Designing PISA-like mathematics problem relating change and relationship using physical distancing context

D S Nusantara, Z Zulkardi* and R I I Putri
Department of Mathematics Education, Universitas Sriwijaya, Indonesia

*Corresponding author's e-mail: zulkardi@unsri.ac.id

Abstract. This research was driven by students' difficulties in solving PISA-like mathematics problems on change and relationship content. The students were not familiar with solving contextual-based problems like PISA, and teachers tended to provide routine problems at low levels. For these reasons, this research aimed to produce a PISA-like mathematics problem that was declared valid, practical, and had potential effects on students' mathematical proficiency. Design research used as the main framework of research with the type of development studies that had two phases: the preliminary and formative evaluation. Data were collected by conducting a walkthrough, test, interview, and document review. The developed PISACmat was valid from its compatibility with the PISA framework, which related to daily life problems in determining the length of the queue at the shopping center by using physical distancing context on change and relationship content. Practicality was seen from the developed PISACmat can be easily understood by students and well solved even with different strategies. Also, the developed PISACmat had potential effects based on students' answers at the field test phase, such as understanding the problem, in reality, transforming the real-situation into a mathematical problem, solving a mathematical problem, and interpreting mathematical solution.

1. Introduction
Change and relationship are one of the contents of the Program for International Student Assessment (PISA) that very essential for students to be mastered as it is closely related to daily life which is central in describing, modeling, interpreting the growth of change phenomena [1][2][3]. However, this importance of the content does not in line with the fact that Indonesian students were lack coping with contextual-based problems like PISA [4][5][6]. Specifically, a shocking result released by PISA at the end of 2018 shows that the trend of Indonesian students' proficiency on change and relationship content was significantly below the OECD average with a score of 379 out of 489 [7][8]. With such low scores, the underlying factors were indicated students were not familiar to solve contextual-based problems like PISA [4], teachers only provided exercises on routine issues at low levels [9][10], lack of teachers' ability in designing PISA-like [11], and limitation of learning resources provided by textbook [12].

The poor performance of Indonesian students in recent decades has gained much attention from educators and policymakers to reform the 2013 curriculum. A bold move was taken by the Indonesian Minister of Education and Culture (MOEC) by issuing four educational policy programs in an attempt to reform and improve the quality of education in Indonesia, commonly known freedom of learning or Merdeka Belajar [13]. The boldest one is starting from 2021, scrap the national examination and replace it with the minimum competency assessment (MCA) and survey of character, which will be valid for
students in the middle level [14]. MCA covers three aspects: literacy, numeracy, and character education, which similar to good educational practices at the international level such as PISA [15]. Numeracy is known mathematics literacy in PISA, which is described as a fundamental proficiency in mathematics that provides students to experience mathematical processes (formulate, employ and interpret) in a variety of situations in real-life problems [16][17].

Besides, the plausible effort that can be made by developing a problem that has the characteristic of PISA by incorporating the local context, so Indonesian students are familiar with the problems like PISA task [18]. The provision of context in mathematics learning has been successful in the Netherlands and adopted by Indonesia, known as PMRI [19][20]. The mathematical concepts become more meaningful for students because an abstract mathematical concept can be transformed into the form of easily-understood representation through didactical phenomena [21][22]. The phenomenon of the COVID-19 outbreak, also known as an ongoing of the global pandemic, is an excellent example of context which can be implemented in mathematics learning [23]. In line with it, the Indonesian MOEC instructed the direct learning amid the COVID-19 pandemic should focus on education in life skills to face of COVID-19 outbreak [24]. Students must abide by the health protocol, such as physical distancing in this current situation. Furthermore, physical distancing is one of the interesting contexts that can be used and related to change and related content which is a representation of the growth of change.

Several previous studies have been conducted and shown good results by producing the development of PISA-like mathematics problems using local [25], national [26], and international [27] contexts that attract students to learn and enhance mathematical literacy skills [28][29]. However, there have not been any PISA-like mathematics problems using the didactic phenomenon of the COVID-19 pandemic (PISAComat), which is a physical distancing context. In this study, researchers are interested in developing a mathematics problem with the characteristic of PISA using physical distancing context on change and relationship content, which aimed to produce valid, practical, and had a potential effect on students' mathematical proficiency.

2. Method
Design research was used as the main framework with the type of development studies that involved students of secondary school in Palembang. This framework of the research consisted of preliminary and prototyping/formative evaluation [30][31][32]. The development process was supported by the online learning system. Several activities were undertaken at the preliminary phases, such as analyzing the 2013 curriculum and evaluating PISA items from 2000 to 2018 as a reference to produce the research instruments, i.e., the draft of PISAComat equipped with lattices, question card, scoring guideline. Then, researchers examined the initial students' mathematical proficiency to determine the research subject.

The development process through prototyping/formative evaluation phases ranging from self-evaluation to field test. Several research instruments were examined and evaluated based on the PISA 2018 framework. After that, it piloted to experts and one to one at once. The initial prototype was given to experts commonly in two methods: mail review was implemented by proposing the initial prototype to the lecturers who were competent in designing PISA-like and panel review was done online through zoom meeting to the mathematics teachers. Along with it, one to one performed by involving three students with various capabilities to evaluate the clarity and legibility of PISAComat regarding language, image display, and the process of students' thinking. A valid prototype resulted from the comments and constructive suggestions given by experts and one to one after revision. To see the practicality of PISAComat, the valid prototype was given to six students with various capabilities. This phase reflected the PISAComat was categorized valid and practical. Then, the field test phase was conducted by involving 32 students in online learning through the WhatsApp group to explore the potential effect on students' mathematical proficiency. The techniques for collecting data were a walkthrough, test, interview, and document review, which were analyzed descriptively to describe the result of each phase of the development.
3. Result and discussion

The researchers, along with mathematics teachers examined the initial students' mathematical proficiency by categorizing the mathematical processes when answering the mathematics problem. There were three students in one to one, six students in a small group, and 32 students as the subject of the field test. The change and relationship content were taught at the eighth grade students with the subject of number pattern in the 2013 Curriculum. The PISAComat which was designed adapted from the PISA item 2009 included in the content of change and relationship with the context of apples. Students tend to ask to look for the general Formula from the situation given and the length of the queue at the shopping center. PISAComat was categorized difficulty level of 3,4 in PISA. The developed PISAComat was equipped with the lattices, question card, and score guidelines which were evaluated and examined by researchers. The result in this phase called the prototype I and piloted to the prototyping/formative evaluation phase. A draft PISAComat before revision (see figure 1).

![Figure 1. A draft PISAComat before revision.](image)

1. Based on the information from the news above, write down the formula for the \( n \)th term.
2. If there is a row of 6 people queuing at the shopping center, then determine the length of the queue?

In parallel, expert reviews and one to one were conducted to see the validity of the developed PISAComat. The prototype I (as in figure 1) was validated by experts regarding content, construct, and language through mail review, and panel review, as well as one to one phase, was conducted involved three students with heterogeneous capabilities through zoom meeting. In this phase, the researchers observed and identified how each student solved the developed PISAComat. The following table 1 is presented comments and suggestions from expert review and students.

From the comments and suggestions of the experts (as in table 1), the developed PISAComat was adapted from the PISA item 2009, and the chosen context is one of the health protocols known as physical distancing following the current situation of the COVID-19 Pandemic. The developed PISAComat, according to the domain of content in PISA (change and relationship) which correlates with basic competence in curriculum 2013 on number pattern material in the 8th grade. The developed PISAComat followed the difficulty level of 3,4 in PISA and eighth graders' abilities. The chosen context is categorized camouflage which seems artificial and non-realistic. Then, experts suggested avoiding some repetition of ideas or sentences, avoiding to introduce word problems that are too general, and convert it into the table. The PISAComat was categorized as a word problem containing irrelevant information to find the solution. To resolve it, the problem was changed into the form of a table. Besides, students have difficulty in determining the Formula from the given situation in number 1. Then, question number 2 was exchanged with question number 1 to lead the students' process of thinking in finding the solutions as expected by researchers. These comments and suggestions were taken into consideration to
revise the prototype I dubbed the prototype II. The PISAComat was declared to be valid, reflected in the comments and suggestions from experts, and students' understanding when solving the problems [31].

**Table 1.** Comments and suggestions from experts and students on PISAComat.

| Validators                  | Comments/Suggestions                                                                 | Revision                                                                                   |
|----------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Experts (lectures and teachers) | The selected context is attractive and authentic according to the current situation, but the language construction indicated the context chosen as camouflage context | Changing the camouflage context into real context by selecting the picture directed to an image-rich context (the length of the queue at the shopping center) |
|                            | The sentence makes the problems as a word problem, convert it into the form of the table | Providing the table                                                                        |
|                            | The selected picture does not match with the headline of the news                     | Changing the picture                                                                        |
| One to One (Students)      | I do not understand this problem                                                       | Exchanging unit number 1 and 2                                                              |
|                            | I do not get the important information from the news                                    | Changing the picture and providing the table                                                 |

The small group phase was performed by involving six students who work it individually. The problem can be easily understood by students and well solved even with different strategies. Students can understand the problem by completing a table given based on a physical distancing situation. Furthermore, the revised result produced prototype III that has been practical. From the small group result, it can be seen the practicality of the prototype where the problem is given can be understood easily and interpreted well by the students [31]. The developed PISAComat after revision (see figure 2).

![Figure 2. The PISAComat after revision.](image)

1. Given the situation above, which shows the number pattern of customers are waiting in line (queue), complete the following table.

| Number of customers (n) per person | Length of queue (s) per meter |
|-----------------------------------|------------------------------|
| 2                                 | 1,5                          |
| 3                                 | 3                            |
| 4                                 | ...                          |
| 5                                 | ...                          |
| 6                                 | ...                          |

2. Determine the general formula between n and s, expressing your answer in terms of n.

At the field test phase, prototype III (as in figure 2) was tested by involving 32 students to see potential effects on students' mathematical proficiency. The students' answers indicated that almost all of the students were understanding the problem well. However, some students were still
misunderstanding in transforming the situation into a mathematical problem. It reflected from several students who made mistakes in completing the table and interpreted the issue into the form of a formula based on the physical distancing situation. A total of 27 students can understand the problem well and transform it into a table, but five students were misunderstanding in solving the problem. The focus of students' mathematical proficiency measured by seeing students' answers through the stages of mathematization in PISA includes: understanding the problem in reality, transforming the real-situation into a mathematical problem, and solving mathematical problems. The students' answers on PISAComat unit number 1 can be seen in figure 3.

Figure 3 shows the different students' strategies used in answering unit number 1. BS strategy shows the formulation used to calculate the length of the queue at the shopping center: for each n, only subtract 1 person and multiplied by 1.5 to find the length of the queue. Another strategy provided by BS: for each row, add 1.5 of the length of the string in the previous row. IR's strategy represents the most used strategy for students by determining the length of the queue by summing 1.5 continuously for each additional person. Unlike with the ND strategy, a misunderstanding can be done by students in calculating the length of the queue by multiplying directly 1.5 for each n person. It also expressed by [3][4][6] that students with the high ability categorized were able to find the right pattern while students with the low ability categorized were having difficulties in finding the right pattern and explaining it through the mathematical model.

Based on the result analysis of the students' answer unit number 2, most of the students interpreted the mathematical solution by specifying the general Formula that fits the given situation. There were 19 of 32 students who determined the general Formula correctly, but some answers were not supported by the explanations. Some other students' answers were also supported by the validation of the answers. However, 13 students who were not proper in solving the given problem included: error in determining the mathematical Formula and unfinished answer. The following various formulas used by students relating to the given situation can be seen in figure 4.
Figure 4 represents the finding Formula by students with various capabilities. The BS strategy used the concept of an arithmetic sequence to find a formula that is associated with a given situation. The mathematical Formula used by IR is the representation of the most used formulation given by the students by using the concept of direct proportion to represent the situation. Most of the students used this Formula because this material (direct proportion) has recently been studied in grade 7th. However, some students could not find the proper Formula and could not validate their answers. In line with ND's strategy by using the concept of linear equation, but in this case, ND tends to use the Formula without analyzing and validating the answer to the given situation as stated in the research results [22][27] that students tend to use prior knowledge and integrate it to solve the problem. Furthermore, the same results are also shown [28][29], which stated students focus on obtaining a solution without considering the explanation and proof (validation) of the process of finding the answer.

4. Conclusion
The PISAComat on changes and relationship content using the physical distancing context generated through the development process was declared valid, practical, and has potential effects on students' mathematical proficiency. Valid was seen regarding content, construct, and language include: PISAComat adapted to PISA item 2009, which correlates with basic competence in curriculum 2013 on number pattern material in the 8th grade, the chosen context is one of the health protocols known as physical distancing following the current situation of the COVID-19 Pandemic, the difficulty level of 3, 4 in PISA and the eighth-graders' abilities, and the PISAComat avoid some irrelevant information (word problem) that is altered by providing the table. The practicality of PISAComat was viewed from a small group phase, which is the problem that can be easily understood by students and well solved even with different strategies such as students complete a table has given based on physical distancing situation and students determine the general Formula with various mathematical concepts. Besides, the developed PISAComat had potential effects based on students' answers at the field test phase: understanding the problem, in reality, transforming the real-situation into the mathematical problem, solving a mathematical problem, and interpreting mathematical solution.

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