The impactful developed PISA-type problems for students' mathematical literacy through the context of Siger tower

Sri Retnawati[1], Rully Charitas Indra Prahmana[1*], Mónica Arnal-Palacián[2]

[1] Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] University of Zaragoza, Zaragoza, Spain
*Email: rully.indra@mpmat.uad.ac.id

Abstract

Indonesia's mathematical literacy levels remain low, as evidenced by its poor performance in PISA rankings over the past decade. One contributing factor is the students' unfamiliarity with PISA-type problems, which emphasize content, context, and process skills. The Siger Tower, an iconic landmark in Lampung, offers a multifaceted context encompassing tourism, arts, culture, religion, and education. This study aims to develop valid, practical, and potentially impactful PISA-type mathematics problems using the Siger Tower as context to enhance mathematical literacy. The research employs a design research methodology with two phases: preliminary design and formative evaluation. The formative evaluation phase includes self-evaluation, expert review, one-to-one testing, small group testing, and field testing. Data analysis is conducted using descriptive methods. The study produced ten PISA-type mathematical problems contextualized with the Siger Tower. These problems were validated in terms of content, construct, and language by expert reviewers and through one-to-one testing. Practicality was assessed during small group testing, and potential impacts on mathematical literacy were evaluated during field testing. The findings indicate that the developed problems effectively engage various basic mathematical skills, thereby promoting mathematical literacy.

Keywords: design research, mathematical literacy, PISA-type mathematical problems, Siger towers

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INTRODUCTION

In the 21st century, students must possess several critical abilities, including mathematical literacy (Nur, 2020; Widyastuti & Wijaya, 2020; Haara et al., 2017). Mathematical literacy is defined as the capacity to formulate, apply, and represent mathematics in various contexts, as well as the ability to reason and use mathematical concepts (Rizki & Priatna, 2019). This aligns with the definition provided by the Organization for Economic Cooperation and Development (OECD), which describes mathematical literacy as the ability of individuals to formulate, apply, and explain mathematics in diverse contexts, encompassing reasoning and the use of mathematical concepts to describe, explain, or predict events (OECD, 2013). Consequently, mathematical literacy can be understood as students' capacity to interpret and apply mathematical reasoning and concepts to solve problems and predict outcomes in different contexts. The measurement of students' mathematical literacy, as reflected in the PISA survey results over the past decade, is summarized in Table 1 (OECD, 2013; 2016; 2019; 2023).

Table 1 indicates that students in Indonesia require further improvement in their mathematical literacy skills. Indonesia's low ranking is attributed to several factors, including the limited number of PISA task in Indonesian, the tendency to find mathematical concepts and formulas, and the difficulty of students in solving mathematical problems requiring higher-order thinking skills. This is because Indonesian students are accustomed to solving problems at a lower level of thinking, limited to knowledge and application (Zulkardi et al., 2020). Furthermore, students are not accustomed to solving contextual problems (Aini et al., 2018). Additionally, students are less accustomed to solving problems related to mathematical literacy skills (Stacey, 2011; Charmila et al., 2016).

Table 1. Indonesian students' PISA results in the last 10 years

Year	Rating	Score
2012	64 from 64	375
2015	63 from 70	388
2018	73 from 79	379
2022	70 from 81	366

Kohar et al. (2014) stated that one effective approach to enhance students' mathematical literacy abilities is to facilitate their familiarity with problem-solving techniques that foster mathematical literacy skills. This can be achieved through the implementation of projects and practice problems. The OECD (2013) emphasizes the significance of contextualizing mathematics to enhance mathematical literacy. The context used in projects or math problems also influences the improvement of students' mathematical literacy skills (Charmila et al., 2016). Contextualizing mathematics in students' daily lives makes it easier for them to grasp its relevance and utility (Kadir & Masi, 2013; Risdiyanti & Prahmana, 2018). The use of local contexts can assist students in comprehending the phenomenon of their own experiences, enabling them to establish meaningful connections between abstract ideas and practical applications in real contexts (Nizar et al., 2018; Putri, & Zulkardi, 2020).

The development of PISA-type mathematics problems used in mathematics learning has been documented in a number of studies, including those conducted in the context of nature and culture (Oktiningrum et al., 2016), the context of soccer and table tennis (Nizar et al., 2018), the context of basketball, soft tennis, and volleyball (Jannah et al., 2019), and others. Contextualized studies have been conducted in the context of the global pandemic (Zulkardi, 2020), the context of Lampung (Putra et al., 2016), the context of Jambi (Charmila et al., 2016), the context of Bangka (Dasaprawira et al., 2019), and in the context of the pandemic period (Sistyawati et al., 2023; Wulandari & Haqiqi, 2022; Prastyo, 2020; Putra & Vebrian, 2019). The results of several studies demonstrate that incorporating context into PISA-style math problems enhances students' familiarity with mathematical literacy tasks

The Sigar Tower, inaugurated in 2008, has become a prominent tourism attraction in Lampung province. Its strategic location at the zero-kilometer point of Sumatra, precisely on the hill west of the Bakauheni port, has contributed to its popularity. For those who use the sea route and can see the Siger Tower, it serves as a clear indicator that they are at the gateway to the southern island of Sumatra (Chindodayoza, 2019). The Siger Tower incorporates elements that can be associated with the context of mathematics learning, including geometry, numbers, and data (Hidayat et al., 2017). The Siger Tower can be utilized as an introductory tool for fundamental concepts in mathematics, including number, folding symmetry, two-dimensional shapes, and three-dimensional shapes (Merliza, 2022). The Siger Tower is also a source of pride for the Lampung people, who are closely associated with students. Therefore, the Siger Tower in Lampung can be leveraged as a context for developing PISA-type math problems.

This study aims to develop PISA-type math problems using the context of the Siger Tower to potentially foster mathematical literacy skills. The Siger Tower serves as a starting point for creating task. The contribution of this research is to provide examples of problems that can be used by students to develop or foster mathematical literacy skills. This research is expected to be a reference in developing PISA-type math problems with the same approach and topic.

METHOD

The research method used in this study is a research design type development study. This research was conducted in two stages, namely the preliminary research (preparation and design stage) and the prototyping stage (formative evaluation) which consists of self-evaluation, expert reviews, one to one, small group, and field test (Tessmer, 1994; Zulkardi & Putri, 2006), illustrated in Figure 1.

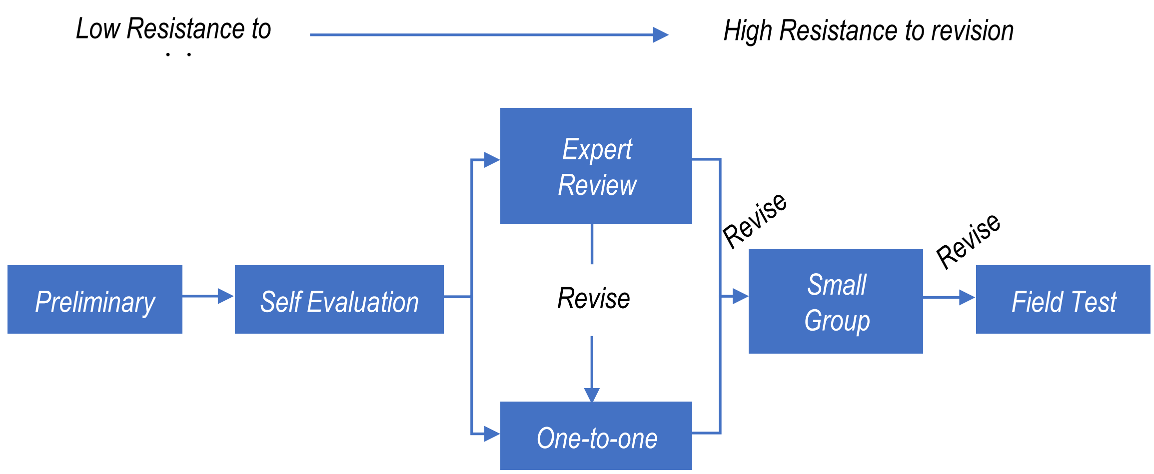


Figure 1. Formative evaluation design flow

Preliminary Design

The preliminary design is the first stage of the research process. Its objective is to identify and analyze the place and object of research by contacting the principal and mathematics teacher who will be the subject of the research. It also aims to review the literature and various theories related to the development of PISA-type mathematics task, the 2018 PISA framework, analyze the curriculum, and the context that will be taken. Once the relevant literature had been reviewed, the grids, question cards, lesson plans, and scoring guidelines were designed in accordance with the characteristics of PISA task (OECD, 2019), presented in Table 2.

Table 2. Characteristics of PISA task

No	Characteristic	Information
1	Content	1. Questions made according to the mathematical literacy domain of *the PISA 2022* framework 2. Questions made in accordance with basic competencies and materials tested 3. Questions made according to indicators of students' mathematical literacy ability
2	Construction	1. The level of questions made is according to the ability level of grade IX students 4. The problems used in the questions are in accordance with the characteristics of the question level in the *PISA* framework
3	Language	1. Sentences on questions made according to EYD (Enhanced Spelling) 2. Sentences on communicative questions 3. The sentence on the question does not cause double interpretation

Formative Evaluation

The second stage is formative evaluation. At this stage, the researcher conducts self-evaluation to evaluate and review the PISA-type math task that have been developed, including the question grids and scoring guidelines. This process resulted in the first prototype. Furthermore, the first prototype was reviewed by experts and four students. Expert testing can be conducted in three ways: in person, via mail or email, or through panel sessions (Tessmer, 1994; Permatasari et al., 2018). Experts were asked to validate the content, construct, and language. Their suggestions were incorporated into the revision of the prototype during the expert review stage.

The on-to-one process was conducted in conjunction with the expert review, with four students participating in the test. The students had heterogeneous abilities. They were asked to work and observe the questions, then asked to comment on the questions. The results of the expert review and one-to-one validation were used to revise the first prototype. After the validation process by expert review and one-to-one, the first prototype was deemed to be valid. The results of the expert review and one-to-one validation were used to revise the first prototype, leading to the creation of the second prototype.

Once the second prototype was complete, it was tested on 15 students who were not included in the research subjects but had similar characteristics and abilities. This small group test was conducted to assess the practicality of the PISA-type math problems that had been created. If students can understand the problem well, then the problem is considered practical. Following the small-group testing, the feedback from students is used to refine the second prototype, resulting in the third prototype. The small-group test is designed to confirm the results of the prototype I stage and produce the third prototype (Tessmer, 1994). Furthermore, the third prototype was subjected to a field test. This stage is designed to assess the potential impact of the questions posed on the analysis of student responses, based on indicators of mathematical literacy skills.

RESULTS AND DISCUSSION

The results of this study are described based on the research stages, which include two main phases: preliminary design, which aims to identify needs and design the basic framework of the project, and formative evaluation, which serves as an iterative process to evaluate the initial prototype to improve and refine the design.

Preliminary Research

At this stage, several analyses were conducted to determine the characteristics of PISA questions based on content, construct, and language. These analyses included school analysis, curriculum analysis, student analysis, and analysis of PISA questions. The results of these analyses were then associated with the process competencies in PISA and the ability level in PISA. This information was used to inform the creation of PISA-type math questions using the context of Siger Tower. Once the literature review was complete, the design stage commenced. During this stage, researchers developed several learning tools, including lesson plans, teacher instructions, question grids, and scoring rubrics. Researchers created PISA-type math questions based on the 2018 PISA framework. At this stage, researchers produced nine questions with three content areas: quantity, shape and space, and change and relationship. These questions were developed in the context of Siger Tower.

Formative Evaluation

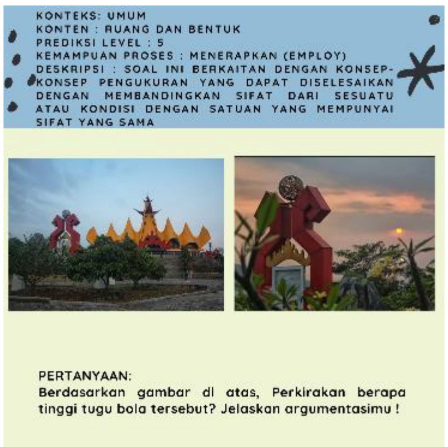
Formative evaluation is a crucial aspect of the development or prototyping phase. The outcomes of formative evaluation serve as a foundation for enhancing the intervention prototype towards a superior and comprehensive intervention and refining the preliminary design underlying principles towards the final design (McKenney & Reeves, 2014).

Figure 2. Questions card 1

The initial stage in formative evaluation is self-evaluation. The objective of this stage is to evaluate the question cards that have been designed before they are given to expert review and students at the one-to-one stage. The next stage is expert review and one-to-one. The results of the first prototype were given to experts for a review related to the question cards, at the same time one-to-one was also carried out which involved 4 students on the recommendation of the mathematics teacher in class IX.

Figure 2 shows one of the questions with the results of an expert review that they have provided suggestions for improvement. These include adding more meaningful information to the images presented, which would enable them to be used as a reference or clue in answering questions, summarize in Table 3.

Table 3. Difference between question card 1 before and after revision

Before Revision	After Revision	Revision Result
		Following expert review and student feedback, the image in the question has been replaced with a more meaningful one. This will serve as an image clue for comparison with the object in question.

Following the expert review and student validation, question card 2 was deemed to be satisfactory and therefore did not undergo any changes, as shown in Figure 3.

Figure 3. Questions card 2 (a) and Question Card 3 (b)

Question card 3, however, did require some amendments. The expert review suggested that the data in point B, namely speed, distance and time, should be deleted. The question should be changed to "What do you think is the trajectory of the drone?" and the words "Figure 1" and "Figure 2" should be replaced with "Point 1" and "Point 2", presented in Table 4.

Table 4. The difference between question card 3 before and after revision

<table>
<tr><th>Before Revision</th><th>After Revision</th><th>Revision Results</th></tr>
<tr>
<td>
</td>
<td>
</td>
<td>1. Following the expert review and student feedback, the following improvements have been made:
2. The question in point B has been amended to "What do you think of the drone trajectory?"
3. The words "picture 1" and "picture 2" have been replaced with "point 1" and "point 2".</td>
</tr>
</table>

Following the expert review, the experts have provided suggestions to develop the question presented in Figure 4.

Figure 4. Question Card 4

These include changing the picture to a ticket figure so that the information is available in the figure, deleting the number of students and separating the information and questions, as shown in Table 5.

Table 5. The difference between question card 4 before and after revision

<table>
<tr><th>Before Revision</th><th>After Revision</th><th>Revision Result</th></tr>
<tr>
<td>
</td>
<td>
</td>
<td>Based on the advice of expert reviews and students, there are several improvements that are improved:
1. Change the image to a ticket image.
2. Separate information and questions
3. Smear the number of students</td>
</tr>
</table>

Once the expert review and one-to-one stages have been completed, the next stage is small group. In this stage, the evaluator tests the draft instruction with several students, noting their performance and comments. The evaluator then asks the learners about any improvements that could be made and any additional content that should be included (Tessmer, 1994). Furthermore, the test was carried out by administering nine PISA-type mathematics questions in the context of the Siger Tower in the second prototype. This test lasted for two hours, during which students worked on the questions individually without discussion.

In Question Card 1, students had difficulty understanding the picture due to a lack of careful observation. The picture included a man standing upright under a monument, which could serve as a comparison point. Once students received questions that guided their understanding, they were able to solve the problem well, each providing different answers based on their representation. Some students used the height of the adult male as a reference to estimate the height of the statue, thereby solving the problem according to their interpretations.

In Question Card 2, students were able to carefully and correctly observe the information in the picture, which enabled them to solve the problems accurately. They combined the information from both sides of the problem card to address the question appropriately, ensuring the solution was in line with the representation.

In Question Card 3, students drew a circle and a line intersecting at the center to estimate the positions of points A and B. They then assumed an area, added it to the total, and determined the drone's displacement from point A to point B. At point B, students used the information obtained from point A to determine the drone's clockwise trajectory, facilitating a solution that matched the representation.

In Question Card 4, students effectively demonstrated their problem-solving abilities by estimating the number of participants in a study tour to be 455, calculating the discount for every ten people, and subtracting the discount from the total amount payable. This approach allowed them to solve the problem in accordance with the representation. The final stage in developing PISA-type math problems was the field test stage, during which Prototype 3 was tested at SMP N 1 Way Tenong. The research involved 32 students from class IX G, who worked on nine question cards over two hours. The subsequent section outlines the nine question cards tested with students and includes an analysis of their answer sheets and observations of the learning process during the field test stage.

In question card 1, students are required to demonstrate their mathematical ability by using context understanding to solve mathematical problems (M3). They must then proceed to the reasoning and argumentation stage by using the chain of thought to connect the surrounding image information (PA3). Finally, communication skills are required to conclude mathematical results (K3). The student answer can be seen in Figure 5.

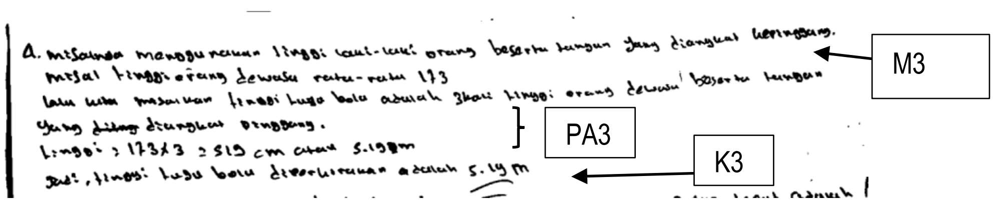


Figure 5. Student Answer of Questions Card 1

From students' responses, it is evident that they can leverage mathematical ability indicators to solve mathematical problems (M3), use reasoning and argumentation by employing chains of thought to connect surrounding image information (PA3), and utilize communication skills to conclude mathematical results (K3) in determining the height of the ball monument. Thus, it can be concluded that Question Card 1 has the potential to elicit mathematization ability (M3), reasoning and argumentation ability (PA3), and communication ability (K3).

In question card 2, students are required to use representation skills, namely making mathematical representations of real-world information (R1). The student answer of question card 2 can be seen in Figure 6.

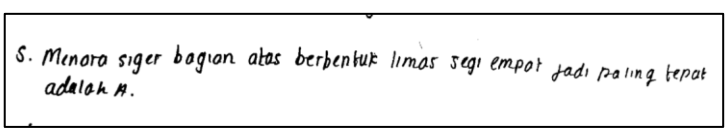


Figure 6. Student Answer of Questions Card 2

In Figure 6, students have been able to use the representation ability of the indicator of making mathematical representations of real-world information (R1) by using the information in the picture. So, it can be said that question card 2 has the potential to bring out the representation ability of the indicator of making mathematical representations of real-world information (R1).

In question card 3, students need to involve the ability to apply an indicator strategy (MS3) to determine the displacement of the drone from point a to point b. Furthermore, students also involve the ability to use language and symbolic operations (B3) to determine how many degrees the drone displacement angle is. Then, students also involve communication skills to make conclusions based on the results that have been obtained (K3). The student answer of questions card 3 can be seen in Figure 7.

In Figure 7, students use the ability to apply an indicator strategy (MS3) to determine the displacement of the drone by looking at the picture in the problem. Furthermore, students use language skills and symbolic operations (B3)

to calculate the displacement of the drone clockwise. Furthermore, students use communication skills (K3) to conclude mathematical results. So, it can be said that the question card 3 point a can potentially bring out the ability to apply a strategy indicator (MS3), language skills and symbolic operations (B3) and communication skills with indicators to conclude mathematical results (K3).

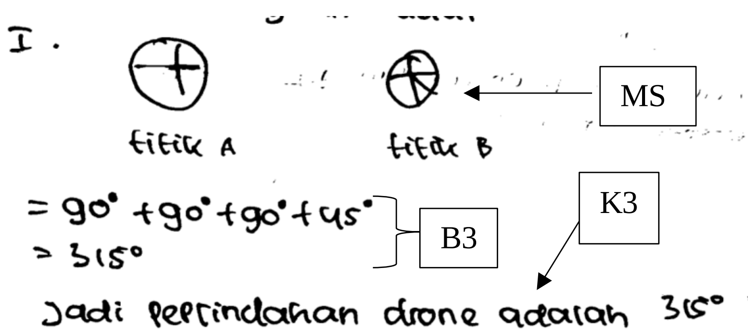


Figure 7. Student Answer of Questions Card 3-point a

In point b of question card 3, students are required to use the ability to connect previously obtained information to determine the mathematical solution (PA3) to determine the trajectory of the drone used. Furthermore, students are required to use communication skills indicators to communicate explanations and arguments in the context of the problem (K4). The student answer of point b of questions card 3 can be seen in Figure 8.

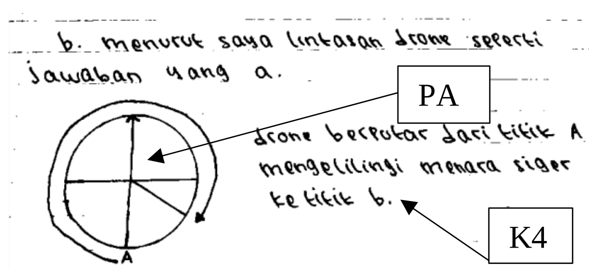


Figure 8. Student Answer of Questions Card 3-point b

Figure 8 shows that students use all the ability to connect previously obtained information to determine the mathematical solution (PA3) to determine the trajectory of the *drone*. Furthermore, students use indicator communication skills (K4). So, it can be said that question card 3-point b can potentially bring out the ability to connect previously obtained information to determine mathematical solutions (PA3) and communication skills indicator (K4).

In question card 4, students are required to use the representation ability indicator (R3) to represent the number of children participating in the *study tour* and the communication ability indicator (K3) to communicate the mathematical results that have been obtained. The student answer of question card 4 can be seen in Figure 9.

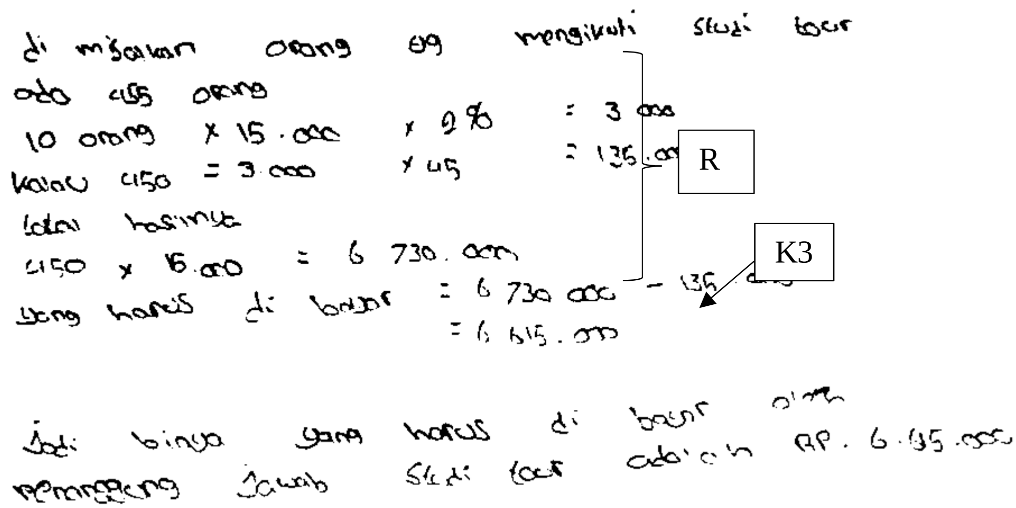


Figure 9. Student Answer of Questions Card 4

In Figure 9, students use the representation ability indicator (R3) by using the information on the ticket to solve the problem. Then, students also involve the K3 indicator communication skills by writing the conclusion of the amount to be paid by the person in charge of the *study tour* obtained based on the analysis of the information on the ticket done previously. Thus, it can be said that question card 4 has the potential to bring out representation ability (R3) and communication ability (K3).

Discussions

The results of the analysis indicate that most students can apply mathematical literacy skills in solving PISA-type problems, including representation and communication skills. This aligns with the findings of several researches which suggest that students can comprehend, formulate, and solve problems effectively by providing sound reasoning and argumentation (Jannah et al., 2019; Nusantara et al., 2020). In general, most students still have difficulty in solving math problems because they are not accustomed to solving problems in the PISA format (Dasaprawira et al., 2019). This is in line with the findings of Novita et al. (2012), which indicate that students are accustomed to acquiring formal mathematical knowledge within the classroom, which subsequently enables them to solve questions in terms of language.

However, when students received answers to questions, they responded quickly to solve their comprehension problems. This is in line with Cahyono's (2010) view that with the feedback provided by the teacher, students can interpret and share mathematical insights in their social life so that students can understand a concept. In addition, the interviews showed that PISA questions with context can make students enjoy solving them and can provide students with mathematical literacy skills, including reasoning and argumentation. Because the given context is an icon of pride of Lampung province, students feel interested in studying the given problem so that they can communicate their reasons and arguments. Correspondingly, students feel excited and interested in solving PISA-like mathematics problems so that they can engage their mathematical literacy skills (Efriani et al., 2019., Siahaan et al., 2022., Permatasari et al., 2018). Dasaprawira et al. (2019) stated that students feel happy when they conceptualize students' answers for students' creativity without any restrictions, and students can think broadly when they hear different answers from other students.

The development of PISA questions is related to the PISA framework, which is a reference for the assessment of mathematical literacy on an international scale. For this reason, there are two types of questions developed in the PISA framework, namely original PISA questions and PISA-type questions. The original PISA questions are questions that are tested on students by the OECD to assess the education system of 72 countries around the world (OECD, 2016; 2019; 2023). Meanwhile, PISA-type questions are questions developed by researchers to be tested on students according to student characteristics, both social and cultural, and adapted to the mathematical literacy domain of the PISA framework (Siahaan et al., 2022).

This PISA question is used to measure mathematical literacy, which means that students' high mathematical literacy skills cause them to be able to work on PISA questions, and high PISA scores are due to students' high mathematical literacy skills. While the results of the analysis at the field test stage showed that the PISA-type questions developed could have a potential effect on mathematical literacy skills, the PISA-type questions developed by this researcher have the potential to improve mathematical literacy skills. Therefore, if mathematical literacy is good, then PISA scores are good. This is in line with the opinion of Stacey (2011), who states that good mathematical literacy skills, when working on PISA-type questions developed in accordance with the social and cultural characteristics of students, provide different PISA scores at higher levels, which means that PISA scores also increase. Argina et al. (2017) stated that one of the successes in increasing PISA scores is the teaching process, one of which is using how to practice working on PISA-type problems that use contexts that are close to students.

The research makes a substantial contribution to the field of mathematics education by identifying effective strategies for enhancing students' mathematical literacy and performance on international assessments such as PISA. By demonstrating the positive impact of incorporating PISA-type questions, contextualized learning, and targeted feedback mechanisms, this study provides valuable insights for educators and policymakers. These insights can inform curriculum development, instructional practices, and assessment strategies, aiming to foster students' mathematical proficiency across diverse cultural and social contexts.

Moreover, the findings emphasize the critical importance of aligning educational practices with international standards. This alignment ensures that students are not only prepared for global academic challenges but also equipped to contribute meaningfully to the 21st-century workforce. The study's results highlight the necessity for educational systems to adopt practices that meet the rigorous demands of international benchmarks, thereby enhancing students' readiness for both academic and professional success on a global scale.

In addition, the research underscores the role of culturally relevant contexts in mathematics education, which can enhance students' engagement and understanding. By integrating real-world scenarios into the learning process, educators can make mathematics more relatable and meaningful for students. This approach not only improves mathematical literacy but also encourages the development of critical thinking and problem-solving skills, which are essential for students' future academic and career endeavors.

CONCLUSION

This study demonstrates the validity, practicality, and potential for enhancing students' mathematical literacy through the PISA-type mathematics problem set developed using the Siger Tower context. The validity of the problem set is confirmed through an expert review process and individual testing, which indicates the alignment of the questions with the PISA mathematical literacy domain and their suitability for ninth-grade students. Furthermore, the practicality of the questions is evidenced by the results of the small group test, where students were able to comprehend and apply the questions in a learning context. Analysis of students' responses during the field test phase revealed that these questions effectively elicited various mathematical literacy skills, including mathematization, representation, reasoning, argumentation, and communication.

However, this study also acknowledges certain limitations, such as the limited sample size and the focus on a single specific context, namely the Siger Tower. Consequently, it is recommended that future research involve a larger sample size and incorporate a broader range of contexts in the development of PISA-type mathematics problems. Expanding the variety of contexts could provide a more comprehensive evaluation of the problem set's effectiveness across different scenarios.

Additionally, future research should consider employing more complex research methodologies, such as controlled experimental designs, to further validate the impact of these questions on students' mathematical literacy. Such approaches would enhance the robustness of the findings and provide stronger evidence regarding the efficacy of the PISA-type problem set in improving mathematical literacy skills among students.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

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Author Contributions

Sri Retnawati: Conceptualization, investigation, formal analysis, writing – original draft, and visualization; **Rully Charitas Indra Prahmana**: Methodology, writing – original draft, writing – review & editing, and visualization; **Mónica Arnal-Palacián**: Writing – review & editing and supervision.

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