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Evaluasi Pembelajaran Fisika Terintegrasi Seni dalam Pendekatan STEAM untuk Meningkatkan Literasi STEM dan Kreativitas Peserta Didik

(Evaluation of Art Integrated Physics Learning in a STEAM Approach to Improve STEM Literacy and Student Creativity)

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ABSTRACT. The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach is a development of STEM learning that integrates elements of art to strengthen students' creativity and conceptual understanding. STEAM-based physics learning is considered to be able to overcome abstract physics characteristics, but its implementation requires an appropriate and comprehensive evaluation system. This study aims to evaluate the learning of art integrated physics in the STEAM approach reviewed from STEM literacy and student creativity. The research uses a qualitative descriptive approach through literature study and analysis of art project-based physics learning practices. Data was collected from national and international journal articles, reference books, and relevant learning documents. Data analysis techniques are carried out through data reduction, data presentation, and conclusion drawn. The results of the study show that the evaluation of STEAM-based physics learning is more effective using authentic assessments, such as performance assessments, project assessments, portfolios, and science arts products. The evaluation is able to represent the understanding of physics concepts in a contextual manner and increase STEM literacy and creativity of students. This research is expected to be a reference in the development of a STEAM-based physics learning evaluation model in high schools..

INTRODUCTION

Physics is a core subject in the natural sciences that plays an important role in shaping students' logical, critical, and analytical thinking skills. However, learning physics is still often perceived as difficult and abstract due to the dominance of mathematical approaches and the lack of real context. This condition has an impact on low student engagement and learning outcomes [1].

The STEM approach comes as a solution through integrated and contextual learning. As it developed, STEM expanded to STEAM by including elements of art (Arts) as a means to enhance creativity, expression, and conceptual understanding. Art in physics learning serves as a medium for the representation of abstract concepts, such as the visualization of waves, light, and motion [6]. Although STEAM-based physics learning has great potential, the main problem lies in the evaluation aspect. Conventional evaluation systems that focus on written tests have not been able to measure learning outcomes holistically, especially in the aspects of creativity and STEM literacy [2]. Therefore, a study is needed on the evaluation of art integrated physics learning in the STEAM approach so that the learning process and outcomes of students can be assessed comprehensively.

Physics learning aims to develop understanding of concepts, science process skills, and scientific attitudes. Physics is not only concerned with the mastery of formulas, but also the ability to model natural phenomena, think critically, and solve problems. Therefore, physics learning needs to be designed in a contextual and meaningful way. Art has an important role in helping learners understand abstract concepts through visualization, symbolization, and creative expression. In physics learning, art can function as a medium for concept representation, a means of scientific communication, and a tool for reflection understanding. Art integration can also increase students' emotional engagement and learning motivation.

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The STEAM approach emphasizes cross-disciplinary integration between science, technology, engineering, art, and mathematics. STEAM encourages project-based learning, real problem-solving, and the development of creativity and innovation. In STEAM, art acts as a bridge between conceptual understanding and creative application[5].

RESEARCH METHODS

This study uses a qualitative descriptive approach with a literature study method. Data sources were obtained from articles from accredited national journals and reputable international journals, reference books, and learning documents relevant to the evaluation of STEAM-based physics learning.

The data collection technique is carried out through searching scientific databases such as Google Scholar and national journal portals. The data was analyzed using interactive analysis techniques that included data reduction, data presentation, and conclusion drawn. The focus of the analysis is directed at the form of learning evaluation, assessment instruments, as well as indicators of STEM literacy and creativity in integrated physics learning in the arts.

Kajian literature

1. Educational Evaluation

Educational evaluation is a systematic process of collecting, analyzing, and interpreting information to determine the level of achievement of learning objectives. Evaluation not only functions as a tool to measure learning outcomes, but also as a basis for decision-making in improving the learning process. In the context of 21st century learning, evaluation is directed at authentic assessments that assess the real abilities of learners in the context of the real world [3].

STEAM Learning integrates *Science*, *Technology*, *Engineering*, *Art*, and *Mathematics* to create an *interdisciplinary* and contextual learning experience. Evaluation in this context not only assesses academic results, but also evaluates the *critical thinking skills*, creativity, collaboration, and problem-solving skills that characterize 21st century learning. STEAM specifically emphasizes the role of art as a medium of creative expression in science and technology that can enrich educational evaluation practices.

2. Physics in artwork

Studying art using glasses and scientific methods provides opportunities where we can produce an order of science that has the potential to inspire modern science today. "Experiential Physics" is a study of interest to the scientific community in addition to the study of physical science that is currently developing, as well as "Theoretical Physics" and "Experimental Physics".

Figure 1. Example of a "ring pendulum" physics experiment that uses an art device to understand physical events

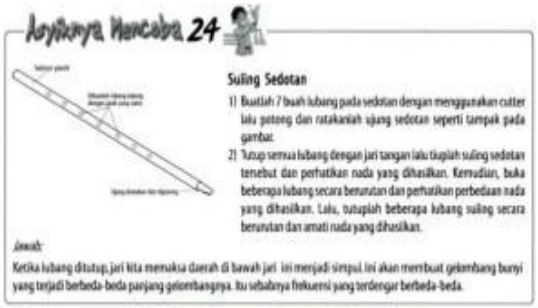

Figure 2. An example of a physics experiment is a "straw flute" that uses an art device to understand a physical event.

In How to "experience physics" is one of the basic principles of "Physics Gasing" (Physics Easily Fun and Fun). Here, students are invited to experience for themselves how to use various simple devices around them to understand various physics concepts. In figure 2, two experiments are shown that can be carried out by such students in order to get the best understanding of the concept (mechanics) of vibration and sound waves. In the experiment, for example, students were invited to understand the characteristics of sound waves (mechanical waves) that propagate through air molecules, and how to perform mechanical engineering to produce sounds with various wavelengths (and of course also sound frequencies) that give the "tone" characteristics of sound. By understanding the concept of resonance (the characteristic of vibrating by the similarity of frequencies), it provides students with a further understanding of the physical engineering that can be acquired in the manufacture of musical instruments.

The study of experimental and theoretical physics today has advanced so much that so many models (mathematical and computational) of physics have been able to provide many answers to the mysteries of the physical aspects of the universe. In fact, some physics modeling has also penetrated the study of social and economic sciences, in the study of economics and sociophysics [10]. Various questions about stock price fluctuations using the latest physical models can be explained where many things have not been recognized by conventional economic science before.

The patterns of art, musicality, and experimental physics, vibration/sound wave mechanics, as discussed above, also exist in visual cultural artworks. Physics today captures a variety of natural phenomena using geometry that is completely different from geometry long before physicists used computers to analyze the data. Geometry that usually speaks in real number-dimensional shapes and spaces (dimensions 1, 2, 3, and so on) has recognized various geometric patterns and shapes of buildings and fractional dimensional spaces. This is called "fractal" [11]

In the concept of fractal geometry, we recognize the wake with fractional dimensions. For example, it is now known that there is a 1.5-dimensional building, as a geometric shape of the building that is between a line (dimension 1) and a flat building (dimension 2). There is, for example, a building with dimension 2.7, which is a physical object whose shape is between a flat building (dimension 2) and a spatial building (dimension 3). The "symmetry" pattern also becomes unique. In conventional geometry, common symmetry is always known as the form of similarity on different sides of the building. In fractal geometry, similarities are not only in different sides, but in themselves [12]. One part of the wake can provide a symmetrical pattern with the overall wake, and vice versa

A similar thing is found in cultural arts crafts, namely 2-dimensional works such as batik, giving an image of batik ornamentation that does not follow conventional geometric patterns [13]. [14] For example, tersenut works tend to have the same social appreciation related to the cultural life of the archipelago.

A message articulated in the form of this painting shows that art workers try to create works of art by following geometric patterns that are appropriate from a naturalist perspective. It follows rules such as "perspective", "lighting" and so on, so that this work of art comes to life. However, at that time, a message expressed in paintings used factual principles in his artistic creations [15].

Figure 3. Depiction of batik motifs "Mega Mendung" and "Sawat"

The image above shows that this artwork is in the form of elements of the context of building space. The most precise and simple example of describing fractals is the Sierpinski triangle in Figure 3. When we observe in more detail, there is the formation of small triangles inside a large triangle that is similar to a large triangle. And so on until the number is infinite. This geometric rule with a continuously repeating pattern with different scales but having similarities to the initial pattern is the simplest example of a fractal. Fractals in physics refer to structures or phenomena that exhibit repeating patterns at various scales, which often cannot be explained with classical geometry approaches. This concept is useful for modeling complex and irregular physical systems, such as fluid turbulence, crystal growth, or galaxy distribution[16] Fractals have been applied in various fields of modern physics.

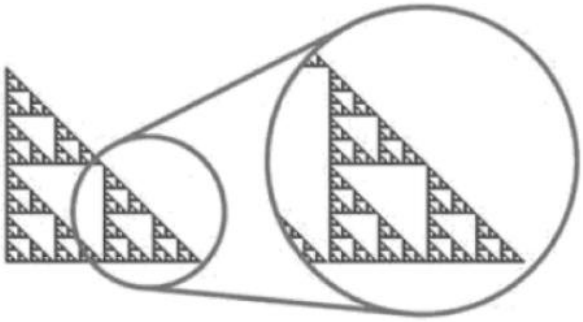

Figure 4. Sierpinski's triangle and the properties of similarities in itself

The integration of art in evaluation comes through an authentic approach that combines aesthetics, visual design creativity, and artistic expression in physics learning. Literature studies show that STEAM increases student engagement and creativity in physics concepts. For example, the STEAM approach has been identified as an effective strategy for developing students' creative thinking skills in physics learning through tasks that involve design and artistic expression, such as modeling or visualizing physics concepts.

3. Evaluation in STEM Physics

Studies show that evaluation in STEM physics has traditionally focused on measuring science process skills and understanding physics concepts. Development of a STEM-based physics learning outcome test instrument to measure students' science process skills, where evaluation instruments are tested for validity and reliability in the

context of physics learning in high school [9]. This instrument has proven to be valid and reliable for assessing science process skills, but learners' skill outcomes are still in the medium category — demonstrating challenges in comprehensive STEM evaluations. The evaluation of STEM-based science literacy performance assessment instruments in physics lessons shows the importance of developing a measuring tool that can assess science literacy and high-level thinking skills in physics learning. [8]. The literature review also found that STEM-based physics learning contributes positively to the improvement of critical thinking skills, especially when evaluation is carried out systematically in various contexts of physics learning practice.

The literature review emphasizes that *authentic* STEAM assessments can improve the critical thinking skills of physics students, especially in the aspects of analysis, evaluation, and creation — a category similar to the upper level of Bloom's taxonomy, and supports cross-disciplinary project-based learning. [7].

The STEAM method not only assesses physical concepts but also assesses students' ability to *transform* those concepts into meaningful art forms or products, such as visual representations of physical phenomena, creative experiments, or artistic *design thinking*. STEAM-based learning evaluation requires the use of instruments that are able to authentically assess learning processes and products. Relevant forms of evaluation include performance appraisal, project appraisal, portfolio, and self-reflection. Evaluation not only measures the final results, but also the thinking process and creativity of students [4].

RESULT AND DISCUSSION

1. STEAM-Based Physics Learning Evaluation

The results of the study showed that art integrated physics learning was more effectively evaluated using authentic assessments. Widely used forms of evaluation include project appraisal, performance appraisal, and portfolio. This evaluation allows students to demonstrate an understanding of physics concepts through contextual science artworks.

2. The Role of Art in Evaluating the Understanding of Physics Concepts

Art acts as a medium for the representation of abstract physical concepts. Visual artworks, performances, and science installations are able to depict concepts such as energy, waves, and light in a concrete way. This makes it easier for teachers to evaluate students' conceptual understanding in depth.

3. STEM Literacy and Student Creativity

STEAM-based evaluations have been shown to improve STEM literacy, which includes the ability to understand concepts, apply knowledge, and solve problems. In addition, the integration of the arts in evaluation encourages creativity and high-level thinking skills that are aligned with the demands of 21st century education.

Table 1. Indicators of Evaluation of Art Integrated Physics Learning in the STEAM Approach

Aspects Assessed	Evaluation Indicators	Form of Evaluation	Description of Assessment
Cognitive (Physics)	Understanding of physics concepts	Open/project tests	The accuracy of the physical concepts represented in the artwork
Science Process	Process skills	Performance observation	Ability to observe, analyze, and inferre physical phenomena

Creativity	The Originality of the Work	Product rating	The uniqueness of ideas and innovations in integrating physics and art
STEM Literacy	Concept application	Project rubric	Ability to apply physics concepts to real-world contexts
Affective	Scientific attitude	Observation & reflection	Cooperation, curiosity, and responsibility[1]

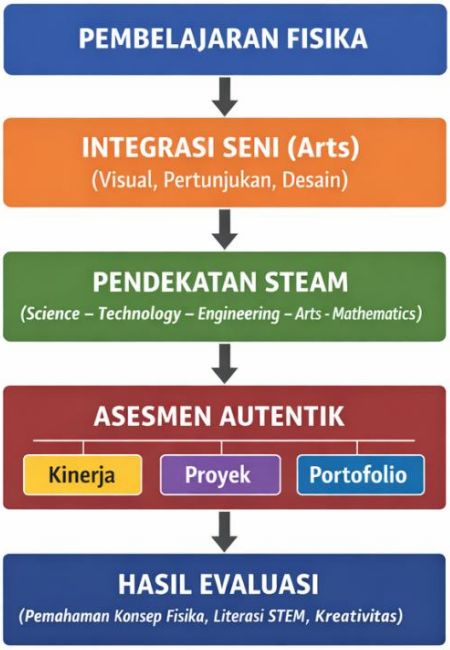

Figure 5. An Evaluation Framework **for Integrated Physics Learning in the STEAM Approach**

Table 2. Assessment Rubric for Arts-Based Physics (STEAM) Projects

Assessment Aspects	Score 4 (Excellent)	Score 3 (Good)	Score 2 (Sufficient)	Score 1 (Less)
Physics Concepts	Precise and in-depth concepts	The concept is quite precise	The concept is partially correct	A misconception
Art Integration	Strong & meaningful integrated art	Art is enough to support the concept	Art is less relevant	No art integration
Creativity	Highly innovative & original	Innovative	Less innovative	Imitation
STEM Literacy	Real and contextual applications	The app is quite contextual	Limited applications	Out of context
Presentation	Highly communicative	Communicative	Less obvious	Unclear

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CONCLUSION

[1]

The evaluation of art-integrated physics learning in the STEAM approach requires a holistic and authentic assessment instrument. Project-based assessments and science arts products are more effective in measuring students' understanding of physics concepts, STEM literacy, and creativity than conventional evaluations. Therefore, physics teachers are advised to develop a contextual and process-oriented STEAM evaluation model and learning outcomes. Therefore, this evaluation requires an assessment model that not only measures cognitive understanding but also creativity, artistic design, and high-level thinking skills. The literature shows that STEAM enhances the creative and critical thinking skills of physics students through authentic assessments and multi-faceted rubrics. However, its implementation requires teacher training, instrument development, and a clear evaluation model to effectively assess the art dimension.

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