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Development of STEM-Based Physics Learning Media Materials on Temperature and Heat to Improve Students' Mastery of Concepts

Ayu Safitri Melita[1*], Aris Doyan[1,2], Muh Makhrus[1]

[1] Physics Education Study Program, FKIP, University of Mataram, Mataram, Lombok, West Nusa Tenggara, Indonesia.
[2] Master of Science Education Study Program, University of Mataram, Indonesia.

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Corresponding Author:
Ayu Safitri Melita
ayumelita39@gmail.com

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Abstract: The research conducted in this development is aimed at producing STEM-based learning media products in physics subjects, especially in temperature and heat materials to improve students' mastery of concepts that are valid, practical, and effective. The design of this study uses a 4D model in the form of Design, Define, Disseminate, and Development. With STEM-based learning media in the form of a digital calorimeter as a product being developed. Test instruments, validation sheets, and response questionnaires were used as data collection techniques. Evaluation of product validity was carried out by three media experts and material experts and used Aiken-V as a method of analysis. The practicality of the product is analyzed using the practicality test while the effectiveness is obtained by increasing students' mastery of concepts with ¬N-gain. The results of the validator's assessment of the digital calorimeter media showed an average result of Aiken-V of 0.94 which was very valid. The average results for the practicality assessment of the developed media can be seen from the student response questionnaire which shows a value of 4.51 in the fairly practical category. The average result for the effectiveness of the developed media can be seen from the increase in mastery of the concept, which is equal to 0.60 with high criteria. So it can be concluded that STEM-based physics learning media to improve students' mastery of concepts is valid, practical, and effective.

Keywords: Concept mastery; Digital calorimeter; Media calorimeter

Introduction

Learning Natural Sciences (IPA) is a process of systematically finding out about nature in order to master a collection of knowledge in the form of facts, concepts, principles, discovery processes and have a scientific attitude (Sevtia et al., 2022). Physics is one of the domains of ethnoscience and a branch of science that studies natural phenomena including materials, humans, and interactions between humans and other materials (Astuti et al., 2021). This is because physics is considered as a body of knowledge that is useful for the development of technology, discoveries, and other sciences.

One of the factors supporting education is the availability of learning media. Media is an effective supporter in helping the learning process occur (Rahma, 2019). Learning media has a very important role in learning activities because of its role as an intermediary so that the messages conveyed by the teacher can be absorbed and well understood by students (Rindani, 2021). The use of learning media will really help the effectiveness of the learning process and the delivery of messages and lesson content (Gawise et al., 2022).

Specifically for the field of science, one suitable learning approach is the STEM (Science Technology Engineering Mathematics) approach (Dewati et al., 2019). STEM is an acronym for Science, Technology, Engineering, and Mathematics. As an approach, STEM is an approach in education where Science, Technology, Engineering, Mathematics are integrated with the educational process focusing on solving problems in real

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everyday life as well as in professional life (Davidi et al., 2021). Character in STEM learning is the ability of students to recognize a concept or knowledge in a case (Mulyani, 2019). As in learning physics, STEM helps students to apply technology and assemble an experiment that can prove a law or scientific concept. This conclusion is supported by data that has been managed mathematically (Agustina, 2017).

Understanding concepts in learning is indeed very important to find out how well students understand learning that is in accordance with educational goals (Zahroh et al., 2020). The basic concept errors received cause students difficulties in solving problems (Purwasih et al., 2021). Mastery according to the Big Indonesian Dictionary is understanding or ability to use knowledge, intelligence, etc. Concepts are real ideas that enable one to classify objects or events that are usually stated by definition. Concepts are the basis for higher mental processes to formulate principles and generalizations (Umam et al., 2020). A student must know the relevant rules based on the concepts he has acquired to be able to solve problems.

According to Azizah et al. (2020) conceptual understanding is one of the main aspects that need attention in learning physics because it can affect student learning outcomes. Concept is an abstraction that represents a class of events, objects, or things that have something in common. In other words, the concept is the result of the thoughts of a person or group of people expressed by definitions, laws and theories. In the process of learning physics, teachers must be able to make students not only memorize and know about physics concepts, but also must be able to make students understand and understand these concepts, and link their interrelationships with other concepts (Ikbal, 2022).

Teachers are required to have media and strategies for creating active and effective learning and have the right strategy for teaching physics material so that students are able to achieve the desired indicators (Bakhruddin et al., 2021). Previous research has proven that learning media can improve the quality of students' thinking. Gagne stated that media are various types of components in the student's environment that can stimulate their thinking skills for learning (Hasibuan et al., 2022). While Briggs argues that all physical devices can present messages and stimulate students to learn. Consideration of the use of media in learning is one of the important roles of a teacher to find alternatives for students in learning so as to be able to attract students' learning interest (Dewantara et al., 2020).

Experiments in school laboratories generally still use analog measuring devices. Analog measuring instruments cause students to experience difficulties because the data obtained is not quite right. Errors that cause inaccurate data are errors in tool calibration, errors in scale readings and accuracy in using tools (Suantini et al., 2021). One of the experiments that still uses analog measuring devices is the calorimeter. The development of learning media must be carried out continuously by the teacher in dealing with every technological development (Widianto et al., 2021). The development of media in the form of a digital calorimeter will be applied to the physics lesson of temperature and heat.

Based on the description regarding the problem of students' low mastery of concepts, it is necessary to conduct further research using STEM-based learning media to improve students' mastery of concepts. The use of learning media can also minimize a case of misconceptions in students (Bastomi et al., 2017). Because of this, the teacher as a facilitator plays an important role in the learning process (Yuniani et al., 2019).

One way to use technology in learning is the use of technology as a medium in the learning process. This is an important reference for the development of STEM-based physics learning media to improve students' mastery of concepts. The hope is that the development of this media can become one of the guidelines especially for teachers in the learning process which is able to improve students' mastery of concepts.

Method

This study uses research and development methods (Research and Development) to determine the feasibility, practicality and effectiveness of the developed learning media. The design of this study uses a 4D model in the form of 4 stages, namely: Define, Design, Development, and Dissemination.

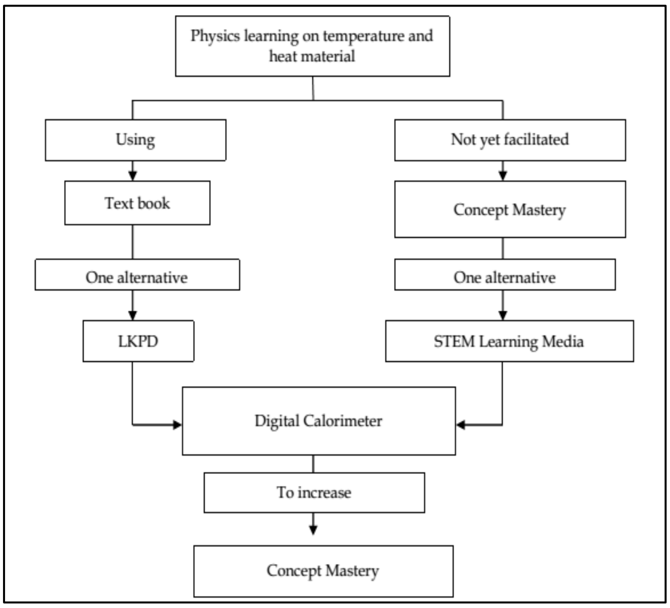

Figure 1. Research flow using physics learning media

This research was carried out at MA Al Aziziyah Putri West Lombok with the research subjects being students of class XI IPA 2 for the 2021/2022 academic year. The data collection instrument that was applied was to provide a validation sheet to the validator for the learning media being developed. In addition, a response questionnaire to determine the practicality of learning media and test instruments used to determine the effectiveness of learning media. The research flow is shown in Figure 1.

The validity of learning media is calculated based on the assessment of the three experts using the Aiken's V Formula as Formula 1.

$$\frac{\sum S}{n\,(c-1)} \quad (1)$$

Table 1. Validity Assessment Criteria (Akbar, 2013)

Aiken's V score	Category
0 – 0.20	Very invalid, should not be used
0.21 – 0.40	Invalid or may not be used
0.41 – 0.60	Invalid, it is recommended not to use it because it needs major revisions
0.61 – 0.80	Valid, or can be used but needs minor revision
0.81 – 1.00	Very valid or can be used without revision

The reliability of the learning media assessment results is based on agreement between validators (inter rater reliability). Agreement between validators was analyzed using a percentage of agreement. Learning media is said to be reliable if the percentage of agreement is ≥ 75%, the percentage of agreement formula is as follows.

$$PA = 1 - \frac{A-B}{A+B} \times 100\% \quad (2)$$

Description:

PA = Percentage of Agreement

A = The frequency of assessments by experts giving high scores

B = The frequency of assessments by experts giving low scores

Data on the practicality of learning media will be obtained from observation sheets of the implementation of learning by observers, and then will be analyzed to determine the average percentage with the Equation 3.

$$\%Average = \frac{\text{The total score of the raters}}{\text{Maximum total score}} \times 100\% \quad (3)$$

After being analyzed, interpretation of the data will then be carried out based on practicality criteria. The level of practicality of the instrument is determined based on the Table 2.

Table 2. Practicality Criteria (Fathirma'ruf. et al., 2022)

Percentage Value Range (%)	Practicality Level
0 – 20	Very impractical
21 – 40	Less practical
41 – 60	Practical enough
61 – 80	Practical
81 – 100	Very practical

Analysis of the effectiveness of the media consists of an analysis of the increase in mastery of concepts and critical thinking skills. To analyze the increase, the N-gain value analysis will be used as follows (Formula 4).

$$N - gain = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \times 100\% \quad (4)$$

With the following N-gain acquisition categories.

Table 3. Criteria for obtaining N-gain (Kurniawati et al., 2020)

Interval	Criteria
$g > 70$	High
$30 \leq g \leq 70$	Medium
$g < 30$	Low

Result and Discussion

Validity

Validation was carried out to determine the feasibility of STEM-based learning media to improve mastery of the concept consisting of 3 experts related to the learning media that had been developed. Whether or not a learning media is appropriate can be seen when the validity assessment shows a valid category.

Media Calorimeter Validation

Table 4. Aiken-V Score Data for Digital Calorimeters

Items	Aiken-V score	Criteria
1-13	0.94	Very valid

Table 5. Percentage of Agreement Score Data for Digital Calorimeters

Instrument	Percentage of Agreement			$PA_{average}$	Category
	PA_{12}	PA_{13}	PA_{23}		
Digital Calorimeters	97	99	84	93%	Reliable

The digital calorimeter is designed for use in learning using the STEM-based inquiry based learning method. The resulting product is a digital calorimeter that can be used when conducting experiments in the laboratory to measure temperature and can also be used as a substitute for a thermometer.

Based on Table 4, the digital calorimeter validation results are categorized as very valid according to the three validators. The average validation component based on Aiken-V is 0.94 which indicates that the digital calorimeter media is very valid to be used to facilitate the improvement of students' mastery of concepts. Table 5 shows agreement between validators, it is found that the product developed has a percentage of agreement > 75%, namely 93% or is included in the reliable category which shows consistency between the three validators, which are very appropriate and aligned.

LKPD Validation

LKPD which is designed to support the use of digital calorimeter media and which facilitates questions with indicators of mastery of the concept. LKPD is assessed based on several important components of LKPD development, namely related to structure and appearance. Details of validation scores and reliable percentages in Table 6.

Table 6. Aiken-V Score Data for LKPD

Items	Aiken-V score	Criteria
1-13	0.70	Valid

Table 7. Percentage of Agreement Score Data for LKPD

Instrument	Percentage of Agreement			$PA_{average}$	Category
	PA_{12}	PA_{13}	PA_{23}		
LKPD	99	89	78	92%	Reliable

Based on Table 6 it is known that the STEM-based LKPD is very valid and relevant for use in any experimental implementation related to concept mastery and critical thinking skills. Based on the results it can be seen that the average score of Aiken-V is 0.85 with a very valid category. Based on Table 7 the percentage of agreement, which is an agreement between validators, it is known that LKPD has a high level of relevance with a percentage of 92%, which means that LKPD is reliable.

Table 8. Aiken-V Score Data for Syllabus

Items	Aiken-V score	Criteria
1-13	0.80	Valid

The syllabus is an outline lesson plan that contains core competencies, basic competencies, learning materials, competency achievement indicators, time allocation, and learning resources used. The syllabus validation results are presented in Table 8.

Table 9. Percentage of Agreement Score Data for Syllabus

Instrument	Percentage of Agreement			$PA_{average}$	Category
	PA_{12}	PA_{13}	PA_{23}		
Syllabus	89	98	58	81%	Reliable

Based on Table 8 it is known that the STEM-based syllabus with the inquiry-based learning model is valid and relevant for use in any experimental implementation related to concept mastery. Based on the results it can be seen that the average score of Aiken-V is 0.80 with a valid category. Then, for the agreement scores between validators or the percentage of agreement in Table 9. It is known that the syllabus has a high level of relevance with a percentage of 81% in the reliable category.

Lesson plans (RPP) validation

RPP development is carried out based on STEM-based learning with the Inquiry Based Learning (IBL) model. RPP was developed based on the basic competence of temperature and heat material. The phases listed in the RPP are adjusted to the STEM-integrated inquiry-based learning phase. RPP validation results are presented in Table 10.

Table 10. Aiken-V Score Data for RPP

Items	Aiken-V score	Criteria
1-10	0.85	Very valid

Table 11. Percentage of Agreement Score Data for RPP

Instrument	Percentage of Agreement			$PA_{average}$	Category
	PA_{12}	PA_{13}	PA_{23}		
RPP	92	95	97	94%	Reliable

Based on Table 10, it is known that the STEM-integrated inquiry-based learning model-based RPP is valid and relevant for use in any experimental implementation related to concept mastery. Based on the results it can be seen that the average score of Aiken-V is 0.7 with a valid category. In Table 11 regarding the percantegae of agreement data it is known that the RPP has a high level of relevance with a percentage of 94% in the reliable category.

Test Instrument Validation

The concept mastery test instrument is arranged in the form of multiple choice of 10 questions. Each question is adjusted to 5 indicators of mastery of the concept. The concept mastery instrument was validated by three experts. The validation results are presented in Table 12.

Table 12. Aiken-V Score Data for the Concept Mastery Test Instrument

Test instruments	Aiken-V Score	Criteria
Concept Mastery	0.79	Valid

Table 13. Percentage of Agreement Score Data for Concept Mastery Test Instruments

Instrument	Percentage of Agreement			$PA_{average}$	Category
	PA_{12}	PA_{13}	PA_{23}		
Concept Mastery	89	98	88	91%	Reliable

Based on Table 12, it was found that the validation score for the concept mastery instrument was very valid and relevant to use in any experimental implementation related to concept mastery. Based on the results it can be seen that the average score of Aiken-V mastery of the concept is 0.79. Based on Table 13, it shows agreement between validators that all products developed have a percentage of agreement > 75%, namely 91% referred to in the reliable category.

Practicality

The practicality of the developed STEM-based learning media is known from the implementation of learning, student response questionnaires, and teacher response questionnaires. The implementation of learning can be seen from the learning that was successfully carried out during learning using digital calorimeter media.

Implementation of Learning

Table 14 shows that the learning process for two meetings using digital calorimeter media obtained an average score of 70% in the practical category. This indicates that each stage of learning at each meeting is carried out properly.

Table 14. Data on the Results of Learning Implementation Analysis

Class	Percentage of Learning Implementation (%)	
	P1	P2
XI IPA 2	70	70

Student Response Questionnaire

After learning is carried out, students are given a response questionnaire to fill out. The statements listed in the questionnaire consist of 6 questions related to STEM-based digital calorimeter media that are interesting, easy to operate, and support the learning process. From the analysis per category can be seen in Table 15.

Table 15. Data on Analysis Results per Category of Student Responses

Item			Average score
Interesting Digital Calorimeter	Ease of Use	Supporting Learning	
4.18	4.71	4.62	4.51

Based on Table 15, the score for the digital calorimeter statement is attractive with an average value of 4.18, indicating practical. Whereas in the statement of ease of use digital kmedia calorimeter with an average score of 4.71 indicates practicality. Furthermore, statements support learning with an average score of 4.62 indicating practical. This shows that students' responses to the use of digital calorimeter learning media in learning with an average value of 4.51 are stated to be practical.

Teacher Response Questionnaire

The teacher was also given a response questionnaire to fill out. The statements listed in the questionnaire consist of 10 statements related to the use of STEM-based digital calorimeter media in learning. Data from the analysis per category can be seen in Table 16.

Table 16. Data from Analysis Results for Each Category of Teacher Response

Item			Average score	Category
Learning Aspects	Aspects of the Digital Calorimeter	Aspects of LKPD		
4.3	4.0	4.2	4.16	Good

Based on Table 16, the score for statements on aspects of using digital calorimeter media based on STEM and LKPD in learning is at an average score of 4.3 which indicates that learning is in the practical category. Furthermore, the teacher also agrees that using STEM-based digital calorimeter media is able to make students interested and happy in learning and is in the range of a score of 4.3. Meanwhile, the average score of all items is 4.16. This indicates that the teacher's response to learning using STEM-based digital calorimeter media has received a very good response.

Effectiveness

In testing the effectiveness of STEM-based physics learning media, it can be seen from increasing mastery of concepts by using a test instrument in the form of multiple choice questions. Based on this, the following results were obtained.

Concept Mastery

In the concept mastery test, the results of the test analysis were divided into three, namely the results of the pretest-posttest, the results of the N-gain test and the results of the LKPD. At this stage the limited trial subjects used were 1 class with 32 students. Based on the results of calculating the average pretest-posttest score, the N-gain results for each indicator of mastery of the concept are obtained from Table 17.

Table 17. Results of N-gain Analysis Pretest-Posttest Mastery of Concepts

Class	N	Concept Mastery			Description
		Pretest	Postest	N-gain	
XI IPA 2	32	2.96	9.40	0.61	High

Based on the calculation of the average score in Table 17, it was found that the students' prior knowledge was 2.96. Meanwhile, after learning the improvement experienced by students. The posttest result was 9.40 which means students experienced a high increase in mastery of concepts. The N-gain test shows an increase in students' mastery of concepts after learning using the developed STEM-based digital calorimeter. Students experienced an increase which was still in the high category. This data shows that the use of STEM-based digital calorimeters is effective in increasing students' mastery of concepts. Supporting data for this increase is obtained from the results of the LKPD and the learning process using a digital calorimeter.

Table 18. Conceptual Understanding Score for Each Indicator on LKPD

LKPD	Indicator					Total	Category
	1	2	3	4	5	Average	
1	3.78	3.78	3.62	3.75	3.84	3.44	Practical
2	3.78	3.87	3.65	3.75	3.81	3.56	Practical

In addition to analyzing the average score of the pretest-posttest mastery of the concept, it also analyzed the average score of the acquisition for each student worksheet mastery of the concept in the learning process using a digital calorimeter. Table 18 shows the results of the learning scores of students facilitated by LKPD in increasing mastery of concepts in the range of average values of 3.44 on LKPD I and 3.56 on LKPD II. In the learning process using a digital calorimeter facilitated by LKPD, it was found that the practicality score was in the practical category.

Conclusion

Based on the results of research using the 4D model from the define to disseminate stages in the development of physics learning media in the form of digital calorimeters, it can be concluded that STEM-based physics learning media on temperature and heat materials to improve students' mastery of the concepts developed are included in the very valid category. This was obtained from the validation results by three validators which showed an average Aiken-V score of 0.94 and 93% reliable for all supporting devices, namely syllabus, lesson plans, worksheets, and instruments for mastering concepts. Then for the practicality assessment of STEM-based physics learning media obtained from the results of the practicality test of 70% implementation of learning in each phase with the responses of students and teachers in the very good category, as well as the acquisition of the LKPD results in the learning process, namely 3.77. And for the effective category to increase students' mastery of concepts, this can be seen from the results of the effectiveness test from the average N-gain score for mastery of concepts, which is 0.61 in the medium category.

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