbekistan Hong Kong Bangladesh Afganistan	Oman Palestina Singapura Tajikistan	Jepang Kuwait Irak Nepal
Grup E	**Grup F**	**Grup G**	**Grup H**
Thailand Maladewa Timor Leste Indonesia	Korea Utara Republik Rakyat Tiongkok Pakistan	Uni Emirat Arab India Yordania	Iran Vietnam Kirgizstan

(Source: https://id.wikipedia.org/wiki/Sepak_bola_pada_Asian_Games_2014)

In the group stage using a half-competition system (each team played one match againts the others). Two teams which had the highest rank in each group then qualified to the next round by using knockout system (if lost directly fall) until the winner was found. How many matches were in the men's football? Write down the reason that support your answer.

Figure 1. Prototype 3 of Problem Unit 1

The Arrangement of Table Tennis Players

Source: www.google.com

Table tennis is one of the sports in Asian Games 2018. Indonesian table tennis coach will make the arrangement of table tennis players. Here are the list of Indonesian table tennis athletes:

Female Table Tennis Athlete
Hani Tri Azhari
Novita Oktariyani
Indriyani Lilis
Gustin Dwijatlyanti

Question 1

How many arrangement of women's double table tennis players can be formed by coach? Write down the reason that support your answer.

Figure 2. Prototype 3 of Problem Unit 2

Field Test

In this phase, Prototype 3 was tested on the tenth-grade students of senior high school consisting of 33 students. In this phase, all students worked on Prototype 3. The focus of this phase was to determine the potential effects of the problems developed on the students' mathematical literacy capability. Based on the students' work on the field test phase, the results obtained are presented in Figure 3.

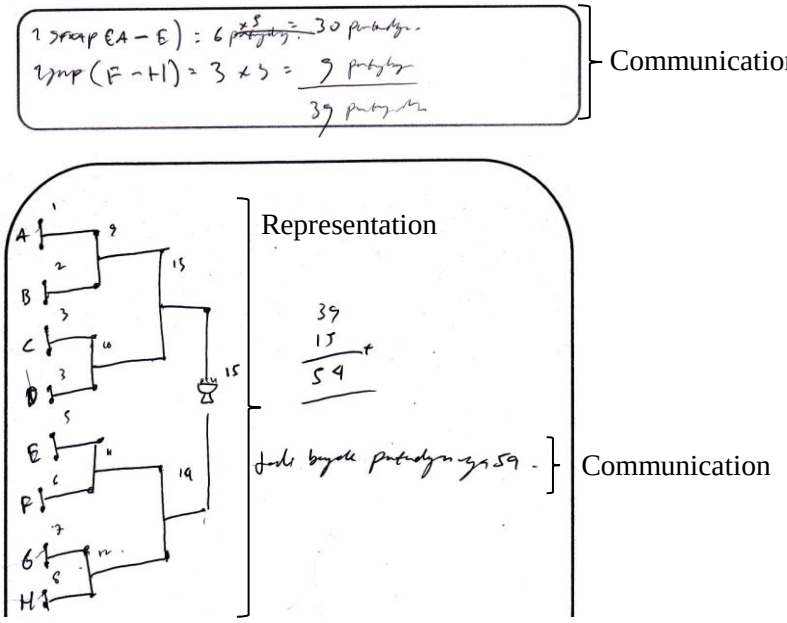

Figure 3. Students' answer to Unit 1 using Strategy 1.

Figure 3 is a students' strategy to answer the Unit 1 problem. Based on the students' answer, it could be seen that the emerging capability was the capability of communication because they could write the process in solving the problem by using the calculation in the group stage to get the first champion. It showed the indicator of communication capability namely writing down the process of achieving solutions. They could write the

process in reaching the solution. They concluded that the number of men's football matches was 54 matches. It showed the indicator of communication capability namely concluding the mathematical results.

From the students' answer, it could be seen that the capability emerged was representation capability because students used the matching scheme in determining the number of matches after the group stage in 2018 Asian Games to get the first champion. This showed the indicator of representation capability by using various representations in problem solving.

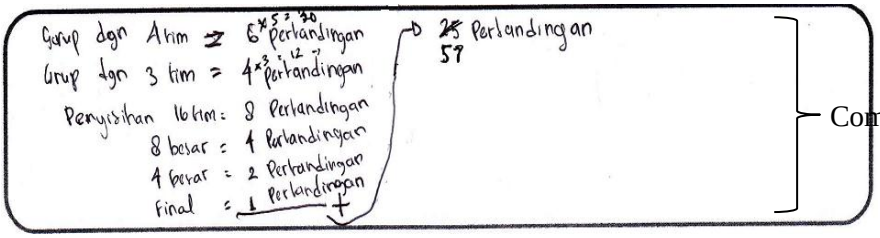

Figure 4. Students' answer to Unit 1 using Strategy 2.

Figure 4 is another student's answer strategy. From the student's answer, it could be seen that the emerging capability was communication capability because they could read and write data from the number of teams in the table of men football group division at 2018 Asian Games and then counted the number of matches but there was still an error in counting the number of matches on each team consisting of 3 teams. It showed an indicator of communication capability namely writing down the process of reaching the solution. They could write down the process of reaching the solution. Moreover, they had already concluded that the number of matches was 57 matches, but the results still had errors. It showed an indicator of communication capability which is concluding mathematical results.

From the students' answers, 6 out of 33 students could write the process of reaching the solution and concluded the mathematical results. This showed that students were able to apply communication capability. From the students' answers, 3 out of 33 students could use various representations in solving the problem. This showed that they were able to apply representation capability.

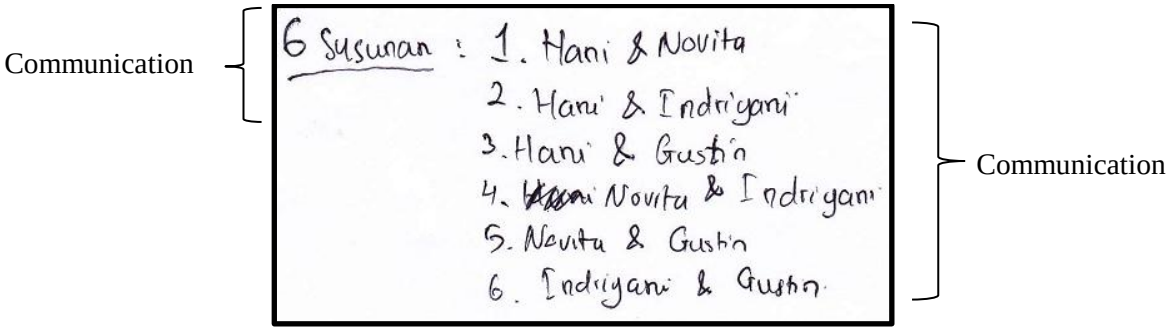

Figure 5. Students' answer to Unit 2 using Strategy 1.

Figure 5 presents one of the students' strategies to answer the problems in Unit 2. From the students' answer, it could be seen that the capability emerged was the communication capability because the students could read the table and write women's doubles table tennis consisting of 4 athletes. This phenomenon showed the indicator of communication capability namely writing down the process of reaching the solution. Moreover,

they had concluded the number of arrangements of women's doubles table tennis player was "6 arrangement" so it showed the indicator of communication capability namely concluding mathematical results.

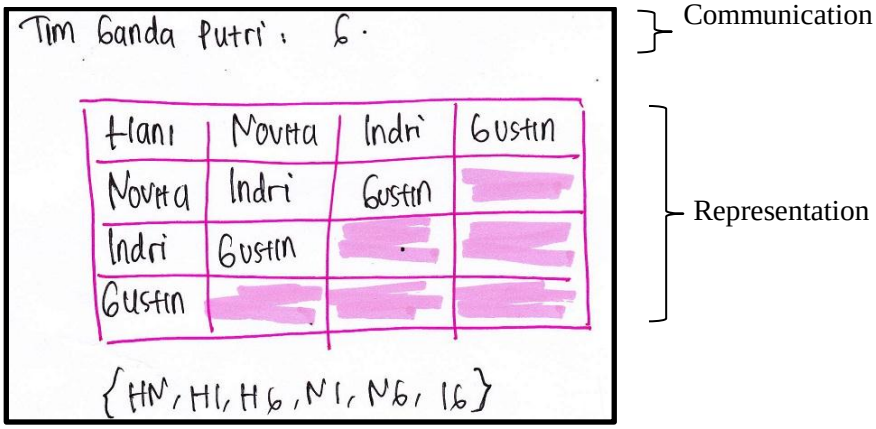

Figure 6. Students' answer to Unit 2 using Strategy 2.

Figure 6 presents the other student's strategy that we found during the field test. From the students' answer, it could be seen that the capability emerged was representation capability because students used the table in determining the number of arrangements of women's doubles table tennis players. This phenomenon showed the indicator of representation capability using various representations in problem-solving. They concluded the number of women's doubles table tennis arrangement was 6. Thus, it showed the indicator of communication capability namely concluding mathematics results.

From the student's answers, there were 20 out of 33 students could write the process of reaching the solution and could conclude the mathematics result. This phenomenon showed that the students were able to apply communication capability. From the students' answers, there were 5 out of 33 students could use various representations in solving the problem. This phenomenon showed that the students were able to apply representation capability.

CONCLUSION

This study has produced 2 PISA-like mathematics problems on uncertainty and data contents consisting of 2 questions, Unit 1 level 4 with football context and Unit 2 level 3 with table tennis context at the 2018 Asian Games. The validity of problems was shown by the validators' assessment of the content, constructs, and language and also from students' comments/suggestions of one-to-one phase to the clarity/readability of the problems. The practicality of the problems was shown in the small group phase that the students had been able to understand the problems well. The problems developed also had a potential effect on the students' mathematical literacy capability. The aspects of mathematical literacy capability emerged were communication and representation. Communication capability was shown by the ability of students writing the process of achieving solutions and concluding mathematics results. Furthermore, the representation capability was shown by the ability of students using various representations in problem-solving. Based on the study results and discussion, it is recommended for teachers and students to use PISA-

like mathematics problems with the context of football and table tennis to familiarize them with PISA-like mathematics problems and train their mathematical literacy capability.

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