Development of Digital Teaching Materials on Earthquake Themes to Improve STEM Literacy

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Abstract. This study aims to produce digital teaching materials on the theme of Earthquakes that can improve student STEM literacy. The research method uses research and development with the ADDIE model which includes Analyze, Design, Develop, Implement and Evaluate. Data was collected using expert validation sheets, valid questions about STEM literacy, 25 questions, questionnaires for teachers and students, and understanding tests. The collected data is analyzed descriptively. Analysis of the content contained in STEM literacy in student handbooks so far shows teaching materials that have not been charged with STEM literacy (31%). The digital teaching material designed has been validated by material experts and media with yields of 97.5% and 87.50%. The assessment was also carried out by teachers with the acquisition of CVR for material and media by 0.88 and 0.87. The acquisition of student teaching material trials in one to one trial (81%), small group trials (85%) and field trials (86%), and the results of test students' understanding of 54%. After being revised, teaching materials were implemented for 32 class VIII students. Before and after implementation, pretest and posttest were conducted with an average gain of 50.50 and 76.50, and N-gain averaged 49.34%. Based on this, it is concluded that digital teaching materials designed can improve STEM literacy in the medium category.

1.Introduction

One discussion of 21st century learning is learning that can integrate aspects of science, technology, engineering and mathematics (STEM). STEM is learning that supports students who are literate in STEM [1]. The demands of implementing STEM are driven by human resource needs in the STEM field in the future [2]. Job fields in various sectors depend on fields, engineering technology and mathematics [3]. However, it is still found between the application of the curriculum with 21st century skills that include ways of thinking, working, tools working and living in the world [4]. STEM literacy does not only mean achieving literacy in these four strands, or trying to map overlapping interdisciplinary skills, concepts, and processes [5]. STEM Literacy as a solution to change at this time, can change the policy of these changes, can communicate complex ideas, and find measurable solutions to problems that are currently unimaginable [6].

On the other hand, the ability of Indonesian students to solve science problems that demand skill and creativity still weak from the survey in 2015 International Student Assessment (PISA) Program which has not been invited to 64 in 70 participating countries [7]. Of course this is a very

pragmatic challenge, in the midst of human resource needs that can master 21st century skills, the ability of literacy skills is still far from expected.

Science learning with the STEM approach needs to be supported by the availability of appropriate teaching materials. Outstanding textbooks have not yet integrated STEM [8]. Teaching materials in 21st century learning are not only in the form of hard papers, but also can be in the form of listening materials, interactive multimedia, web-based, and e-book electronic teaching materials. The e-book is a teaching material in the digital version [9]. Teaching materials in the form of e-learning bridge the gap between preparation and academic practice as an effort to facilitate the availability of teaching materials for students in digital form which is also still limited in availability [10].

Vibration and Wave Material in the Grade VIII 2013 Curriculum IPA book is very closely related to the earthquake sub-material in class VII IPA books. Earthquake material is still rarely studied in depth in science learning at the junior high school level. Meanwhile, Indonesia is in the ring of fire area, making it vulnerable to tectonic and volcanic earthquakes in each region. Thus, knowledge about mitigation should be planted early as an effort to prevent the impact of the earthquake. STEM integrated disaster mitigation education must be applied early, it can even be applied in various ages [11].

The application of STEM learning has a positive impact on students 'meta-analysis abilities [12], increased interest in the subject and STEM career in middle-class students [13], building students' science process skills [14], building indispensable creativity and literacy to deal with the 21st century [15], it can improve STEM literacy which includes redesigning the design, folding and measuring aircraft construction [16], increasing student scientific literacy [17], positively impacting student motivation in program-based science and engineering activities, continuing higher education in the field of science, as well as their perceptions of science [18], science learning activities are increasing [19], and the STEM approach must be implemented continuously [20], giving a positive impact on attitudes and science learning [21].

The dependence of students on gadgets is the potential to innovate in developing digital teaching materials. This research will develop teaching materials about earthquakes and their mitigation that are digitally packaged. Digital teaching materials in the form of e-book can increase students' interest in studying the theory of acid base [22]. Earthquake and Tsunami integrated textbooks can be developed using the SETS approach by incorporating local reality content in Aceh [23]. The structure of the material in this teaching material contains the STEM approach. The use of STEM-based teaching materials can improve scientific and technological literacy [24]. This teaching material is expected to meet the needs of teachers to facilitate students in learning science on the theme of the Earthquake.

2. Methods

The research method uses research and development with the ADDIE model namely Analyze, Design, Develop, Implement and Evaluate [25]. The location of the study took place in SMP Negeri 1 Cipanas within 3 months. The sample used consists of a team of experts, teachers and students. Expert team to assess material aspects and media in teaching materials totaling 3 people. Teacher samples to test the validation of teaching materials and provide responses to the teaching materials developed amounted to 15 people. While the sample of students to validate the instrument 25 people, test teaching materials 44 people, test of understanding 26 people, implementation of 16 people and respond to 32 teaching materials.

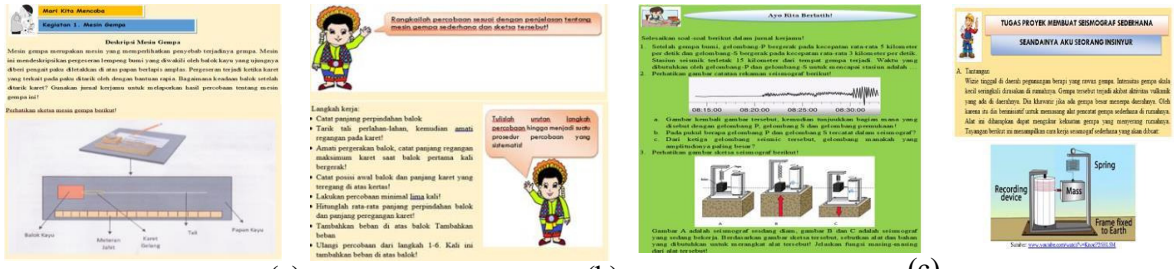
This research uses several instruments including judgment expert, questionnaire and STEM literacy questions. Judgment expert for assessment of teaching materials from material and media experts. Questionnaires are used to validate teaching materials for teachers, test teaching materials for students, understanding tests for students, teacher and student responses to teaching materials. While the STEM literacy questions were given by one group pre-test post-test design to determine the achievement of STEM student literacy on the theme of the earthquake [26].

3. Result and Discussion

Preliminary studies are the initial stages of needs analysis in this development [24]. The results of the analysis show that the science content in Grade VII natural science teaching materials in the earthquake

sub-material and class VIII of the Vibration and Wave material only reached 31%. This is in line with the analysis by Wahyu [27] which concluded that the science material on class VIII teaching materials had not been charged with scientific literacy. This preliminary study was then used as a reference for designing teaching materials that contained STEM literacy. The STEM literacy aspect was evaluated with aspects of scientific literacy on the PISA 2018 framework [7] which included aspects of knowledge, competence and attitude. In addition, teaching materials must facilitate students to develop critical and creative thinking skills [17], STEM approach [20], attractive packaged teaching materials in accordance with the development of junior high school students [24], and packaged in digital forms that can be accessed offline [22]

The preparation of teaching materials begins with an analysis of the material from the earthquake theme. The earthquake theme is material that is integrated with wave material and energy in terms of facts, concepts, procedural and cognitive. Facts and concepts are reinforced by the task of making earthquake machines and simple seismographs as aspects of competence in technology and engineering literacy. Epistemic competency arises in several features such as "Let's Try", "Let's Practice" and Earthquake Mitigation material. The teaching material in this epistemic aspect is a form of integration with aspects of content and practice on technology and engineering literacy. Three STEM strands are always related to aspects of mathematical literacy, namely using a scale, determining the epicenter of the earthquake, determining earthquake magnitude, calculating the length, width and height of the building, calculating the area of an earthquake house and calculating the wavelength of a seismograph graph. Some features are shown in Figure 1.

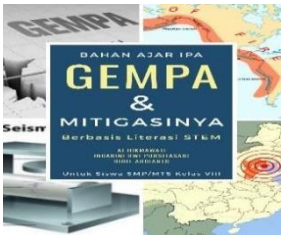


(a) (b) (c)

(d)

Figure 1. Some of the Features contained in Teaching Materials, 1 (a) and 1 (b) the "Ayo Kita Mencoba" feature, 1 (c) "Ayo Kita Berlatih", and 1 (d) " Tugas Proyek" Features

The drafting of teaching materials is arranged systematically, starting from the introduction, contents, and closing. The introduction consists of cover, introduction, table of contents, basic competency, and learning objectives. The content section includes 5 sub-themes, each end of the sub-theme is inserted into practice questions and / or project assignments to train student STEM literacy. The closing section consists of a summary of the material, competency test, bibliography, glossary and author's biodata. Teaching materials are also colored with the character of a little girl named "Tana" to guide the stages of learning that must be done. The cover and Tana icons in teaching materials are shown in Figure 2. In this teaching material, the dimensions of STEM literacy can be found both in the material presentation, learning videos, practice questions, competency tests, and project assignments. The dimensions of STEM literacy refer to the PISA 2018 framework which includes aspects of knowledge, competence, attitudes and the STEM component itself.



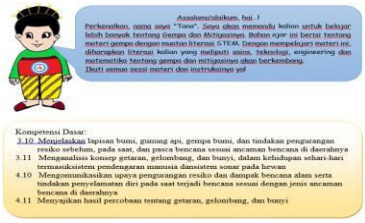


Figure 2. Cover and Icon "Tana"

Teaching materials that are already in digital form are assessed by expert validators in terms of material and media. This assessment involved 3 experts, namely Physics lecturers and Geology Engineering lecturers as material experts, and Computer Science lecturers as media experts. Table 1 shows the results of material and media experts' assessment.

Table 1. Data on Teaching Material Evaluation by Material Experts and Media Experts

No.	Assessed Indicators	Percentage of Expert Appraisal
1.	Material	97.50%
2.	Media	87.50%

Based on the table, the average percentage of material evaluations by experts is 97.50% including the eligibility of contents 90.88%, presentation of 97.17%, language 100% and literacy content of STEM 100%. The first expert validator provides suggestions for adding evaluation models that can be inputted and there must be mathematical formulations in some of their scientific concepts. The second expert validator suggested that the unclear image be repaired then be equipped with clear information, and each question given in the competency test and practice questions must be completed with the answer key. The two expert validators concluded that teaching materials could be used with revisions.

The assessment aspects of the media by experts include 80% cover design, 85.71% teaching material design content, 87.50% software engineering, and 100% audio visual communication. So that the average percentage of all aspects of the assessment is 87.50%. According to expert validators, overall learning media applications have been user friendly and optimal. In order for the media to be better, it needs to be equipped with application usage guidelines, in the table of contents the exercises and evaluations are added, providing information on minimum hardware specifications that support the application so that teaching materials can be used to the fullest. The validator added that the cover of teaching materials is equipped with class design specifications and must be tested on various hardware specifications. The media validator concluded that teaching materials could be used with revisions.

The validation test of teaching materials was carried out by 15 science, physics and geography teachers. Assessment data were analyzed using the CVR method from Lawshe [28]. Teaching materials are declared valid if the minimum CVR value is calculated by 15 validators greater than 0.49. Table 2 shows the table of validation results obtained from the teacher using CVR.

Table 2. CVR Value Data Average Validation of Teaching Materials by Teachers

No.	Assessed Indicators	CVR average	Criteria
1.	Material	0.88	VALID
2.	Media	0.87	VALID

Based on the table, it was found that overall the average CVR value for material validation which included the feasibility of content, presentation, language and STEM literacy characteristics was 0.88. The smallest aspect of the CVR value is the aspect of content and language feasibility. The assessment of the aspect of content eligibility is quite low, especially in points 1c, 2a, 2d. In items 1c, 2a, and 2d, there are 3 validators who answer "no" so that the average CVR value is 0.6. Point 1c about the depth

of the material, with the criteria of the material presented must be in accordance with the level of education of the SMP / MTs and in accordance with Basic Competence. Some validators answer "no" because the material contained in teaching materials according to them is too deep and not in accordance with Basic Competence in class VIII. Point 2a about the accuracy of concepts and definitions. The evaluation criteria for this item are the concepts and definitions presented do not cause many interpretations and are in accordance with the concepts of definitions that apply in the theme of the Earthquake. Some earthquake terms are indeed displayed in different terms such as faults and faults, earthquakes and miss, etc. This is so that the vocabulary in the term earthquake theme becomes diverse and rich. While item 2d about the accuracy of images, diagrams and illustrations. Some images that are unclear and inefficient are then replaced with better images and captions.

In the language aspect, the lowest CVR values are found in items 8b, 10 and 11a of 0.6. In point 8b the effectiveness of the sentence, some teachers argue that the sentence used is still too complex and has not been directly targeted. In this case, some sentences that have not been effectively corrected. Criteria in points 10 and 11a, namely the language used in explaining a concept must be in accordance with the level of cognitive development of students. So that some concepts that are not clear are meant to be reviewed again and improved according to the cognitive development of students. Overall the teaching material is materially valid because the average CVR value is more than 0.49.

As with media validation by experts, the average CVR value of the media includes aspects of cover design, content design of teaching materials, software engineering and audiovisual communication of 0.87. The highest CVR value is in the aspects of cover design and software engineering. While the aspect of audiovisual communication has the lowest CVR value. The assessment item that gets the lowest score is found in item 19 about creative in the following ideas pouring ideas. The theme of the earthquake raised in this teaching material actually contains a different idea than usual. The material presented is integrated material from class VII and class VIII. In addition, teaching materials are packaged and added features adapted to STEM literacy content. The display of teaching materials also seems motivating because it is colored with an icon of a picture of a little girl named "Tana" representing the author to guide all the steps in learning in the teaching material.

The media in teaching materials are declared valid because the CVR value is greater than 0.49. So it is hoped that this teaching material can be used as a companion and can overcome the lack of depth in the material contained in the teaching materials currently used [8]. The lack of features and maintainable that cannot be accommodated by the application tools used in this study can be updated in the next study. Testing of teaching materials is given after the teaching material is declared valid. Trials go through 3 stages, one to one trial, small group trial and field trial to 44 students of class IX who have balanced low, medium and high abilities [29]. Students in the One to one trial test amounted to 3 people, the small group trial amounted to 15 people divided into 3 groups of low, medium and high ability students, and the field trial was given to one class of students totaling 26 people. The trial process in each stage consists of observing the teaching material followed by filling out the questionnaire. Figure 2 shows a comparison of the results of the trials at each stage. One to one trial trial results were 81%, 85% small group trials, and 86% field trials. if the percentage of responses is in the interval of 82% - 100%, then the results of the trial include a very good category [30]. Thus it can be said that the one to one trial trial, the feasibility category is still in good criteria, while in the small group trial and consecutive field trials the teaching material category increases very well.

Furthermore, the feasibility of teaching materials is supported by the results of tests of students' understanding of teaching materials. Understanding test was given to 26 class IX students in the form of multiple choice questions about the understanding of the teaching materials developed. The highest percentage of understanding is found in the sub-theme of the Impact of Earthquake Damage, while the lowest percentage is in the sub-theme of Earthquake Magnitude. Understanding criteria for teaching materials included in the easy-to-understand criteria are in the Indonesian sub-themes and the Ring of Fire and the Impact of Earthquake Damage. While the sub-themes of Seismograph, Earthquake and Earthquake Mitigation, including criteria meet the readability requirements.

Teaching materials that have been validated by experts, teachers and tested to students are then implemented. The implementation of teaching materials involved 16 class VIII students. Teaching materials are given using the blended learning learning model. Blended learning is a learning model that combines distance learning with face-to-face [31]. The choice of this model is based on the teaching

material developed that can be studied remotely and the content can be accessed online. This teaching material consists of five sub-themes, if taken into account, the effective meeting will last for 5 meetings. By using blended learning in the experimental class, learning is carried out into 3 meetings. The next 2 meetings were filled with questions and answers and completion of project assignments. Completion of project assignments takes one week for the finishing process. So the meeting becomes shorter and more effective. The deepening of the material can be learned by students at home, while the completion of tasks can be discussed with the teacher and his classmates. Likewise for the completion of project tasks.

One of the purposes of this study was to determine the effectiveness of STEM literacy achievements of class VIII students after studying digital teaching materials on the theme of the Earthquake developed. The effectiveness of the use of teaching materials can be seen from the differences in the results of STEM literacy before and after the teaching material was implemented in students [23]. The pre-test and post-test instruments provided were in the form of STEM literacy questions in reasoned multiple choices in 25 questions. Question items are empirically validated using the SPSS program. Students conduct a pre-test to obtain students' initial ability to STEM literacy about the theme of the Earthquake. Table 3 shows the results of descriptive statistical analysis using the SPSS program.

Table 3. Results of Descriptive Analysis of Student Posttest Pretest Data

	Pre-test	Post-test
Minimum Value	32	68
Maximum Value	66	94
Average value	52.50	76.50
Normality test	0.200	0.200
Homogeneity Test	0.648	
Different Test	0.000	
N-gain	49.34	

Based on the results of the analysis, it was found that the data was normally distributed with a significance of more than 0.05. So that it can be done a different test between the results of the pre-test and the results of the post-test. The results of different tests show that there are differences between the results of the STEM literacy and post-test students' STEM. This difference has a tendency to increase. This appears in the minimum value and the maximum value of the results of the pretest and posttest. The minimum and maximum values of STEM student literacy tend to increase after students use digital teaching materials developed. This increase is seen in the difference between the pretest and posttest mean values with an N-gain value of 49.34. This value is less effective because its effectiveness is between 40-55 according to Hake [32]. According to Melzer, N-gain achievement of STEM student literacy is included in the medium category. Thus it can be stated that digital teaching materials on the theme of the Earthquake can improve student STEM literacy.

The achievement of STEM student literacy is also supported by the results of increasing students towards the use of instructional materials developed. Data on student acquisition results are obtained from filling in student work journals. This student journal contains a collection of assignments on digital teaching materials that are packaged like LKS. This task is divided into 5 appropriate sub-themes which are divided into sub-themes of teaching materials. The lowest average results in sub-theme 3 amounted to 73.53, while the lowest average value in sub-theme 4 was 89.15. The low average value of the sub-themes depends on the material content of the sub-themes which are quite difficult related to earthquake magnitudes. In sub-theme 4 about the impact of earthquake damage, students can use their reasoning well in answering all the questions contained in the journal.

The low value of the effectiveness of STEM literacy achievement is influenced by internal and external factors. Internal factors come from students' motivation and cognitive abilities. While internal factors can be identified from the learning strategies applied, the characteristics of teaching materials, the availability of supporting learning media, and the availability of time. In this study, the sample used,

students who were treated using instructional materials developed were only 16 people. Actually, the number of these samples is less ideal for implementation in one class, which averages 32 people. This happens because in the middle of the data collection process, many students cannot participate in the learning process or data collection, because their activities clash with other activities that they must follow. So that there are only 16 students taking optimal data collection. This can be used as a reference for the next study with the number of students. The use of learning models also needs to be considered so that the effectiveness of learning appears. For the development of teaching materials, so teaching materials can be developed to be more interactive.

Questionnaire students are given to find out students' responses to the teaching materials developed. The questionnaire involved 32 students from the experimental class and the control class. The filling process is carried out after students do learning using developed teaching materials. Based on the distribution of questionnaire filling results, it was found that the percentage of student responses to teaching materials reached 77% with good criteria.

The teacher questionnaire was given to find out the teacher's response to the use of digital teaching materials developed. The questionnaire involved 14 science teachers. The filling process is carried out after the teacher observes the teaching material developed. Then the teacher fills out the teacher response questionnaire on the instrument. Based on the distribution of questionnaire results, it was found that the percentage of teacher responses to teaching materials reached 85.32% with very good criteria

4.Conclusion

It can be concluded that students experienced an increase in STEM literacy between before and after the implementation of the earthquake theme teaching material with N-gain of 49.34 in the less effective category. The ineffectiveness of the results of this test is caused because the sample of students is too little and has not been compared with a class that uses old teaching materials. Therefore, further research on the implementation of the use of teaching materials uses two classes, namely the experimental class and the control class. Then the sample of students given treatment should also be multiplied, so that the value of effectiveness is more significant.

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