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Developing a Test of Mathematical Literacy based on STEM-PjBL using ADDIE Model

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Abstract.
Mathematical literacy is one of the eminent skills in the learning process in the 21st century. However, the mathematical skills of Junior High School students in Indonesia need some improvement. This study aims to develop a test of mathematical literacy based on the integration of Science, Technology, Engineering, and Mathematics (STEM) and Project-based Learning (PjBL). The study involved research and development using the Analysis, Design, Development, Implementation and Evaluation model (ADDIE). The results showed that the developed mathematical literacy test based on STEM-PjBL is valid and practical to be implemented by the expert validator. Moreover, the construct validity through implementation in the classroom obtained the result that the instrument is valid and reliable. This instrument is expected to be disseminated to the wider population to accustom the students to the problem embedded in project-based learning and STEM activities.

Keywords: Mathematical Literacy; Instrument Test; STEM-PjBL; ADDIE Model

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1. Introduction

Mathematical literacy is the ability to formulate, implement and interpret mathematics in various contexts involving mathematical reasoning, using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena to assist individuals in making constructive and reflective decisions(1-4). It implies that mathematical literacy is mastery of knowledge and implementing the reasoning, concepts, facts, and mathematical tools in solving everyday problems. Mathematical literacy provides the students with a sensitivity to mathematical phenomena and problem solving in the daily life (1)(3)(5), as well as in decision-making as citizens who build and care (6). Moreover, mathematical literacy is also related to grasping the concept, students who have high concept understanding meet the description of good mathematical literacy abilities (7).

However, the mathematics achievement of junior high school students in Indonesia based on PISA is consider at the lower rank (2). Several factors influence the low achievement PISA mathematics of junior high school students in Indonesia (8). One of them is that the students are unfamiliar with the PISA model test. The problems of the PISA model of mathematics focus on measuring the mathematical literacy skill. This problem assesses the mathematical literacy competency by examining the students' effectiveness in formulating, implementing and interpreting mathematical problems into daily life problems (9).

On the other hand, the existence of a mathematical literacy test is essential for both teachers and students to familiarize and implement it to the school material. The teachers also face the difficulty at assesing mathematical literacy since the lack of kowledge about indicators of mathematical literacy. Assessment becomes one of the crucial aspect in the learning process (10 – 13). A good assessment test should reflect the student's mastery level (14). Therefore, there is a need for an assessment that can train, familiarize, and develop students' mathematical literacy.

In line with the need to equip students with mathematical literacy skills, the STEM approach provides connectivity among fields such as Science, Technology, Engineering and Mathematics; therefore, the students could have a holistic comprehension (15). The learning process using the STEM approach is contextual learning that allows students to understand phenomena in daily life. As a result, it could stimulate students' curiosity and mathematical reasoning. This is in line with the purpose of the mathematical literacy aspect, which equips students to have sensitivity to the mathematical phenomena and solve the contextual problems (1)(3)(5). The research shows that STEM could stimulate students' critical thinking by identifying and solving the problem using the technology within collaborative learning (16-18).

Another learning model is project based learning (PjBL) which uses a contextual approach, the students playing an active role in solve problems, make decisions, research, present and create documents (19). PjBL is designed to be used on complex problems that students need in investigate and understand. Both STEM and PjBL have complementary advantages and disadvantages. Students understand concepts by making products in PjBL model, while in STEM learning, there is a process design and redesign in the engineering design process that makes students produce the best product (20). Considering the advantages of STEM-PjBL; therefore, the current study intends to involve the aspect of STEM-PjBL in developing the instrument test of mathematical literacy.

Regarding the background, the purpose of this study is to develop the instrument test of mathematical literacy based on STEM-PjBL aspect.

2. Method

The study employ the Research and Development (R & D) approach since the purpose is to develop the valid and practical instrument test of mathematical literacy based on integration of STEM-PjBL aspects. The research procedures involve the ADDIE model consisting of five stages: Analysis, Design, Development, Implementation and Evaluation (21).

In the phase of *analysis*, the researchers analyse several aspects such as the students needs, the possible topics to be developed, the students' characteristics, and the solution of that problems by developing the intrument test of mathematical literacy based on STEM-PjBL aspects. On the *design* stage, the need analysis and the interview results become a consideration for determining the topic to be developed, deciding the used mathematical literacy's indicators, identifying the lattice problems, considering the contextual problem related to the choosen topic, considering the STEM-PjBL aspect to be embedded on the problems, then predicting the number of question items and the time allocation of doing the test. Further, in the *development* phase, the lattice problems were determined based on the indicator of mathematical literacy by Ojose (1), develop the question items based on the lattice problem and indicator of mathematicalloteracy, solving the problem and making the scoring rubric. The next stage is *implementation*, the developed test on the previous stage was validated by the expert validator then revise to be implemented for the classroom assessment for a piloting study. At last, in the *evaluation* stage the students' result from the classrom implementasion were evaluated to check its validity and reliability.

3. Result and Discussion

This section provide the description of the results and elaborate it in the discussion section as follows.

3.1. Results

Developing the instrument test of mathematical literacy based on STEM PjBL aspect involves the stages on the ADDIE model. The results of each stages will be described as the following procedures.

3.1.1. Analysis

The analysis stage describes the background of developing the instrument test of mathematical literacy based on STEM-PjBL. The researchers find that the students need to be accustomed to the mathematical word problems connected to the contextual problems in their daily lives. Since the students' mathematical literacy are below the standards, which is in line with the PISA results for Indonesian students (2); therefore, there is a need to provide the students with mathematical exercise that contains mathematical literacy aspect. Moreover, the students also need to have an opportunity to complete the task that contains the situation, which promotes them to think critically, decide on a solution to solve the problem through a trial and redesign their planned solution. Furthermore, based on the interview with the mathematics teachers, the possible topic to be developed is the number pattern which is possible to embed with STEM-PjBL aspects.

3.1.2. Design

In the *design* stage, the need analysis and the interview results become a consideration for determining the topic to be developed. The references were gathered to obtain the valid data and information related to the chosen topic, Number Pattern. Further, designing the outlines of test instruments which consist of design instrument tests such as determining the instructions for completing the test, the items test, predicting the number of question items and the time allocation of doing the test and creating the scoring rubric. Then, the items test was tailored to the indicators of mathematical literacy. The choosen framework of mathematical literacy indicators were derived become the lattice problems. The design of the test instrument is tailored to the indicators of mathematical literacy which employ the STEM-PjBL aspect including mathematics thinking and reasoning, mathematical argumentation, mathematical communication, modelling, problem posing and solving, representation, symbols, tools and technology, construction problems, and language.

3.1.3. Development

In the *development* phase, the lattice problems were determined based on the indicator of mathematical literacy by Ojose (1), developing the question items based on the lattice problem and indicator of mathematical literacy, solving the problem and making the scoring rubric.

3.1.4. Implementation

The next stage is *implementation*; the developed test in the previous stage was validated by the expert validator and then revised to be implemented for the classroom assessment for a piloting study. At this phase, the researcher analyzed the result of expert validation about the quality of the test instrument in terms of several aspects, as seen in Table 1, namely, mathematics thinking and reasoning, mathematical argumentation, mathematical communication, modelling, problem posing and solving, representation, symbols, tools and technology, construction problems, and language.

TABLE 1: Validation of Mathematical Literacy.

No.	Aspects	Score
1.	Mathematics Thinking and Reasoning	4.00
2.	Mathematical Argumentation:	4.40
3.	Mathematical Communication	4.50
4.	Modeling	4.17
5.	Problem Posing and Solving	4.00
6.	Representation, Symbols,Tools and Technology	4.20
7.	Construction problems	3.50
8.	Language	3.75
Average Score		**4.07**
Criteria		**Valid**

After the expert validator validated the instrument test of mathematical literacy, the result show that it is categorized as a valid instrument. The refinement instrument was conducted based on the suggestions until ready to be implemented in the classroom. The pilot study was conducted on class IX SMP Negeri 6 Semarang students. After implementing the instrument test of mathematical literay, an evaluation will be conducted to check its validity and reliability.

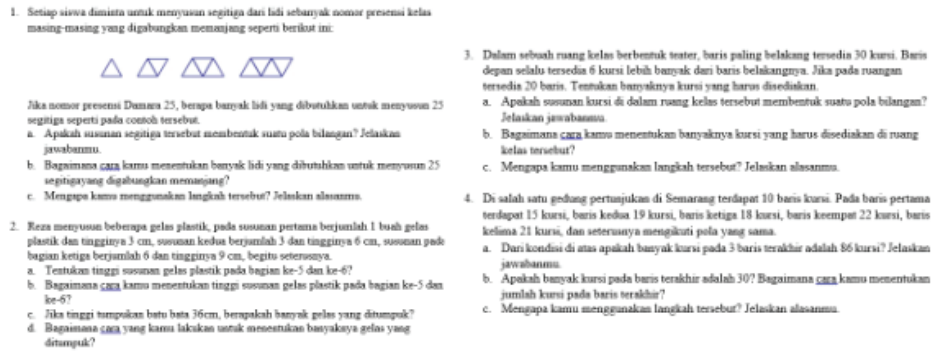
3.1.5. Evaluation

At last, in the *evaluation* stage the students' result from the classrom implementasion were evaluated to check its validity and reliability. Therefore, the developed instrument could be continously eveluated for further improvement. The validity and reliability analysis used the Winstep analysis described in Table 2 as follows.

Table 2: Winstep Analysis.

Category	Criteria	Level
Pearson Reliability	More than 0.7 is consistent	0.89 (consistent)
Cronbach Alpha	More than 0.7 is consistent	0.88 (consistent)
Item reliability	More than 0.7 is reliable	0.92 (Reliable)
Difficulty level	-0.61 – 0.56 is moderate	Moderate
Distinguished Power	More than 0.2 is good	Good
Item Valid (Outfit_MNSQ)	0.5 – 1.5 is valid	All valid except item 2b (1.52)
Item Valid (Outfit_ZSTD)	-2.0 – 2.0 is valid	All valid

Based on the criteria Distinguished Power, Item Valid (Outfit_MNSQ), Item Valid (Outfit_ZSTD) therefore, all the items are valid except the item 2b should be deleted. The test is figured out at Figure 1 as follows.


1. Setiap siswa diminta untuk menyusun segitiga dari lidi sebanyak nomor presensi kelas masing-masing yang digabungkan memanjang seperti berikut ini:

Jika nomor presensi Damara 25, berapa banyak lidi yang dibutuhkan untuk menyusun 25 segitiga seperti pada contoh tersebut.
a. Apakah susunan segitiga tersebut membentuk suatu pola bilangan? Jelaskan jawabanmu.
b. Bagaimana cara kamu menentukan banyak lidi yang dibutuhkan untuk menyusun 25 segitigayang digabungkan memanjang?
c. Mengapa kamu menggunakan langkah tersebut? Jelaskan alasanmu.

2. Reza menyusun beberapa gelas plastik, pada susunan pertama berjumlah 1 buah gelas plastik dan tingginya 3 cm, susunan kedua berjumlah 3 dan tingginya 6 cm, susunan pada bagian ketiga berjumlah 6 dan tingginya 9 cm, begitu seterusnya.
a. Tentukan tinggi susunan gelas plastik pada bagian ke-5 dan ke-6?
b. Bagaimana cara kamu menentukan tinggi susunan gelas plastik pada bagian ke-5 dan ke-6?
c. Jika tinggi tumpukan batu bata 36cm, berapakah banyak gelas yang ditumpuk?
d. Bagaimana cara yang kamu lakukan untuk menentukan banyaknya gelas yang ditumpuk?

3. Dalam sebuah ruang kelas berbentuk teater, baris paling belakang tersedia 30 kursi. Baris depan selalu tersedia 6 kursi lebih banyak dari baris belakangnya. Jika pada ruangan tersedia 20 baris. Tentukan banyaknya kursi yang harus disediakan.
a. Apakah susunan kursi di dalam ruang kelas tersebut membentuk suatu pola bilangan? Jelaskan jawabanmu.
b. Bagaimana cara kamu menentukan banyaknya kursi yang harus disediakan di ruang kelas tersebut?
c. Mengapa kamu menggunakan langkah tersebut? Jelaskan alasanmu.

4. Di salah satu gedung pertunjukan di Semarang terdapat 10 baris kursi. Pada baris pertama terdapat 15 kursi, baris kedua 19 kursi, baris ketiga 18 kursi, baris keempat 22 kursi, baris kelima 21 kursi, dan seterusnya mengikuti pola yang sama.
a. Dari kondisi di atas apakah banyak kursi pada 3 baris terakhir adalah 86 kursi? Jelaskan jawabanmu.
b. Apakah banyak kursi pada baris terakhir adalah 30? Bagaimana cara kamu menentukan jumlah kursi pada baris terakhir?
c. Mengapa kamu menggunakan langkah tersebut? Jelaskan alasanmu.

Figure 1: Intruments Test of Mathematical Literacy.

3.2. Discussion

Based on the study's results, the analysis stage shows that both students and teachers need a mathematical literacy instrument test that embeds the STEM-PjBL aspects. Since the students' mathematical literacy is below the standards which is in line with the PISA

results for Indonesian students (2); therefore, the students need to be accustomed to the mathematical words problems connected to the contextual problems in their daily life. In the designing stage, this phase becomes crucial since the planning for developing test should consider several aspects. As CoPo (14) stated that the good assessment test should reflect the students' mastery level. Therefore, the rigorous consideration was handled in this stage from determining the indicators mathematical literacy that involve the aspect of STEM-PjBL. Moreover, the contextual problem should be brought to familiarize the students in solving the problem into their daily life. This stage involves the further design that should be developed in the development phase. After the instrument test was developed, the expert validator checked the content validity. Content validity is estimating the validity by examining the feasibility or relevance of the test content through rational analysis by a competent panel of expert judgment (22). A good instrument that can be used as a basis for decision making is an instrument that meets several criteria, including validity and reliability (23). In the implementation stage, the developed test on the previous stage was validated by the expert validator then revise to be implemented for the classroom assessment for a piloting study. Validity is a fundamental criterion that must be considered in developing tests. American Educational Research Association (24) states that validity refers to the extent to which evidence and theory support the interpretation of test scores for the use of the proposed test. Based on the source of the evidence used, there are three types of validity: content validity, criteria-related validity, and construct validity (22)(25-28). After the expert validator validated the instrument test of mathematical literacy, the result show that it is categorized as a valid instrument. At last, in the evaluation stage the obtaining data shows that the developed instrument is consistent. It means that the use the same instrument for different people or times will obtain the same results. Stanley (29) defines reliability as the consistency of measurement to one another. The reliability is also one indicator of an instrument whether it is good or not. The development of mathematical literacy instruments that have evidence of validity and good reliability coefficients will produce a set of instruments that are feasible to use to measure students' mathematical literacy achievements.

4. Conclusion

The developing instrument test of mathematical literacy based on STEM-PjBL was involved a rigor and detail procedures of research and development (R&D) using ADDIE model. Each stage of analysis, design, development, implementation, and evaluation

provide an overview for the mathematics education enthusiast, particularly mathematics teachers, as a consideration for preparing the similar instrument test for other topic. The result show that from the expert validator, it reveals that the developed instruments test of mathematical literacy based on STEM-PjBL is valid and practical to use. Moreover, based on the practice validity, the instrument obtained Pearson Reliability, Cronbach Alfa, and Item Reliability concequtively 0.89, 0.88 and 0.92 which mean consistency and reliability. Meanwhile, based on the criteria of distinguished power, outfit_MNSQ, and outfit_ZSTD, all the items are valid except item 2b should be deleted. Therefore, this instrument could contribute to providing both the teachers and students with the instrument test of mathematical literacy involving the STEM-PjBL aspect particularly for the Number Pattern topic. There is a significant need for further study to conduct a research that aims to develop instrument test of mathematical literacy that also support other mathematical skill needed for the learning in the 21^{st} century.

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