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STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) IN IMPROVING PRIMARY SCHOOL STUDENTS' MATHEMATICS LITERACY

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Abstract

This research aims to develop a STEM-based mathematics learning design for elementary school students. Therefore, this research is included in research and development. The learning design development process follows the Plomp model, which consists of five stages: 1) the initial investigation phase; 2) the design phase; 3) the construction phase (realization); 4) the test, evaluation and revision phase; and 5) implementation phase. The data was collected through interviews, observation, and essay tests. Interviews are used to identify student and teacher responses to learning design. Observations are carried out during the implementation of learning to monitor the process directly. The essay test is used to measure students' mathematical literacy abilities. Data from interviews and observations were analyzed using qualitative descriptive analysis, while quantitative descriptive analysis was used to describe the average student success and the effectiveness of the learning design. The STEM-based mathematics learning design developed is based on the Project Based Learning learning model, adapted to STEM theories and the needs of elementary school students. This design includes six phases: orientation, strategy construction, application, communication, reflection, and assessment. The results of limited trials show that STEM-

based mathematics learning designs are effectively implemented in the classroom and can improve students' abilities in solving mathematical literacy problems according to the PISA dimensions.

Keywords **:** Literacy, Mathematics, STEM

INTRODUCTION

Along with developments in time and technology, various strategies have been implemented to improve the quality of human resources in various sectors. One of them is in the education sector. The education sector in Indonesia continues to strive to increase quality human resources to support national development and adapt to global progress. Therefore, the education system must develop achievements and various skills such as creativity and global awareness known as "21st Century Competencies" (Soland, Hamilton, & Stecher, 2013).

21st Century Competencies require students to have mastery in the fields of mathematics and science from a global perspective. Mastery of knowledge in global perspective issues is very important because Indonesia is in a global community. Therefore, strategic steps need to be planned so that students are prepared and able to compete in the industrial world which is predicted to occur in 2030 (OECD, 2016). This preparation does not only focus on achieving success for students according to national standards but also on how they have ability standards that are equivalent to students in developed countries.

The 2015 Program for International Student Assessment (PISA) published the results of assessments for students' mathematics and science literacy skills in Indonesia, which placed Indonesia in 62nd place out of 70 countries assessed. PISA results show that students' mathematical literacy in Indonesia is still far from the established standards (OECD, 2016). PISA is one of two international assessments that focus on students' skills and competencies that are acquired from school and can be used in everyday life, including mathematical literacy. PISA is held every three years with subjects aged 15 years (Stacey, 2014; OECD, 2016).

PISA defines mathematical literacy as an individual's ability to formulate, use and interpret mathematics in various contexts. It

includes mathematical reasoning and the use of mathematical concepts, procedures, facts, and tools to explain and predict phenomena. This helps individuals recognize the role of mathematics in the world and make informed decisions (OECD, 2016: 65). Mathematical literacy focuses on the ability to use mathematical understanding in present and future life (Stacey, 2014). Thus, mathematical literacy is important for students to prepare them to face life and professions in the future (Gatabi, Stacey, & Gooya, 2012; Novita & Putra, 2016).

The government is responding to the weak mathematical literacy based on PISA results by implementing the 2013 Curriculum. This curriculum is a follow-up to the PISA report which found that many of the competencies in PISA were not adopted in the previous Indonesian curriculum (Permendikbud No. 67, 2013). Learning resources must be able to develop mathematical literacy, and students must be accustomed to working on PISA model questions in school learning (Zukardi, 2002; Kohar, 2013).

Currently, STEM (Science, Technology, Engineering, and Mathematics) education has become a new paradigm and an important issue in global learning. This concept emerged because current education is inadequate in terms of mathematics and science, thus causing a shortage of qualified labour and disparities in global industry (Cooney & Bottoms, 2003). STEM education aims to improve people's abilities in science and technological innovation so they can compete globally (Utami, Septiyanto, Wibowo, et al. 2017). STEM education is expected to meet 21st-century needs, including critical thinking and problem-solving skills.

Kelley & Knowles (2016) define STEM education as an approach to teaching two or more STEM domains through authentic contexts to connect each STEM field to improve student learning. STEM-based learning can improve 21st-century skills, especially the 4Cs (Communication, Collaboration, Critical Thinking and Creativity), thereby creating human resources capable of responding to global challenges. Permanasari (2016) stated that STEM-based learning can train students to apply their knowledge to design solutions to environmental problems by utilizing technology.

Roberts (2012) added that STEM education is realized when science or mathematics learning involves authentic problem-solving activities in social, cultural and functional contexts. STEM education seeks to integrate the disciplines of science, technology, engineering,

and mathematics by building connections between real-life problems; this problem is multidisciplinary (Bozkurt & Ercan, 2016). Therefore, problems or issues are also an important aspect of STEM education, taken from real problems in life which develop students' abilities to think critically and adapt to new knowledge.

Currently, according to Minister of Education and Culture Regulation No. 24 of 2016, mathematics has become a separate subject which was previously integrated into thematic learning. This separation is caused by abstract mathematical objects so mathematical concepts need to be studied in depth. Mathematics must be linked to students' real-life experiences so that what they learn becomes meaningful and useful in everyday life. Even though it is taught separately, learning must be based on a global context, connected to other subjects, and develop 21st-century skills.

Based on the need for 21st-century skills and the concept of STEM education, it is necessary to reconstruct and formulate STEM-based mathematics learning in elementary schools. This research will develop a STEM-based mathematics learning design that is effective in increasing elementary school students' mathematical literacy. This learning design is expected to become a vital foundation for mathematics learning in the future.

METHOD

This research aims to develop a STEM-based mathematics learning design in elementary schools so that it is included in the research and development category. The learning design in question is a collection of learning resources used by teachers and students as a guide to achieving mathematics learning goals. These learning resources include learning syntax which is realized in learning implementation plans, student activity sheets, and mathematical literacy tests.

This research procedure follows the operational stages described by Plomp (1997), which consists of several phases. In the initial investigation phase, activities include analysis of the current implementation of mathematics learning in SD/MI, the study of STEM theories relevant to learning outcomes, and various learning models as a comparison material, as well as analysis of basic competencies and materials to be used.

In the design phase, the results of the literature study are used to design learning design outlines, student worksheets, media, and

evaluation of STEM-based mathematics learning. In addition, focus group discussions were held to obtain input from relevant academics and practitioners.

The realization/construction phase involves preparing an initial draft of a STEM-based mathematics learning design and its supporting components, which follow the mathematics topics that have been selected from the results of the analysis in the previous stage.

After the initial draft is completed, the test, evaluation and revision phases are carried out to test the validity of the design through expert judgment tests, to identify constructive weaknesses in the design being developed. Based on input from experts, improvements were made to learning steps, learning tools and evaluation models. Next, a limited trial was held through Classroom Action Research with an adaptation of the One-Group Pretest-Posttest Design research design, involving fifth-grade students at Undiksha Laboratory Elementary School to analyze the effectiveness of the learning design. Apart from that, student and teacher responses are also researched to obtain material for further improvement and revision.

In this research, there are three main data collection techniques used. First, interviews were conducted to determine student and teacher responses to the learning design being developed, using an unstructured in-depth interview guide (Spradley, 1980). Second, observations were carried out during the implementation of learning, where researchers developed unstructured observation guidelines related to various learning activities in the classroom and student activities in the learning process. Third, the essay test is used to collect main data regarding students' mathematical literacy. This test was prepared according to the PISA mathematical literacy dimensions and was developed by the researchers themselves using formative evaluation techniques.

Data analysis in this research is adjusted to the type of source and data obtained. For interview data analysis, it was carried out qualitatively by categorizing and classifying the data thoroughly based on its logical connections, then interpreted in the overall research context. Researchers try to think in a creative but critical divergent way, to eliminate subjectivity in interpreting data. Quantitative data analysis was carried out descriptively by calculating and finding the average value of student success. In the

experimentation phase, quantitative data analysis aims to determine the effect of implementing STEM-based mathematics learning design on students' mathematical literacy.

RESULTS AND DISCUSSION

The results of the research are STEM-based learning designs which were developed based on the Plomp Model (1997) which are divided into several phases, namely the Initial Investigation Phase, Design/Design Phase, Realization/ Construction Phase and Test, Evaluation and Revision Phase.

The first phase is the Initial Investigation phase, in this phase the results of investigations into the implementation of elementary school mathematics learning and students' mathematical literacy identified several facts, namely that learning is still textbook-oriented and students have not been trained to solve mathematical problems using the steps of the Polya model. The results of an investigation into students' mathematical literacy abilities carried out in Class V of Elementary School in Buleleng found that students were only able to solve PISA level 1 mathematical literacy questions that had explicit information and steps for solving them. An example of a question that can be solved even if it doesn't go through Polya's steps is: *"Pak Gede bekerja sebagai seorang guru. Dia mengajar di SD Tunas Karya. Pak Gede memiliki 4 orang teman pria yang juga berprofesi sebagai guru di sekolah yang sama. Sementara guru wanita di sekolah tersebut adalah sebanyak dua kali banyak guru pria. Berapa banyak guru yang mengajar di SD Tunas Karya?"*

The results of students' mathematical literacy abilities in Buleleng Regency taken from 192 students are clearly summarized as follows.

Table 1. Recapitulation of students' mathematical literacy scores

Question Level	Frequency of score acquisition (%)				
	4	3	2	1	0
Level 1	67.71	17.19	0.00	0.00	15.10
Level 2	3.13	5.21	23.44	63.54	4.69
Level 3	0.52	0.52	30.73	56.25	11.98
Level 4	0.00	0.52	18.23	59.38	21.88

Level 5	0.00	0.00	15.10	60.42	24.48
Level 6	0.00	0.00	15.10	51.56	33.33

Based on this table, the percentage of students who succeeded in answering correctly along with systematic and logical solution steps, namely: for level 1 questions, it was 67.71%, level 2 questions were 3.13%, level 3 questions were 0.52%, and 0% for level 4, 5 questions. , and 6.

The results of the literature study related to STEM theory and linked to empirical findings in the field, the mathematics learning design was developed based on the "Project Based Learning" Learning Model. Next, the learning steps are reconstructed by adapting to the learning objectives, namely understanding the concepts being studied and the ability to solve mathematical literacy questions according to the PISA dimensions.

Then the second phase is design/planning. This phase provides the background for designing the learning design, including an outline of the steps for STEM-based mathematics learning, the topics for which learning tools will be developed, as well as the selection of schools and research subjects.

Next, the third phase or the realization/construction phase produces a STEM-based mathematics learning outline realized in the form of learning tools. The steps for STEM-based mathematics learning which are a reconstruction of the Project Based Learning learning model are as follows.

Phase 1. Orientation

Educators provide learning resources that incorporate technology such as videos (using YouTube), online mass media articles, and the like according to the theme/topic. At this stage, the teacher provides a mathematical problem in a global context or issue whose solution uses the concepts discussed. Problems in this stage are the basis for the next learning stage or can be resolved through a series of activities or projects carried out during the learning process. The essential problem here is important as the initiation of discovery by students (stimulating constructivist activities). The aspects developed are the Science and Technology aspects.

Phase 2. Construction of a solution strategy (plan the strategy)

Design a solution strategy through a series of projects and exploration activities. The aspects developed are the Engineering and Technology aspects. Design the time and activities that will be used to answer the

questions given by collecting information related to the topic/theme raised

Phase 3. Application

In this phase, students answer the questions given by sorting through the information that has been collected previously. Educators check the implementation of students' activities in answering questions.

Phase 4. Communicate

Students present the results of their work and other students respond.

Phase 5. Reflection

Students and educators reflect on the learning activities that have been carried out.

Phase 6. Assessment

Educators provide feedback in the form of tests to measure the extent of students' understanding of the topics discussed

The last is the Test, Evaluation and Revision phase, in this phase a series of expert tests are carried out on the learning tools developed. The experts used were lecturers in elementary school mathematics learning at elementary schools and learning design at the Ganesha University of Education. A recapitulation of expert testing of learning tools is summarized in table 4.2 below.

Table 2 . Recapitulation of Learning Tools Assessment

No.	Component	Validator 1	Validator 2
1.	Clarity of identity	4	4
2.	Complete identity	4	4
3.	Suitability of material to student needs	4	4
4.	Accuracy of learning elements according to STEM theory	3	4
5.	Suitability of time allocation for each learning activity	3	3
6.	Completeness of assessment instruments	4	4
7.	Suitability of assessment techniques	3	3

Learning tools and lesson plans have received validation from experts and have also been developed. The first trial of the product using classroom action research was carried out with an adaptation of the One-Group Pretest-Posttest Design at SDN 1 Banyuning Fifth grade. Before implementation, a focus group discussion was carried

out with the teacher so that learning was under what was designed in the RPP. This implementation aims to find out whether the learning design developed is effective in students' mathematical understanding and literacy. The pretest and posttest results of the developed STEM-based mathematics learning are summarized in the following table.

Table 3. Pretest and posttest results:

Parameter	Pretest	Posttest
Mean	2.67	78.00
Median	0.00	80.00
Mode	0.00	80.00
Standard Deviation	6.91	2.12
Variance	47.82	451.03
Minimum score	0.00	40.00
Maximum score	20.00	100.00

Effectiveness testing is carried out using the gain score (g) formula with the results as follows.

$$(g)= \frac{\text{posttest-pretest}}{\text{SMI-pretest}}$$

$$(g)= \frac{78 - 2.67}{100 - 2.67}$$

$$(g)= 0.77$$

The calculation results obtained a value (g) of 0.77, meaning that the level of effectiveness in implementing STEM-based mathematics learning is classified as very high. This indicates that the learning design developed is effective in improving students' mathematical understanding and literacy. The results of observations also show that students are enthusiastic about participating in learning and are active in working on the projects they have designed.

Referring to research results found that the learning design developed was effective in increasing mathematical understanding and literacy. This learning design is based on the STEM learning model and developed based on the "Project Based Learning" Learning Model. This was done based on findings and investigations in the field regarding the mathematical literacy abilities of Class V elementary school students, namely that students were only able to

solve PISA level 1 mathematical literacy questions for which the information and steps for solving them were explicit.

This success is of course due to the connection between STEM learning and mathematical literacy skills which must be improved. Literacy ability itself is an individual's capacity to identify and understand the role that mathematics plays in the world, to strengthen judgments, and to bind mathematics in a way that suits their needs. individuals today and for life in the future. More operationally, OECD PISA states that someone who has mathematical literacy will have the capacity to (1) Recognize and interpret mathematical problems faced in everyday life (2) Translate these problems into a mathematical context (3) Use knowledge and mathematical procedures for solving problems (4) Interpreting the results into original problems (5) Reflecting on the methods used, and (6) Formulating and communicating the results.

From this description, it can be interpreted that someone who has mathematical literacy will be able to solve various real problems by using a phenomenal approach to defining mathematical concepts, structures and ideas. For this reason, the school mathematics curriculum should depict parallel and layered strands, each of which is grounded in the appropriate experiences of children and the effects of their influence, collectively developing a diversity of mathematical insights into diverse mathematical roots, including the study material of quantity, space and shape, change and relationships.), and uncertainty (uncertainty). More clearly the components that build mathematical literacy can be shown in the chart below.

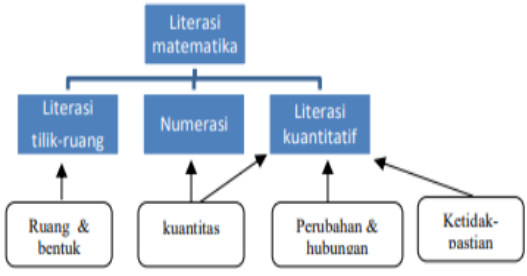

Chart 1. components of Mathematical Literacy

From the description above it is clear that basically, students can carry out mathematical literacy if the students can think rationally and logically and reason, and use them systematically. Someone who has these abilities must of course also be supported by language skills. A person's language literacy ability is not just being able to read and write but also using that language fluently, effectively and critically. Such language teaching must teach critical thinking skills. In other words, mathematical literacy is also greatly influenced by language and critical thinking skills which are related to each other. Of course, someone who has mathematical literacy skills will be able to think critically, rationally and systematically by using symbolic language to solve mathematical problems.

Accurate choice of presentation method or approach is the key to success in actualizing the learning outcomes that have been formulated, in this case, mathematical literacy. The presentation method was developed concerning the learning outcomes that will be actualized. In summary, the method of presentation required for learning can encourage students to be able to solve problems in life both individually and in groups by applying knowledge and utilizing technology as a form of concern and contribution to improving the quality of the environment responsibly. STEM-based learning can train students to apply their knowledge to create designs as a form of solving environmental problems by utilizing technology.

STEM has been widely applied in learning. This situation is demonstrated by research results which reveal that the application of STEM can improve students' academic and non-academic achievements. Therefore, the application of STEM, which initially only aimed to increase students' interest in learning about STEM fields, has become wider. This situation arises because after being applied in learning, it turns out that STEM can increase mastery of knowledge, apply knowledge to solve problems, and encourage students to create something new of course this also affects increasing maximum student learning outcomes. This is due to the application of STEM can be supported by various learning methods and adapted to the problems experienced by students in the field. Integrative STEM allows various learning methods to be used to support its application, in this research the use of the "Project Learning" learning model to improve students' mathematical

literacy skills. This is proven by the development of a STEM-based learning design which was able to improve student learning outcomes in trials at SD N 1 Banyuning in 5 grade, which obtained a gain score (g) of 0.77. Increasing student learning outcomes indicates that the student can master the knowledge needed to solve problems in mathematics. This knowledge can be in the form of information or data which is then used as consideration to choose the appropriate solution to the problem through logical, critical and systematic thinking and placing greater emphasis on the product produced.

Because these learning outcomes intersect with mathematical literacy and creativity, it can also be said that STEM-based learning supported by Project Based Learning can also improve students' mathematical literacy skills. This is also supported by the results of the learning tools produced in this research which were able to improve student learning outcomes and directly increase mathematical literacy skills.

CONCLUSION

The STEM-based mathematics learning design developed in this research uses the Project Based Learning model. This design development considers relevant STEM theories and the learning needs of elementary school students. This learning design consists of six main phases: orientation, construction of problem-solving strategies, application, communication, reflection, and assessment. Each phase is designed to gradually build students' skills in STEM and mathematics contexts. The results of the limited trials carried out show that this learning design is effectively implemented in the classroom. This effectiveness can be seen from the increase in students' ability to solve mathematical literacy questions according to the dimensions set by PISA. With a project-based approach, students not only learn mathematical concepts but also develop critical and creative thinking skills, which are critical in solving complex mathematical problems.

This research is still in the prototype development stage and has been tested on a limited basis in one class with the mathematical literacy questions tested covering levels 1 to level 3 according to the PISA dimensions. Based on the results obtained, several suggestions

can be given for further research and development of this learning design.

Firstly, it is recommended to conduct trials on a wider scale. Testing in various schools with varying conditions and student characteristics will provide more comprehensive data regarding the effectiveness of this learning design. This will also help identify aspects that need to be adjusted or improved to ensure that the learning design can be implemented effectively in a variety of educational contexts. Moreover, the mathematical literacy questions used in the trial should cover all levels according to the PISA dimensions, not just limited to levels 1 to 3. By including questions from levels 4 to 6, researchers can obtain a more complete picture of abilities. students' mathematical literacy and the extent to which STEM-based learning designs can develop these abilities. It is also important to ensure that the learning design can accommodate various levels of student ability, from basic to higher.

Collaboration with teachers and educational practitioners in developing and implementing this learning design is highly recommended. Teachers as implementers in the field have practical insights that can enrich learning designs and ensure that the strategies developed are by real needs and conditions in the classroom. Apart from that, training and assistance for teachers in implementing STEM-based learning needs to be carried out so that implementation in the field can run effectively and follow the expected goals.

Furthermore, further research can also examine the long-term impact of implementing STEM-based learning designs on students' mathematical literacy abilities. Through longitudinal studies, researchers can see the development of students' abilities over time and understand how STEM-based learning affects their skills in the long term. In this way, the learning designs developed can continue to be refined and adapted according to educational needs and developments, so that they can make a significant contribution to improving the quality of mathematics education in elementary schools.

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