Validity of Physics Teaching Materials Based on STEM to Improve Climate Literacy of High School Students

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Abstract *– This study aimed to develop physics teaching material based on Science, Technology, Engineering, and Mathematics (STEM), which criteria valid. The study employed is development research using the ADDIE development model. The ADDIE which consists of five stages, namely Analyze, Design, Development, Implementation, and Evaluation which is limited to three stages, namely; (1) analysis, (2) design, and (3) development for aspects of validity. The validity of the teaching material was determined with the aid of experts and learning practitioners. The validation results of physics teaching material based on STEM were categorized as very valid with a validity level of 92% and student response with a score of 85%. Based on the results obtained, the climate change physics teaching materials based on STEM are suitable for improving high school students' climate literacy.*

Keywords*: Validity; Teaching Material; STEM; Climate Literacy*

INTRODUCTION

Climate change has been one of the most pressing global challenges in recent years. Everything related to climate change is predicted to disrupt social systems and infrastructure, even ecosystems (Nabilah & Hariyono, 2021). One of the impacts of uncontrolled climate change can lead to natural disasters such as major floods caused by heavy rains (Nayan et al., 2018). The impacts of climate change are faced by the current generation and future generations, and perhaps the impacts caused are more worrying (Gunamantha & Dantes, 2019). Human-caused climate change has affected the occurrence of extreme climates in every region worldwide (IPCC, 2021).

Communities need to be empowered to assess scientific evidence and understand the impact of their actions (Mittenzwei et al., 2019), particularly students from elementary to upper levels who are potential future leaders. They need to understand and respond to the effects of climate change (Oliver & Adkins, 2020). When public attention to climate change becomes essential, there is a need to improve climate literacy in students, which is one of the factors in identifying community solutions in the face of climate change (Hestness et al., 2019).

Some studies show that students' climate literacy level needs improvement. Climate literacy analysis on aspects of competence of high school students in Surabaya shows that climate literacy in indicators identifies scientific phenomena as having a low category and a medium category for indicators explaining scientific phenomena and using scientific evidence (Nabilah & Hariyono, 2021). High school students' perceptions of climate change in Samboja, East Kalimantan, showed that most students did not fully understand climate change and only a third of the students in the study thought climate change was a global threat. (Nugroho, 2020).

Previous research has shown a need to improve climate literacy and include content about climate change in learning. One way to improve student climate literacy is the use of PjBL (Project Based Learning) based modules in learning, showing significant results between high school level students

and junior high school level students on the cognitive scale for climate literacy. Junior high school students also show an increase in climate literacy on an affective scale, self-efficacy, and behavior (DeWaters et al., 2014).

Education plays an essential role in improving the knowledge and character of students (Nabilah & Hariyono, 2021). Education has been identified as the most important predictor of individual awareness of climate change (Lee et al., 2015). Knowledge has been proven to increase awareness of climate change (Shi et al., 2016). Understanding climate change and its effects can be essential in making decisions for future adaptation and mitigation efforts (Harker-Schuch et al., 2020). The low literacy of science, which includes climate literacy in Indonesia, can be caused by many factors related to the educational process. One of the factors is the selection of teaching materials used in the learning process (Rusilowati et al., 2016). Teaching materials are needed to guide students in problem discovery and assist students in understanding learning.

Learning in the era of the industrial revolution 4.0 needs to use an approach that can improve 4C skills, namely critical thinking, creativity, communication, and collaboration (Pratiwi & Ramli, 2019). One approach that can improve 4C skills is the STEM approach, which integrates more than one discipline: science, technology, engineering, and mathematics. The use of STEM approaches in learning focuses on solving real-life problems related to everyday life through inquiry and collaboration with peers in building an effective learning environment (Savran Gencer & Dogan, 2020). One learning objective of using a STEM approach is to improve STEM literacy in students. Learning using a STEM approach improves STEM literacy (Yasin et al., 2018). One of the STEM characteristics that must be seen in the learning process is EDP, namely Engineering Design Process (Ulum et al., 2021). The impact of using the EDP process in learning and teaching can improve students' skills in scientific problem-solving (Syukri et al., 2018).

Climate issues are particularly relevant for today's students because they cover many interconnected themes. The climate change material in the 2013 curriculum is included in the sub-subject matter of global warming taught in class XI of High School. Integrating the four components of STEM in climate change-related problem-solving activities using the help of teaching materials can increase students' awareness of climate change, improve critical thinking and analysis, and provide opportunities for collaboration and teamwork. It is an essential component of the 21st century.

The above problems indicate a need to improve students' climate literacy through teaching materials. One of the efforts to create teaching materials that can improve students' climate literacy is integrating STEM approaches into these teaching materials. This research was conducted to produce physical teaching materials for STEM-based climate change materials that are valid and can be used to improve the climate literacy of high school students.

RESEARCH METHODS

The research method used in this research is development research using the ADDIE development model, which consists of five stages, namely Analyze, Design, Development, Implementation, and Evaluation which is limited to three stages, namely; (1) analysis, (2) design, and (3) development for aspects of validity.

The analysis stage is the initial stage carried out in this study. Analyzing the needs

of teaching materials and curricula used in schools is the first step taken by researchers. The results obtained are then used to develop physics teaching materials based on STEM climate change material.

The design stage is carried out by formulating learning objectives and developing concepts and product content. At this stage, a product concept design will be obtained by emphasizing the integration of the four STEM aspects and their relation to climate literacy.

The development stage is a realization activity of products designed in the previous stage by going through several stages, namely collecting materials, making products, testing the validity of teaching materials by experts, and revisions. Validity tests are conducted to assess the feasibility of products that students can use in the learning process.

The data collection instrument is in the form of a validation sheet for teaching materials. Two expert validators and one practitioner validator were validating STEM-based climate change teaching materials. The assessment of the validity of teaching materials consists of four aspects: the content aspect, the presentation aspect, the language aspect, and the visual aspect.

Analysis of the data used for the validation results of experts and practitioners was carried out by (1) determining the score using a Likert scale of 5 options, (2) calculating the average total score of each aspect of the assessment of all validators using equation 1, (3) converting the average score obtained into a qualitative with it a five style shown in Table 1, and (4) calculate the validity value in the form of the percentage indicated in Table 2.

$$\bar{X} = \frac{\Sigma x}{n} \qquad (1)$$

Notes:

$\bar{X}$ = Total score of each validator
Σx = Average score
n = Number of validators

Table 1. Product Criteria Interval Conversion

Range of Values	Category
$Xi + 1{,}8\ Sbi < \bar{X}$	Very Good
$Xi + 0{,}6\ Sbi < \bar{X} \leq Xi + 1{,}8\ Sbi$	Good
$Xi - 0{,}6\ Sbi < \bar{X} \leq Xi + 0{,}6\ Sbi$	Fair
$Xi - 1{,}8\ Sbi < \bar{X} \leq Xi - 0{,}6\ Sbi$	Poor
$\bar{X} \leq Xi - 1{,}8\ Sbi$	Very Poor

(Monita & Ikhsan, 2020)

Calculates the validity value in the form of a percentage by using the equation as follows:

$$P = \frac{f}{N} \times 100\% \qquad (2)$$

Note:
P = Scoring percentage
f = Scores obtained
N = Maximum score

The validity of the teaching materials in this study is based on the validity criteria in Table 2 below.

Table 2. Categories of Validity of Teaching Materials

Range of Values	Category
90% - 100%	Very Valid
80% - 89%	Valid
65% - 79%	Fair
55% - 64%	Invalid
≤ 54%	Very Invalid

(Purwanto, 2012)

After experts validate the teaching materials, empirical trials are carried out. The trial was carried out on 37 students of SMA Negeri 5 Samarinda class XI MIPA 6. The scale used for students' responses to teaching materials is shown in table 3 as follows.

Table 3. Likert Scale Student Response Questionnaire

Criteria	Score
Very Good	5
Good	4
Fair	3
Poor	2

Very Poor	1

(Fraenkel et al., 2012)

The categories for student response are shown in Table 4 as follows.

Table 4. Student's response category criteria

Range of Values	Category
85% - 100%	Very Good
69% - 84%	Good
53% - 68%	Fair
37% - 52%	Poor
≤ 36%	Very Poor

RESULTS AND DISCUSSION

This research produced a STEM-based climate change material physics teaching material product to improve the climate literacy of high school students. The STEM-based teaching materials that have been developed had validated by three validators: two expert validators and one practitioner validator. The results obtained are based on the stages of development of the ADDIE model, which are limited to three stages for the aspect of validity, described as follows.

Results

The analysis stage is carried out in two stages: needs analysis and curriculum analysis. In the needs analysis, the stages carried out are by using literature studies and observations. Literature studies are carried out by analyzing journals, proceedings, and thesis research related to the climate literacy of high school students. The results show that the climate literacy rate of high school students in Indonesia is in the moderate category. The observation results showed that the curriculum used was the 2013 curriculum. In addition, the teaching materials used in learning are only oriented toward the material and practice questions. Teaching materials commonly used in the learning process have not linked material to problems that exist in everyday life. Curriculum analysis is carried out to adjust competency standards, core competency, and basic competency to formulate indicators of achievement of competence and learning objectives.

The design stage is carried out after the analysis stage. This stage begins with the formulation of student competency achievement indicators and learning objectives based on core and essential competencies. After that, a concept map is formulated to describe the sub-subjects that will be presented in the teaching materials. Teaching materials for physics of STEM-based climate change materials are designed contextually with designs equipped with compelling images and illustrations of problems in everyday life related to climate change material. Other stages are compiling practice questions, designing instructions for teaching materials, compiling glossaries, and compiling evaluations.

The development stage obtained STEM-based climate change teaching materials that have been compiled and are ready to be validated. The teaching materials developed to consist of three parts, namely, 1) the initial part, which includes the front cover, preface, table of contents, list of images, instructions for the use of teaching materials, core competencies, essential competencies, indicators of competency achievement, learning objectives, and concept maps; 2) the content section includes an introduction, the content of climate change material which contains content related to problems in daily life by STEM aspects, as well as student worksheets; 3) the final section includes a glossary, a bibliography, and a back cover. The average score of each aspect of the assessment by expert validators and practitioners of the developed teaching materials is presented in Table 5 as follows.

Table 5. Expert and Practitioner Validation Results

Assessment Aspects	Score	Score Interval	Category
Content	55,33	X > 50,40	Very Good
Presenting	54,33	X > 50,40	Very Good
Language	46,00	X > 42,00	Very Good
Graphic	70,00	X > 63,00	Very Good

The percentage for the results of the validation test of STEM-based teaching materials in each aspect is presented in Figure 1 as follows.

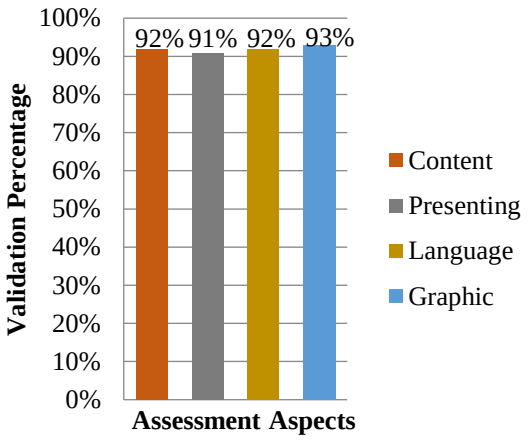

Figure 1. Percentage of Validity Test Results of Teaching Materials for Each Aspect

The analysis results from the validation of experts and practitioners on STEM-based physics teaching materials that have been developed can be seen in Table 6 below.

Table 6. Expert and Practitioner Validation Results

No	Validators	Percentage	Criteria
1.	Validator 1	96%	Very Valid
2.	Validator 2	87%	Valid
3.	Validator 3	93%	Very Valid
	Average	**92%**	Very Valid

The average percentage of validity of teaching materials by validators is 92%. Based on the criteria for the validity of teaching materials, according to Purwanto (2012), then the physics teaching materials of STEM-based climate change materials are included in the good category and are declared very suitable for use in learning.

The results of students' responses to the teaching materials that have been developed can be seen in table 7 as follows.

Table 7. Student Response Results in Every Aspect

Assessment Aspects	Percentage (%)	Category
Display	87	Very Good
Language	85	Very Good
Content	85	Very Good
Function	83	Good
Average	**85**	**Very Good**

Based on Table 5 and Figure 1, it can be seen that the STEM-based physics teaching materials that have been developed contain four aspects of assessment, namely aspects of content, presentation, language, and graphics. The validated STEM-based climate change teaching materials can be seen in Figure 2.

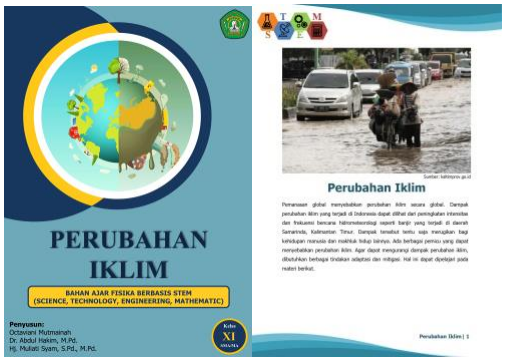

Figure 2. Physics Teaching Materials Based on STEM on Topic Climate Change

Discussion

The product developed in this study is a STEM-based climate change teaching material for class XI SMA/MA students. The teaching materials developed in this study are prepared by adjusting to the needs and the applicable curriculum, namely the

2013 curriculum. It is intended so that the physics teaching materials for climate change material developed can be used as a supporting book in school learning. This research is development research that refers to the ADDIE development model. The ADDIE development model consists of five stages, namely Analyze, Design, Development, Implementation, and Evaluation which is limited to three stages, namely; (1) analysis, (2) design, and (3) development for the following aspects of validity.

There are two stages in the analysis stage: needs analysis and curriculum analysis. In the needs analysis, the stages carried out are literature studies and observations. Literature studies are carried out by analyzing journals, proceedings, and thesis research related to the climate literacy of high school students. The results show that the climate literacy rate of high school students in Indonesia is in the moderate category. Especially for high school students in East Kalimantan, students' climate literacy is sufficient for the knowledge aspect and the high category for behavioral and attitude aspects. The results of a study conducted by Nugroho (2020) related to the perception of climate change, showed that some high school students in Samboja, East Kalimantan did not fully understand climate change and only one-third of the high school students in the study thought that climate change was a global threat.

Based on the results of observations at SMA Negeri 5 Samarinda, data was obtained that the curriculum used in schools is the 2013 curriculum. In addition, the teaching materials used in learning are only oriented toward the material and practice questions. The teaching materials used have not linked the material to the problems that exist in everyday life. Especially in the material on global warming needs to be explained in detail about the sub-material of climate change and has not linked to the problems that exist in the surrounding environment. The use of STEM-based teaching materials has never been used in students. Following the 2013 curriculum, climate change material is a sub-subject of global warming for class XI SMA semester 2. This analysis is carried out by adjusting competency standards, core competencies, and essential competencies to formulate indicators of competency achievement and learning objectives.

The design stage begins with the formulation of indicators of competency achievement and learning objectives based on core and essential competencies. After that, the researcher formulates a concept map describing the sub-subjects presented in the teaching materials. STEM-based physics teaching materials are designed with designs equipped with interesting illustrative images of problems in everyday life regarding climate change material. This stage obtained a product of STEM-based climate change teaching materials that have been compiled. This teaching material consists of three parts, namely the beginning, the content part, and the end. In the beginning, it consists of a front cover, a preface, a table of contents, a list of pictures, instructions for using teaching materials, core competencies, essential competencies, indicators of competency achievement, learning objectives, and a concept map. The content section consists of an introduction that contains an overview to open students' insights about climate change in general and its impact on the surrounding environment. The description of the material in the developed teaching materials is presented in detail and arranged systematically to make it easier for students to understand the material better. Content available, “Kamu

Perlu Tahu!" contains general information related to climate change material, and "Info Sains" contains science information related to climate change material. In addition, there is content regarding "Uji Diri" which contains the evaluation of each sub-material on climate change, and content "Tindakan" which contains directions for simple actions that students can take to reduce the impact of climate change. Other content, such as "Ayo, Pikirkan!" contains problems regarding climate change in the surrounding environment and questions that students must do. Content about "Refleksi Diri" contains directions so students can reflect on the attitudes that will be carried out after studying the climate change material. Content "Rangkuman" contains a summary of the material, and content "Uji Kompetensi" contains multiple-choice questions to determine students' abilities after studying climate change material. In addition to the material, there is a student worksheet containing problem-solving activities related to climate change. The final part consists of a glossary, a bibliography, and a back cover. The completed STEM-based physics teaching materials are then validated to determine the developed teaching materials' feasibility.

The development stage is carried out with due diligence by experts. The feasibility test of STEM-based physics teaching materials is carried out by two expert validators and one practitioner validator. The expert validator consists of two physics education lecturers from Mulawarman University and one practitioner validator, a physics teacher at SMA Negeri 5 Samarinda. The average percentage of validity of teaching materials by validators is 92%. Based on the validity criteria proposed by Purwanto (2012), STEM-based climate change teaching materials are included in the very valid category. The aspect of product feasibility assessment consists of 4 aspects: the content aspect, the presentation aspect, the linguistic aspect, and the visual aspect. The content aspect aims to assess the content components in the teaching materials.

The presentation aspect aims to assess the collapse of the subject matter and the quality of the presentation of the material. The linguistic aspect aims to provide an assessment of language use and the level of readability of STEM-based physics teaching materials. The graphic aspect aims to provide an assessment of the appearance of teaching materials and the design of the contents of STEM-based physics teaching materials. The score for the content aspect was 55.33, with a percentage result of 92%. The score for the presentation aspect was 54.33 with a percentage result of 91%. The score for the linguistic aspect is 46.00 with a percentage result of 92%. The score for the graphic aspect was 70.00 with a percentage result of 93%. The score interval in each aspect of the assessment of teaching materials can be seen in table 1. Based on the product criteria category stated by Monica & Ikhsan (2020) in table 1, the STEM-based physics teaching materials developed fall into the excellent category. Teaching materials that have been validated by expert validators are then validated empirically by providing teaching materials that have been developed in students of SMA Negeri 5 Samarinda class XI MIPA 6 as many as 37 students. Based on the results of the student response questionnaire analysis, it can be seen that the average student response score in each aspect of the assessment is in the very good category with a percentage of 85%. The percentage score in each aspect in a row is 87%, 85%, 85%, and 83%.

Based on the results obtained from this study, this research is in line with the

research conducted by Syahiddah et al (2021) which obtained the result that the STEM-based physics e-module was declared valid and feasible for use with very high criteria so that it could be implemented into various schools and could be used as teaching material for students.

CONCLUSION

Based on the results and discussions, the STEM-based physics teaching materials developed for high school students are categorized as very valid. They are suitable for improving high school students' climate literacy, with a score of 92% and a student response of 85%. The advice that can be given in this study is that it is necessary to implement this teaching material in schools to determine the level of effectiveness of teaching materials to improve the climate literacy of high school students.

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