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Development of STEAM-Based Human Respiratory System Teaching Materials to Improve Students' Critical Thinking Skills

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Abstract

This study aims to examine the validity of teaching materials and the effectiveness of STEAM-based Human Respiratory System teaching materials in improving students' critical thinking skills. The type of research used is research and development (R&D) which uses the ADDIE development model with a trial design of teaching materials using One Group Pretest-Posttest Design. The research subjects consisted of two material expert validators, one media expert validator, 7 subject teachers, and 143 class VIII junior high school students in Comal Pemalang Regency. The research instruments were in the form of needs analysis sheets, teaching materials validation sheets, and assessment instruments. The results of the validity of teaching materials by material and media experts obtained a very valid category. The results of the N-gain analysis on the critical thinking indicator obtained a score of 0.68 in the medium category. STEAM-based Human Respiratory System teaching materials are feasible to use in learning and effective in improving students' critical thinking skills.

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INTRODUCTION

The 21st century is known as the age of knowledge, where knowledge is used as the basis for meeting the needs of life in various aspects. One of them is the development of knowledge-based education. Fundamental changes occurred very quickly and were different from the way of life in the previous century (Wijaya, 2016). Preparing students to adapt to the 21st century is a complex task. Globalization, technology, and changing environments add new urgency to the acquisition of skills and knowledge that students need to be successful in the 21st century (Tican, 2019).

Students must be equipped with the knowledge and skills to do jobs that machines cannot. Skills such as creativity, critical thinking, problem solving and cooperation will form a kind of universal literacy needed to survive in the 21st century (Akgunduz, 2015). Critical thinking skills are one of the 21st century skills that students must have in order to be able to compete in the future. Critical thinking is a thinking process to evaluate and analyze other people's ideas (Putra, 2015). Critical thinking requires an analysis of the information received by providing rational reasons (Ridho et al., 2020).

However, the problem that often occurs is that the curriculum is generally designed with a broad target material so that educators are more focused on completing the material without thinking about the extent of student understanding. The scope of the material is very broad not worth the time given to study the material. As a result, students have difficulty understanding the material and make the score of their learning outcomes unsatisfactory, one of which is on the material of the human respiratory system. Also, the lack of active student involvement in learning causes students to find it difficult to think critically in seeing phenomena that exist in everyday life (Gherardini, 2016).

The results of observations in schools indicate that there are limited resources and learning media in schools so that some teachers use the existing media more often even though they have not been able to support teaching and learning activities properly. The teacher is still the center of learning, meaning that the teacher more often conveys and explains the material. The methods used are also less varied, so that students are not only bored with the material presented, but their learning motivation also decreases. Teaching materials that should be used by students to make it easier to learn learning materials have not been able to support student understanding because they are still theoretical.

In order for students to have 21st century skills, they must be supported by all elements in the field of education. It takes good cooperation between students, teachers and related education offices to jointly develop these skills. One of the efforts to train 21st century skills is to use the STEAM approach in learning in schools. STEAM is a learning approach that integrates the fields of science, technology, engineering, art and mathematics, so that students are given a holistic understanding of the interrelationships of the fields of science through learning experiences (Henriksen, 2017). The implementation of STEAM in learning is very useful, not only being able to develop the cognitive aspect, it can also train other skills that can be used to compete and face challenges in the future (Nurhikmayati, 2019).

The previously well-developed STEM approach was integrated with the arts field with the aim of providing opportunities for students to be creative and innovate in the form of artistic creativity that is integrated into learning outcomes (Buinicontro, 2017), as well as increasing student involvement, creativity, innovation, problem solving skills. problems (Liao, 2016; Bernstein, 2015), in addition to enhancing employability skills (e.g. teamwork, communication, adaptability) needed for career and economic advancement (Colucci, 2017).

Students consider the integration of the STEAM approach in project-based learning to be interesting, exciting, and fun. The integration of STEAM in project-based learning on acid-base materials can develop students' soft skills, namely cooperation, critical thinking, environmental care, responsibility, adaptability, creative thinking, leadership, and honesty (Apriliana, 2018). This study aims to examine the validity of teaching materials and the effectiveness of STEAM-based Human Respiratory System teaching materials in improving students' critical thinking skills.

METHOD

The type of research used is research and development (R&D) with the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The research subjects consisted of 2 material expert validators, 1 media expert validator, 7 subject teachers, and 143 class VIII students from SMPN 1 Comal, SMPN 2 Comal, and SMPN 4 Comal Pemalang Regency. The research instrument consists of a needs analysis sheet, a teaching material validation sheet, and an assessment instrument in the form of multiple choice questions that have been adapted to critical thinking indicators including: interpretation, analysis, conclusion, evaluation, explanation and self-regulation.

The first stage in the research is the analysis stage, which includes needs analysis and curriculum analysis to determine the conditions, characteristics, needs and constraints in the learning process. The second stage is the design stage, this stage is carried out by compiling the design of teaching materials, including: determining the form of teaching materials, compiling the framework of teaching materials, and compiling the necessary instruments. The third stage is the development stage, this stage is carried out to develop teaching materials, validation is carried out by 2 material experts and 1 media expert. Then a limited-scale trial was conducted on 10 students of class IX at SMPN 4 Comal.

The fourth stage is the trial stage, this stage is the implementation of teaching materials for class VIII students of SMPN 1 Comal, SMPN 2 Comal, and SMPN 4 Comal, totaling 143 students. The field trial aims to test the effectiveness of teaching materials in improving critical thinking skills. The test design of teaching materials uses One Group Pretest-Posttest Design. The fifth or final stage of the ADDIE development model is the evaluation stage. This stage is carried out by providing formative evaluation and summative evaluation. Evaluation of teaching materials to find out how successful STEAM-based Human Respiratory System teaching materials are in improving critical thinking skills.

Data analysis from expert validators using quantitative descriptive refers to the guidelines developed by Sugiyono (2017) for the assessment of 4 categories (4 scales) by looking for percentage scores. Product quality categories can be presented in the form of Table 1.

Table 1. Category Score 4 Scale

Score Interval	Category
81.25% < Validation Score ≤ 100%	Very valid
62.5% < Validation Score ≤ 81.25%	Valid
43.75% < Validation Score ≤ 62.5%	Not valid
25% < Validation Score ≤ 43.75%	Invalid

The effectiveness of teaching materials in improving students' critical thinking skills was obtained from the pretest and posttest scores. Then to find out the difference in the level of improvement in students' critical thinking skills, a normalized gain index calculation (N-gain test) is carried out. N-gain can be calculated using the following formula:

$$\text{Ngain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximal score} - \text{Pretest Score}}$$

The results of the N-gain analysis can be categorized into three categories which are presented in table 2.

Table 2. Category of N-gain Score

Score	Category
g>0.7	High
0.3<g≤0.7	Medium
g≤0.3	Low

RESULTS AND DISCUSSION

Validity of Teaching Materials

Teaching materials are validated or assessed by material experts and media experts. Validation of teaching materials is carried out to obtain assessments, suggestions and comments from expert validators which are then used as material for improvement and refinement so that teaching materials are suitable for use by teachers and

students in learning. The results of the validation of teaching materials can be presented in Table 3

Table 3. The results of the validation of teaching materials by material and media experts

Expert	Rated aspect	Percentage	Category
Material expert	Content Feasibility Aspect	88%	Very valid
	Feasibility of Presentation Aspects	89%	Very valid
	Language Eligibility Aspects	85%	Very valid
	STEAM Aspect	88%	Very valid
	Critical Thinking Aspects	91%	Very valid
Average		88%	Very valid
Media expert	Teaching Material Format	88%	Very valid
	Teaching Material Cover Design	96%	Very valid
	Teaching Material Content Design	93%	Very valid
Average		93%	Very valid

Based on data in Table 3, it is known that the average percentage of validity scores by the two material experts is 88% with a very valid category. This shows that the material validator assesses the completeness, breadth, and depth of the material in accordance with KD 3.9. and 4.9. Teaching materials must have complete theoretical and practical material so as to allow learning to take place optimally (Safitri, 2021). Concepts are presented in a coherent manner starting from easy to difficult and from simple to complex so that it will make it easier for students to learn the material. The presentation of material is interactive and participatory which is useful for encouraging student involvement in learning.

The sentences used are simple, can represent the content of the information to be conveyed. Teaching materials are communicative and interactive, where information is conveyed in an attractive language that can evoke a sense of pleasure when students read it. The language used in teaching materials must be in accordance with the level of student development so that it will facilitate understanding of learning materials (Permatasari, 2021).

Teaching materials are integrated with the STEAM approach, where the Human Respiratory System material is linked to the fields of science, technology, engineering, arts and mathematics. The field of science contains all subject matter for the Human Respiratory System, ranging from human respiratory organs, respiratory mechanisms, to disorders of the Human Respiratory System. In addition to containing all subject matter, the integration of science can play a role in developing basic science process skills such as observing, measuring, and communicating (Munawar et al., 2019). With the development of these basic skills, an attitude of curiosity, pleasure and willingness to make discoveries by means of exploration and investigation will be formed (Mu'minah, 2020).

The field of technology, contains all equipment or technology that plays a role in solving problems related to the material of the Human Respiratory System, one of which is spirometry technology. The integration of technology by providing material on spirometry aims to provide an illustration that there is a tool or method that can be used to determine respiratory health. Technology makes humans to create innovations that are used to solve problems and meet needs in a faster and better way (Wahyuningsih et al., 2020).

The field of engineering science contains methods or techniques used to solve problems. Engineering is an engineering of technology (Wahyuningsih et al., 2020). Integration of Engineering in teaching materials, one of which is conducting a spirometry examination. A tool in the form of a spirometer is needed for spirometry examination that can measure respiratory volume. By doing this, students will know the volume of air breathing.

The field of arts, raises students' creativity by carrying out artistic activities such as drawing,

designing, painting. Art integration is used to create a poster. The integration of the arts into STEAM learning helps students explore knowledge and skills with other disciplines by encouraging the problem-solving process (Bush, 2019). The goal of integrating art into the STEAM field is to create a new approach that involves the beauty of working with creative design to solve real-world problems (Belbase et al., 2021).

And in mathematics, it is used to calculate respiratory rate and calculate respiratory volume. The respiratory rate is the number of breaths counted from inhaling to exhaling. Meanwhile, to calculate the respiratory volume, you can use a spirometer by observing the results shown by the spirometer. Mathematical integration is not only limited to calculations, but is also used as a method to solve problems by applying calculations and comparisons (Taylor, 2017).

STEAM-based respiratory system teaching materials were developed in order to improve students' critical thinking skills. Therefore, the material in the teaching materials has been given activities that can stimulate critical thinking skills. For example, in each sub-chapter the material is always given basic questions and also a "let's find out" feature (Figure 1) this will make students curious and think about answering these questions. From this curiosity will create curiosity so that students will think about finding solutions to solve these problems. Learning outcomes do not only focus on understanding the material, but how a learning process becomes meaningful and can provide provisions for students to face problems in real life (Ridho et al., 2020).

(a) (b)

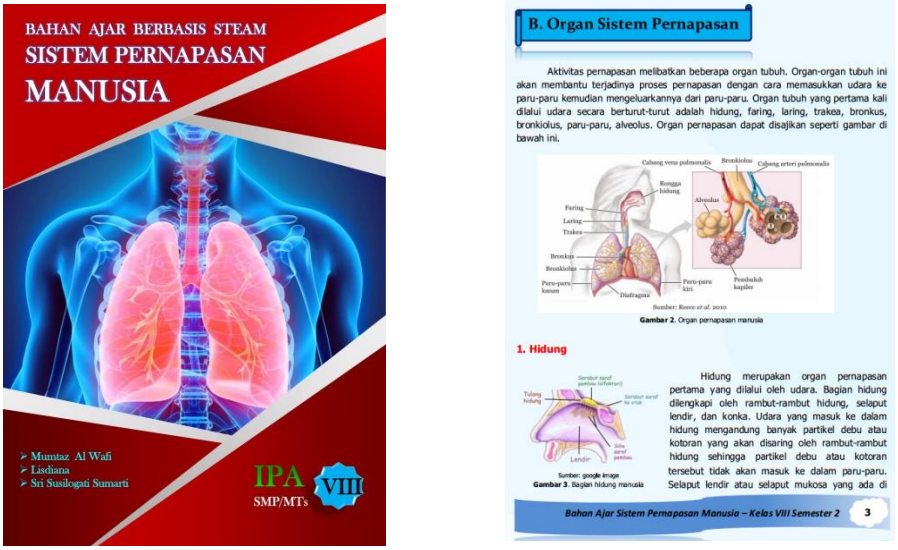
Figure 1. a. Material display, b. Display features "Yuk, cari tahu"

Based on data in Table 3. shows that the percentage of validation of teaching materials by media validators is 93% with a very valid category. The assessment of the media validator includes aspects of the format of teaching materials, cover design of teaching materials, and design of content of teaching materials, these three aspects are categorized as very valid. The format of teaching materials is in accordance with ISO standards. The teaching material is in the form of a printed book that has a size of B5 (176 x 250 mm). The size of the teaching material is in accordance with the content of the teaching material which is not too much so that it gives the impression that the size of the teaching material is proportional, not too big and not too thin.

The cover design is very simple with a red base color combined with blue objects (Picture 2). The size of the letters in the titles of teaching materials is more dominant and proportional than the size of the letters of the author's name by not using too many letter combinations, this aims for harmony and consistency. The cover of the teaching materials does not include many image

objects, there are only images of human respiratory organs. The object is able to describe the content or teaching material.

The teaching materials use the Tahoma font with a font size of 11, the use of letter variations such as bold, italic, and all capital is not excessive. This aims to provide readers with comfort when reading teaching materials. The placement of titles, subtitles, illustrations, and image captions is not excessive. The placement of layout elements is consistent based on a pattern that gives a harmonious and dynamic impression. Illustrations or pictures are in accordance with the material (Figure 2) and can explain the topic of discussion and can attract readers. Pictures can increase students' interest and attention in learning so that students will focus optimally on the subject matter (Irwandani, 2016).



(a) (b)

Figure 2. a. Book cover display, b. Display images on teaching materials

Overall, STEAM-based Human Respiratory System teaching materials received a good assessment from material and media expert validators with a very valid category. In line with the research of Utomo et al. (2020) with the STEAM-based module validity test obtained a score of 89.8%. Another study by Sofia et al. (2020) shows the results of the STEAM-based module validity test obtaining a score of 87.2%. This means that STEAM-based Human Respiratory System teaching materials are feasible and can be used in the learning process by teachers and students by making improvements based on suggestions or input from the validator.

Effectiveness of Teaching Materials

Teaching materials that have been developed with a very valid category are then implemented for class VIII students consisting of 143 students. The effectiveness of teaching materials in improving students' critical thinking skills is determined by measuring student learning outcomes through pretest and posttest. Students' critical thinking skills were assessed using 10 multiple choice questions given at the beginning of the lesson as a pretest score and at the end of the lesson as a posttest score.

The evaluation questions have been adapted to critical thinking indicators, including: interpreting, analyzing, evaluating, concluding, explaining, and self-regulating. The questions tested are ten items with multiple choice type. Multiple choice questions were chosen because they can be used widely with a high level of objectivity and validity (Ridho et al., 2020). The results of the pretest and posttest then calculated the normalized gain index (N-gain test) which aims to determine the level of differences in the improvement of students' critical thinking skills. The summary of the description of the N-gain data analysis on each critical thinking indicator is presented in Table 4.

Table 4. Description of pretest, posttest and N-Gain critical thinking

Rated indicators	Average Pretest	Average Posttest	N-Gain	Category
Evaluation	3.29	7.27	0.59	Medium
Analysis	2.72	6.47	0.51	Medium
Interpretation	2.73	8.25	0.76	High
Conclusion	3.36	8.99	0.85	High
Explanation	2.94	7.87	0.70	Medium
Self Regulation	3.15	7.83	0.68	Medium
Average			0.68	Medium

Based on data in Table 4. shows that the average N-gain of the critical thinking indicator is 0.68 in the medium category. The indicator concludes and interprets the results of the N-gain in the high category, while other indicators such as analyzing, evaluating, explaining, and self-regulating get the results of the N-gain in the medium category. This shows that STEAM-based Human Respiratory System teaching materials can be said to be effective in improving students' critical thinking skills.

The critical thinking indicator that gets the highest N-gain result is the concluding indicator with a score of 0.85 in the high category. This shows that students are able to provide conclusions on a problem very well. Almost all students have been able to make conclusions correctly and completely. The focus of the indicator concludes that students can think critically by making the most appropriate decisions or conclusions based on the problems they face (Agustiana, 2019).

The improvement of students' critical thinking skills occurs because the application of STEAM-based teaching materials makes it easier for students to learn the material of the Human Respiratory System. The material presented is very close to the problems that often occur on a daily basis. For example, when you exercise, you will feel short of breath, this is because the body uses more oxygen and produces more carbon dioxide, so the body responds by breathing deeper and more often to take in the oxygen it needs. From the example above, students will know how to overcome this, namely by adjusting the breathing frequency.

The analyzing indicator gets the lowest N-gain result compared to other indicators, which is 0.51 in the medium category. This shows that students have not been maximal in identifying the relationship between statements, questions and concepts given in the questions. Agnafia's research (2019) shows that the analysis indicator gives a score of 31% which is in the low category, because students have not been able to identify the relationship between concepts and questions.

Analysis is the ability of students to clarify conclusions based on the relationship between statements, information and concepts with questions contained in a problem (Edi, 2021). The analytical ability obtained belongs to the medium category with the lowest N-gain score, this is due to several factors. Students are not used to being faced with a complex problem so that students find it difficult to solve the problem. Students have not been able to examine ideas by analyzing the relationship between statements and arguments in order to distinguish which statements are relevant and which are not. At the time of learning students have not been trained in solving problem-based problems so that students have difficulty in analyzing problems and how to solve these problems appropriately (Purwati, 2016).

Students' critical thinking skills that are less than optimal are caused because learning is still fixated on material that is rote and understanding. So that the focus of students in learning is to memorize lesson material or concepts and are not encouraged to develop thinking skills (Amijaya et al., 2018). This makes students unable to explore and develop their abilities. Teachers as facilitators have not been able to facilitate students to practice critical thinking skills, as evidenced by the learning model used is still lectures and discussions that make students bored and passive during learning (Ramdani et al., 2020). Students will find it difficult to have critical thinking skills if during learning activities in the classroom they do not use

learning models that are able to train critical thinking skills (Ridho, et al., 2020).

Critical thinking skills are closely related to science learning in schools. Critical thinking skills play an important role in science learning that students can use to apply science concepts in everyday life in a society filled with responsible attitudes (Santos, 2017). Therefore, students need to be trained to develop critical thinking skills so that students can solve the problems they face in learning and everyday life (Alfonso, 2015; Difficultyowarni, 2019). Critical thinking skills can help student learning success by analyzing a problem, synthesizing, and evaluating (Tiruneh, 2018).

CONCLUSION

Based on the analysis of the results and discussion of the research, it can be concluded that STEAM-based Human Respiratory System teaching materials are suitable for use in learning by obtaining very valid category validity. Teaching materials are effective in improving students' critical thinking skills with an average N-Gain on critical thinking indicators getting a score of 0.68 in the medium category.

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