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STEAM Essay Question Development Strategy in Sharpening Students' Critical Thinking Skills on Work and Energy Material

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Abstract: This research is a type of research and development using the Borg & Gall development model, which consists of the stages of research and initial data collection, planning, product draft development, initial field trials, revision of initial field trials, main product tests and finally product refinement. At this stage, an assessment instrument with STEAM will be produced, which will then be validated by a team of experts and tested on students to determine the validity, reliability, difficulty level and discrimination of questions. The trial subjects in this study were 20 students of class X-E3 of SMA N 1 Kota Jambi & 20 students of class X-E1 of SMA Adhyaksa 1 Kota Jambi. The products produced in this development research are based on the development results and trials carried out. It can be concluded that this STEAM-based assessment instrument has been declared suitable for use based on the results of the validation of the expert team and analysis of the questions.

Keywords: Assessment Instrument; Critical Thinking Skills; Effort and Energy; STEAM.

Introduction

Education and its systems are dynamic entities that continue to develop following the demands of the times. 21st-century education emphasises students' ability to adapt and respond to global changes [1]. Students need to acquire relevant skills to face the developments of this era, especially in the context of 21st-century skills such as critical thinking, innovation, collaboration, and communication [2].

[3] It is explained that thinking ability is the brain's capacity to receive and process input to produce a response. Critical thinking is considered a basic skill as important as reading and writing. According to Scrivan, critical thinking involves a process in which the results of observation and communication, as well as information and arguments, are assessed and analyzed [4]. This ability includes observation, analysis, interpretation, reflection, evaluation, reasoning, explanation, problem solving, and decision-making [5]. Critical thinking skills are essential for everyone to succeed and face the challenges that arise now and in the future. In addition, students with strong critical thinking skills often generate various ideas during the problem-solving process that are useful in producing answers.

According to [6], evaluation is a systematic effort in the form of valid and reliable data or information, which is then processed to reflect on educational programs and policy decision-making. [7] Learning evaluation is a comprehensive and ongoing procedure that collects data on learning outcomes and processes during and after students' educational experiences. Therefore, assessment is an inseparable element of the learning process, and its purpose is to make decisions that affect students [8]. In evaluation tools, it is important to measure students' abilities objectively and function as an evaluation tool that provides students with an understanding of their limits [9]. Progress in students' critical thinking skills can be evaluated by using appropriate descriptive questions.

[10] It is stated that critical thinking is a process that involves evaluating thoughts or ideas related to the concepts or problems presented. Critical thinking can also be interpreted as analyzing, separating, selecting, identifying, exploring, and developing activities or ideas towards deeper and more comprehensive dimensions. According to [11], the ability to think logically, carefully, methodically, and constructively is called critical thinking and is used to create opinions and make wise decisions. Standard questions are needed in physics learning like this to evaluate students' critical thinking skills [12].

Students' ability to think critically, collaborate with others, and communicate is measured by critical thinking assessment tools at levels C4 through C6. Levels C4 through C6 cover critical thinking skills such as analysis, judgment, and idea development. In addition, using levels C4 through C6 in descriptive questions can help develop assessment tools that measure students' thinking, collaboration, and communication skills more accurately and reliably. Critical thinking descriptive questions also utilize levels C3, C4, C5, and C6 to evaluate students' advanced thinking skills [13].

Bloom's Taxonomy is a framework that classifies educational objectives into six levels of cognitive processes, often abbreviated as C1 to C6. This framework helps educators systematically design, implement, and disseminate learning processes. Here is an explanation of each level: C1 – Remembering: At this level, students are expected to be able to remember and recall previously learned information. C2 – Understanding: At this stage, students not only remember information but also demonstrate understanding by explaining ideas or concepts

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in their own words. C3 – Applying: At this level, students use learned information in new or real-world situations. C4 – Analyzing: At this stage, students are expected to be able to break down information into smaller components to understand the structure and relationships between parts. C5 – Evaluating: Students make judgments or decisions based on certain criteria and standards at this level. C6 – Creating: This is the highest level in Bloom's Taxonomy, where students combine existing elements to form something new or original.

Descriptive questions play an important role for teachers by providing guidance to achieve learning objectives, providing information about student progress, and especially serving as an evaluation tool. Assessment tools are important in students' ability to understand teacher teaching. Therefore, teachers can design instruments to encourage students to improve their critical thinking skills and attitudes towards environmental conservation [14]. Essay assessment is often used to assess students' evaluative skills. This is in line with the definition of critical thinking according to [15], where in doing the test, mental involvement, strategy, and expression are required to solve problems, make choices, and take new ideas. However, Weaknesses in the essay writing style and unacceptable problems in the assessment process, especially the influence of subjectivity in test results analysis [16].

STEAM-based assessment instruments are evaluation tools designed to measure students' understanding and skills in applying **Science,** Technology, Engineering, Arts, and Mathematics (STEAM) concepts in real contexts. These instruments focus on theoretical knowledge and develop critical thinking, problem-solving, creativity, and collaboration skills at the heart of STEAM-based learning. This assessment can be a STEAM-based essay test, where students are asked to explain and analyze concepts through open-ended questions, such as how the principle of kinetic energy can be applied in designing a safe and innovative playground. In addition, project or performance assessment rubrics are used to assess STEAM-based projects, such as experimental design or engineering models, with criteria that include conceptual understanding, creativity, and solution effectiveness.

The science, technology, engineering, arts, and mathematics (STEAM) approach is a learning method that considers the characteristics of skills related to the scientific process. STEAM-based learning integrates five disciplines: science, technology, design, arts, and mathematics. Students can be more effective in solving real-world problems because their learning does not only focus on theory but also involves direct practice through projects that stimulate their science process skills [17]. Therefore, through STEAM-based learning, students' talents in scientific methods can be investigated.

The term STEM was introduced in the United States in the 1990s by *the National Science Foundation* (NSF). STEM is not just a grouping of educational fields but an integrated and holistic approach to solving problems. Over time, STEM evolved into STEAM with the addition of art by *the Rhode Island* School of Design. STEAM integrates art into STEM, allowing students to develop creativity and innovation in their learning. This highlights the brain's ability to be non-analytical and creatively solve problems in innovative ways [18].

STEAM is a learning approach designed to prepare children to face the challenges of the 21st century [19]. STEAM in development and research broadens perspectives, encourages innovation, and creates more holistic and relevant solutions to real-world challenges. The STEAM approach teaches students various skills, such as problem-solving skills, critical thinking, and collaborative skills [20]. STEAM learning can also make students analyze things, think critically, find solutions to problems, provide self-confidence, and improve communication, collaborative skills, and creativity.

Based on the background that has been explained, the researcher conducted a study to determine the results of the development of descriptive questions in the form of appropriate and reliable critical thinking skills questions, which were tested as an assessment tool related to high school physics questions, especially business and energy materials. The title of this study is "STEAM Essay Question Development Strategy in Sharpening Students' Critical Thinking Skills on Work and Energy Material."

Research methods

This research is a type of research and development (R&D). According to Sugiyono (2018), R&D is a research method that aims to produce a particular product and test its effectiveness. The method used in this study is in accordance with the researcher's efforts to develop instruments as research products. The study's main objective is to create an effective assessment instrument for use in physics learning, especially on business and energy in grade X of high school. The researcher conducted validity and reliability tests on the resulting product, which then went through a validation and improvement process to ensure its quality. The revised final product can be distributed and implemented in the context of physics learning at the high school level. In this study, the development procedure used was Borg & Gall, which went through 10 stages of research. However, the researcher utilized seven research phases, including initial research and data collection, planning, product draft development, initial field testing, initial field test revision, main product testing, and finally, product improvement.

Borg & Gall (2003) define 10 sequential steps in research and development as follows:

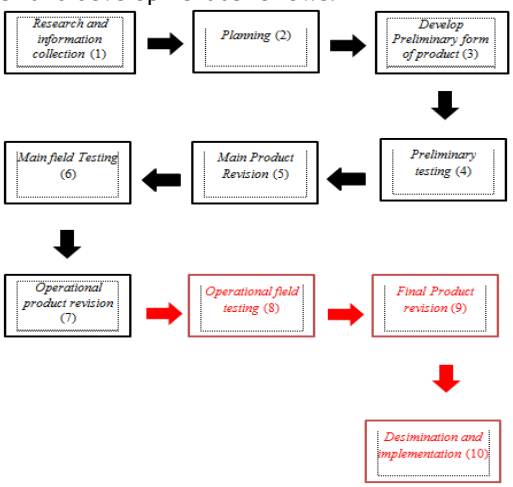


Figure 1. Borg & Gal development model.

In the validation stage of STEAM-based assessment instruments to measure critical thinking skills in business and energy materials, the data analysis aims to ensure the instrument's accuracy, reliability, and suitability to the learning objectives. Some analysis techniques that can be used include validity tests, reliability tests, difficulty level tests, and question discrimination.

Results and Discussion

The result of this study is the development of a STEAM-based assessment instrument consisting of several essay questions, contextual questions, and problem-based project tasks. The instrument's validity has been confirmed through validation by experts, resulting in a high feasibility level in measuring students' critical thinking skills. Limited trials showed positive responses from students and helped identify areas of improvement related to clarity of instructions and complexity of tasks. Furthermore, field trials confirmed that this instrument is effective in facilitating the development of students' critical thinking skills through the STEAM approach.

The critical thinking skills assessment instrument for business and energy materials has been revised based on expert comments and feedback from the questionnaire. After necessary adjustments, the instrument was deemed fit for testing. Following professional advice, the product has been modified and deemed fit for testing. After improvements were made to each material expert validation sheet, language expert validation, and assessment instrument expert validation, the following are the validation test results.

Table 1. Validation of results after fixes are made to the validator.

Aspect	∑ X Per Aspect	Maximum Score	Average Score	Criteria
Materials expert	32	40	80%	Quite Valid
Linguist	28	35	80%	Quite Valid
Instrument Expert Evaluation	39	45	86.6%	Very Valid
Overall Aspect Average			82.2%	Quite Valid

The results of the validation of material experts, language experts, and assessment instrument experts by the validator from Table 1 are presented in the form of a diagram as follows:

Based on Table 1, the material element obtained a percentage of 80% with a fairly valid category, according to the validation results of language experts, material experts, and assessment instrument experts by validator I. In addition, the linguistic component obtained an assessment of 80% with a very good category. Meanwhile, the assessment instrument aspect scored 86.6%, with a very valid category. The average was 82.2%, and most of these categories were valid. Therefore, the trial can be carried out using the feasibility of material experts, validation of language experts, and validation of assessment tool experts by validators.

The student perception questionnaire was conducted on class X-E3 students at SMAN 1 Jambi City and class X-E1 students at SMA Adhyaksa Jambi City with the following results:

Table 2. Perception Students from SMAN 1 Jambi City & SMA Adhyaksa 1 Jambi City.

School	Total score	Maximum Score	Average Score	Criteria
Jambi City	87	1000	68.70%	Quite Valid
Adhyaksa 1 High School, Jambi City	97	1000	69.70%	Quite Valid
	Overall Average		69.20%	Quite Valid

Based on Table 2, the results of the validation of the perception questionnaire of class X-E3 students at SMAN 1 Jambi City and students at SMA Adhyaksa 1 Jambi City show that the average overall perception questionnaire is 69.20% with a fairly valid category. This shows that the STEAM-based assessment instrument to measure critical thinking skills in business and energy materials shows students can think critically in learning.

The validation results show that the STEAM-based assessment instrument received a very valid rating from experts but was only quite valid according to students' perceptions. Several main factors can explain this difference. First, there are differences in perspective and understanding between experts and students. Experts assessed the instrument's suitability to the STEAM concept, critical thinking indicators, and academic and pedagogical question construction. In contrast, students assessed it from their experience when working on the questions.

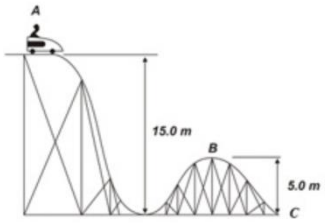
Students tend to give assessments based on their difficulty level and familiarity with the assessment model rather than its academic aspects. Second, suppose students are not previously familiar with STEAM-based assessments. In that case, they may feel that the questions are difficult to understand or different from the exam format they are used to. In addition, the complexity of STEAM-based questions also contributes to this perception because these types of questions often require higher critical thinking skills, such as analysis, evaluation, and synthesis (C4-C6 in Bloom's Taxonomy), so they feel more difficult for students than questions that only measure basic understanding (C1-C3).

Examples of questions containing STEAM to measure critical thinking skills in business and energy materials are as follows:

Question: Look at the picture below! An engineer designs a roller coaster. This roller coaster has a height of 15.0 meters and a top point of 5.0 meters. Calculate:

a. If the mass of the coaster roller weighs 55 kg, how much work does it do? Does the coaster roller fall from its highest point?

b. How are coaster rollers designed to provide a safe and engaging experience? (Evaluation)



Known: An engineer designs a roller coaster
hawal = 15.0 m
end = 5.0 m
m = 55kg
Requested:
a. How much work did the coaster roller do to get it down from its highest point?
b. How is the roller coaster designed to provide a safe and exciting experience?
Answer:

a. $W = mgh$
Looking for *H value:*
$h = h_{end} - h_{start} = 15.0 \text{ meters} - 5.0 \text{ meters} = 10 \text{ meters}$
Using that business formula:
$W = mgh$
$W = (55 \text{ kg}). (9.8 \text{ m/s2}) . (10\text{m})$
$W = 5390 \text{ J}$
So, the work is finished by the waterfall coaster roller from the highest point, which is 5390 J.

b. However, roller coasters must be designed to provide a safe and enjoyable experience considering several factors such as maximum safe speed, track length, curves and forces acting on passengers. Safety and excitement must be balanced, and roller coaster designs must comply with safety standards set by local regulators. Roller coasters can also be designed with exciting elements such as loops and sharp turns to enhance the high-speed experience. In addition, passengers must be equipped with safety systems such as seat belts and shoulder covers to ensure safety during the ride.

c. STEAM Elements
S = Physics principles involved in roller coaster rides, such as the concept of mechanical energy and the law of energy conservation.
T = Coaster roll design in question or picture
E = Discuss an engineer in designing a coaster roller
A = Picture on the question sheet
M = Calculate the Work done by the coaster roller using the work formula.

The initial step in this study was to conduct research and collect initial data, such as needs analysis through school observation and interviews. A needs analysis was conducted to find problems relevant to this study. The researcher interviewed physics teachers of SMA N 1 Kota Jambi class X-E3 and SMA Adhyaksa 1 Kota Jambi class X-E1. The results of this study indicate that teachers rarely measure their students' critical thinking skills through focused tests. Usually, teachers provide assessments by giving tests based on general practice questions using instruments available in textbooks.

Based on the results of interviews with teachers, it is known that the questions used are still at the lower to middle level of thinking skills, namely from understanding to applying concepts. Furthermore, to gain a deeper understanding of the concepts related to this study, the researcher studied business and energy materials. This study was conducted by researching and reviewing materials related to business and energy.

The second step is planning, which includes analysing the standard competency material to be developed, focusing on understanding the relationship between effort and energy through literature studies, observations, and simulations.

The next stage is validating the assessment instrument by material experts, language experts, and assessment instrument experts after the assessment instrument with STEAM was developed to test critical thinking skills in business and energy content. Two expert instructors who acted as validators, I and II, did this validation. In addition to providing input and recommendations on the assessment instrument being developed, the validators will fill out three expert validation questionnaires: one for material, one for language, and one for the assessment instrument, with ten questions per item. In the validation process with validator I, the researcher made two revisions based on suggestions and input to improve the instrument until it was considered valid. Six question items were changed due to considerations to describe the appropriate critical thinking skills better. The results of the revision by validator I can be seen in Table 4.10. Furthermore, the validation process by validator II was carried out with two revisions to ensure its validity, and the validation results are documented in Table 4.11. After that, the validator team assessed the instrument validation questionnaire and obtained a material validation index of 85% by experts. These results indicate that this product is worthy of being tested.

After experts have validated the instrument, the next step is to conduct a trial to assess the validity, reliability, level of difficulty, and discriminatory power of the questions. The research sample consisted of 20 students of SMA N 1 Jambi City class X-E3 and 20 students of SMA Adhyaksa 1 Jambi City class X-E1, who were given the instrument to use in the field trial.

After the trial data was obtained, the instrument was analyzed using Microsoft Office Excel 2010 to assess the validity, reliability, level of difficulty, and discriminatory power of the questions. All the test items for the instrument's validity were declared valid, with the degree of validity varying from moderate to high. The reliability of the test instrument was declared high because, based on the analysis at SMA N 1 Kota Jambi, the reliability value was 0.75. In comparison, at SMA Adhyaksa 1 Kota Jambi, the reliability value reached 0.88. This shows that this STEAM-based assessment instrument can be relied on to measure students' critical thinking skills.

Based on the research results, the average difficulty level of the SMA N 1 Jambi City exam questions is 0.60 with a moderate category, meaning the questions are not too easy or difficult. The average difficulty level of the SMA Adhyaksa 1 Jambi City exam questions is 0.55 with a moderate category, meaning the exam questions are not too easy or difficult. So overall, the level of difficulty of the STEAM-based assessment instrument is good. The analysis of the STEAM-based assessment instrument for the

learning outcomes of SMA Adhyaksa 1 and SMA Negeri 1 Kota Jambi shows that the ten questions have very good discriminating power. Thus, the instrument created has successfully distinguished students with high and low abilities in the subject matter.

After conducting validity, reliability, difficulty level, and STEAM-oriented assessment instrument tests consisting of 10 questions, it shows that the discriminatory power of the questions has met the standards well. Therefore, this instrument can assess students' critical thinking skills in understanding business and energy materials.

After analyzing the student perception questionnaire using STEAM-oriented assessment instruments at SMAN 1 Kota Jambi and SMA Adhyaksa 1 Kota Jambi, the results showed that the average overall questionnaire score reached 70.56% with a sufficient validity category. This shows that the assessment instruments used in both schools effectively measure students' critical thinking skills in understanding business and energy materials.

The difference between expert validation results indicating STEAM-based assessment instruments as "very valid" and students' perceptions that rate them as "quite valid" have been observed in several similar studies. For example, according to experts, in a study that developed the STEM-Oriented Science Critical Thinking Test Instrument, the instrument's validity results reached 1.00, indicating very high validity. However, the test questions showed a value of 0.227, indicating that although the instrument is theoretically valid, students' acceptance and understanding of the instrument may not be as optimal as expected.

These differences in results may be due to several factors, such as the level of complexity of the instrument, students' familiarity with the STEAM approach, and differences in interpretation between experts and students. Therefore, it is important to consider feedback from both parties in developing STEAM-based assessment instruments to ensure their validity and effectiveness in measuring students' critical thinking skills.

Conclusion

This study produced a result, namely a STEAM-based assessment instrument to assess critical thinking skills in the context of business and energy materials. Based on the development and testing that has been carried out, it can be concluded that the STEAM-based assessment instrument is considered feasible to use, as evidenced by validation by a team of experts and analysis of question items. The validation results from the validators were recorded at 82.2% with the category "Quite Valid". The evaluation of question items from each instrument trial showed that all questions in the assessment device were considered valid with the categories "Moderate" and "High". The average difficulty level of question items in SMA N 1 Kota Jambi and SMA Adhyaksa 1 Kota Jambi was in the "Moderate" category, with scores of 0.60 and 0.55, respectively. The discriminatory power of question items was assessed as "Very Good", and the reliability of the STEAM-based assessment instrument in SMA N 1 Kota Jambi reached the "High" category with a score of 0.78. In comparison, SMA Adhyaksa 1 Kota Jambi reached a score of 0.81. This shows that this STEAM-based assessment instrument can be trusted to measure students' critical thinking skills. Based on the analysis of the student perception questionnaire in working on the STEAM-based assessment instrument questions, students of SMAN 1 Jambi City and SMA Adhyaksa 1 Jambi City obtained an average of 68.70% of the total perception questionnaire with a fairly valid category so that the assessment instruments that have been developed in each school can measure students' critical thinking skills in business and energy materials.

Author's Contribution

Tiara Yunicha: Conceptualized and designed the study, collected data, analyzed data, wrote the article and revised the article; Dian Pertiwi Rasmi: Assisted in designing the study, revised the data analysis, and revised the article; Menza Hendri: Assisted in designing the study, revised the data analysis and revised the article.

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