KPJ 8(3) (2024)

KAPPA JOURNAL
Physics & Physics Education

https://e-journal.hamzanwadi.ac.id/index.php/kpj/index

Constructivism as a Foundation in Developing Physics Teaching Strategies

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Received: 29 September 2024
Revised: 05 December 2024
Accepted: 10 December 2024

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DOI:
https://doi.org/10.29408/kpj.v8i3.27615

Abstract: The concept of constructivism has emerged as a key pedagogical approach that highlights the active role of students in constructing knowledge. This theory emphasizes learning through social interaction, experimentation, and self directed discovery, with notable contributions from theorists such as Piaget, Vygotsky, Montessori, and Bruner. This study aims to explore the application of constructivism in teaching physics, specifically focusing on the innovation and effectiveness of this approach in improving learning outcomes. A literature study approach was employed to gather and analyze data from academic journals, textbooks, and previous research articles. The study explored various teaching methods influenced by constructivism, including inquiry-based learning, experiments, demonstrations, and problem-solving activities. Data was collected from a range of academic sources that address the integration of constructivist principles into physics education. The analysis involved reviewing the effectiveness of these approaches in enhancing critical thinking, conceptual understanding, and student engagement in learning. The research found that constructivist teaching methods in physics effectively improve critical thinking, student participation, and understanding of key concepts. Innovative teaching strategies based on constructivism, such as interactive and hands-on learning activities, demonstrated significant improvements in student learning outcomes. This study concludes that the principles of constructivism are highly relevant for physics education, with innovative, constructivist-based teaching strategies proving to be interactive, effective, and impactful in enhancing student learning outcomes.

Keywords: constructivism; physics; learning innovation; effectiveness

Introduction

Physics education, like other fields of study, faces the challenge of creating teaching methods that not only convey information but also develop critical thinking skills and deep conceptual understanding among students. Various traditional teaching methods that focus on lectures and memorization have proven to be less effective in fostering sustainable understanding and student engagement in the learning process. As an alternative, constructivism has emerged as an approach that emphasizes the active role of students in constructing their own knowledge through direct experience and social interaction.

The theory of constructivism, initially popularized by Jean Piaget and Lev Vygotsky, and later adapted by educators such as Maria Montessori and Jerome Bruner, focuses on creating a learning environment that allows students to engage directly in experiments, discussions, and problem-solving. This approach not only prioritizes teaching content but also the development of cognitive and social skills that students can apply in real-life situations.

As a learning philosophy, constructivism focuses on students' activeness in creating their own knowledge (Ayi Abdurrahman, 2024). David Ausubel (Edwar Hareta,dkk 2023) developed constructivism theory by

How to Cite:
Zahara, L., Adnyana, P. B., Wesnawa, I. G. A., & Ariawan, I. P. W. (2024). Constructivism as a Foundation in Developing Physics Teaching Strategies. *Kappa Journal, 8*(3), 351-358. https://doi.org/10.29408/kpj.v8i3.27615

emphasizing the activity of linking new concepts with knowledge that students already have. Constructivist theory figures (Suryana et al., 2022) include: 1) Jean Piaget, according to whom knowledge does not come from the social environment and places more emphasis on learning activities determined by the learner and oriented towards their own discovery, 2) Vygotsky, emphasizes the need sociocultural learning which includes interactions with adults, more capable peers, and also learning will occur if learners/students can handle tasks that they have not yet learned, but these tasks are still within their reach, 3) Maria Montessori, in This further emphasizes the principle that teachers must adhere to, namely that teachers must believe and believe that students' knowledge can be created based on personal understanding, so it is recommended for teachers not to intervene in the development of students' knowledge, teachers must allow students to develop through interaction with their respective environments so that they can become active, independent, andexperiencing progress, 4) Jerome Brunner, believes that students must be able to find order by tinkering with materials that relate to the intuitive order they already have, to get to know the concepts and material being taught, students' mentality must be actively involved when learning , 5) John Dewey, believes that educators require their students to participate in a project or assignment that is centered on a problem, educators are also encouraged to be able to help students to see social and intellectual problems, 6) Tasker, according to him, constructivist learning theory recommends that there are 3 things that must be available in a learning process, include: a) Students play an active role in the construction of meaningful knowledge, b) linking new ideas is very important in the construction process, c) linking newly received information with ideas which was developed.

Although there have been several innovations in physics teaching methods based on constructivism, such as the use of technology and teaching aids for experiments, their implementation is often limited by factors such as inadequate resources, limited time, and large class sizes. These challenges make it difficult for constructivist-based teaching strategies to be applied widely and consistently.

Therefore, this study aims to explore how constructivism can serve as a strong foundation in developing more effective and interactive physics teaching strategies. The researcher also seeks to analyze the challenges faced by educators in implementing this approach and to find solutions that allow for broader implementation and positive impacts on student learning outcomes.

The teacher's role in a constructivist classroom is not limited to giving lectures to students, but to act as a learning expert who can guide students and organize information that interests students, help students develop new insights and connect them with previous learning outcomes (Kuntjojo, 2021). According to Nur (Edwar Hareta, dkk, 2023) Teachers can give students stairs that lead students to a higher understanding provided that students themselves must climb these stairs. Teachers can be guides and provide direction to students to achieve deeper understanding, but students themselves must be active in learning to expand their knowledge. Learning is associated with a process of constructing knowledge so that it can change the structure of existing knowledge. In other words, learning can restructure knowledge into long term memory where knowledge is stored permanently (Salsabila dalam Istiarini et al., 2023).

Based on several problems in the field of education, especially physics education in the learning process, several studies have been carried out applying constructivism-based learning models (Rerung et al in Handaka et al., 2018) Based on the results of research conducted by The difficulties experienced by students when studying Physics are (1) students do not understand the questions so the application of the formula is also wrong, (2) students have difficulty using formulas that match the question request, (3) students have difficulty understanding what is known and what is asked in the question. questions that are in the form of stories, (4) students know the formula used but are unable to apply it mathematically, especially for cross multiplication and roots. Innovations in physics teaching include the use of technology, visual aids, and interactive simulations. Literature studies on these innovations will be evaluated to understand how these techniques can support constructivist principles. Physics learning often faces challenges in terms of engagement and understanding of abstract concepts. Constructivism, as a learning theory, offers an approach that can help students build an active understanding of concepts. This research aims to explore the application of constructivism in physics teaching and assess its innovation and effectiveness. The objectives of this research are; 1) identify the principles of constructivism that are relevant for teaching physics; 2) analyze innovations in constructivism-based physics teaching strategies, 3) assess the effectiveness of constructivist approaches in improving physics learning outcomes.

Method

Data analysis is carried out using thematic analysis, which involves identifying, analyzing, and reporting patterns (themes) that emerge from the reviewed articles. Each article is thoroughly read to understand its context, research objectives, methods

used, and findings. Notes are made on key elements related to the application of constructivist theory. Each article is examined for elements related to the implementation of constructivism, such as the use of problem-based learning, experiments, discussions, and other active learning methods. After these categories are identified, thematic analysis is performed to identify key patterns and relationships between themes. The main focus is to identify patterns that highlight the effectiveness of applying constructivist theory in physics teaching, as well as the challenges faced by educators.

Result and Discussion

This section outlines the analysis of several articles related to constructivist theory in physics learning. This article will be analyzed based on: a) the results obtained, b) innovation and c) the effectiveness of the implications of constructivist theory.

1. Constructivist Implementation of Learning Outcomes/Concept Understanding

Learning physics is often considered a challenge, especially in terms of understanding abstract concepts and student involvement in the learning process. The constructivist approach, which emphasizes students' activeness in constructing their own knowledge through direct interaction with course material, has proven effective in overcoming some of these problems. Various studies reviewed in this article show that the application of constructivist methods, such as inquiry, experimentation, demonstration, and problem solving, can significantly improve student learning outcomes. Constructivism-based learning involves students in active learning activities, where they not only receive information but also engage in a process of discovery and experimentation. For example, the application of guided inquiry and modified free inquiry methods in physics learning shows an increase in students' understanding of concepts and critical thinking skills. Likewise, the use of constructivism-based problem solving methods, which helps students overcome challenges in solving physics problems. Below is table 4.1 of constructivist research data on student understanding of concepts and learning outcomes.

Table 1. List of articles regarding the implementation of constructivist theory

Researcher Name	Application of Constructivist Theory	Results
Arif Handaka, et al.	Physics Learning Through Constructivism Using Guided Inquiry Methods and Modified Free Inquiry	There are differences in the influence of the constructivist approach using the modified free inquiry method and the guided inquiry method on knowledge, attitudes, and skills.
Fartina, et al.	Constructivist Learning Model Through Experimental and Demonstration Methods	The constructivist learning model using experimental and demonstration methods influences student learning outcomes in Static Fluid material.
U. Kulsum & S. E Nugroho	Cooperative Problem Solving Learning Familiarizes Students with Constructing Knowledge	The application of the Cooperative Problem Solving learning model in physics learning improves high school students' ability to understand concepts and engage in scientific communication.
Solehat	Novick-Type Constructivist Learning Model	The Novick-type constructivist learning model significantly improves students' understanding of science concepts and generic skills.
Maiyena & Imamora	Development of a Constructivism-Based Electronic Physics Module	The developed electronic module is highly valid.
Ardiansyah	Development of Basic Physics Teaching Aids Based on Constructivism	Constructivist-based teaching aids help build students' generic science skills.
Nana & Surahman	Development of Digital Learning Innovation Using the Blended POE2WE Model with a Constructivist Approach	The modules being developed still need improvement or improvements in various aspects
Nana & Surahman	Development of Digital Learning Innovation Using the Blended	still needs improvement or improvement in various aspects

	POE2WE Model with a Constructivist Approach	
Salmah	Learning Based on a Constructivism Approach Using the Bandicam Application	Students' understanding of concepts is better
Fayakun & Joko	Physics Learning Using Contextual Models (CTL) Using the Predict, Observe, Explain Method	Improve Higher Level Thinking abilities
Ritonga et al.	Utilizing Adobe Flash with a Constructivist Approach	Student motivation increases.
Ashari Najib	Increasing Student Learning Activities through Constructivist Learning in General Physics Courses	Student learning activities increase.

In Table 1, there is research conducted by (Handaka et al., 2018) with the title Physics Learning Through Constructivism Using Guided Inquiry Methods and Modified Free Inquiry in View of Achievement Motivation and Scientific Attitudes using experimental methods, applying constructivist theory to guided inquiry and free inquiry to optimize student involvement. The results obtained show differences in the influence of the constructivist approach using the modified free inquiry method and the guided inquiry method on the value of knowledge, attitudes and skills.

Research conducted by (Fartina et al., 2023) with the title Application of the Constructivist Learning Model Through Experimental and Demonstration Methods on Student Learning Outcomes in Fluid Material, applying constructivist learning theory in the experimental class and control class. In this research, the achievement of the constructivist learning process through the experimental method produces higher learning outcomes compared to constructivist learning using the demonstration method, this is because in constructivist learning students become people who think critically and analyze things because they think and are directly involved.

Other research conducted by (Kulsum & Nugroho, 2014) with the title Application of the Cooperative Problem Solving Learning Model to Improve Students' Concept Understanding and Scientific Communication Ability in Physics Subjects, constructivist theory is applied when students construct meaning or understanding based on the initial knowledge they have, integrating new knowledge into existing schemes in the students' own thinking . Problem solving theory, which is based on constructivist theory, emphasizes understanding and solving problems in the context of students' meanings. The results of the research show that the application of the Cooperative Problem Solving learning model in physics learning is able to improve high school students' ability to understand concepts and scientific communication.

Furthermore, research conducted by (Solehat, 2013) with the research title Implementation of the Novick Type Constructivist Learning Model to Improve Understanding of the Concept of Refraction of Light and Generic Science Skills for Vocational School Students by implementing the Novick Type Constructivist Learning Model using experimental research. The results of this research are that the Novick type constructivist learning model can significantly improve students' understanding of science concepts and generic skills. Indicators of students' conceptual understanding in this study looked at aspects: 1) transition, 2) interpretation and 3) extrapolation. Meanwhile, the generic science skill indicators in this research consist of: 1) direct observation, 2) indirect observation, 3) symbolic language, and 4) mathematical modeling. According to (Nopiyadi, 2022) The Novick type Constructivist learning model is more recommended than the Constructivist learning model because the Novick type syntax is simpler and more efficient. The Novick type Constructivism Model only consists of 3 syntaxes, while the Constructivism Model has 4 syntaxes covering four activities, including: a.) Relating to students' prior knowledge. b.) Contains real experiential activities (experiences). c.) Social interaction occurs. d.) Formation of sensitivity to the environment (sense making).

The conclusions from the various studies presented show that the constructivist learning approach has a positive impact on students' understanding of concepts and skills, especially in learning physics. Inquiry methods (both guided inquiry and modified free inquiry), experimentation, and constructivism-based problem solving have been

proven to increase student engagement, critical thinking skills, and understanding of scientific concepts. Each study that uses constructivism theory shows varying results, depending on the method applied. Free inquiry and experimental methods tend to provide better learning results than demonstration methods. Apart from that, the Cooperative Problem Solving model and the Novick type Constructivism model are also effective in improving students' understanding of concepts and scientific skills, with the Novick type being recommended because its syntax is simpler and more efficient. Overall, learning that actively involves students in the knowledge construction process is proven to be able to improve their learning outcomes and scientific skills.

b. Learning Innovation with Constructivist Theory

One of the important points in this discussion is innovation in the use of technology to support constructivist learning. Digital simulations, electronic modules, and other visual aids provide opportunities for students to become more involved in the learning process. An example of the application of this technology is the development of a constructivism-based physics module which has proven effective in increasing student motivation and learning outcomes. Constructivism-based physics teaching aids are also able to improve students' generic science skills, although further improvements are still needed in their implementation. Innovations such as the use of digital simulations and visual aids have been shown to increase student engagement and understanding of concepts. Evaluation of these methods shows that they support the constructivist approach well. For example, research conducted by (Maiyena & Imamora, 2020) can be seen in table 1 with the title: Development of Constructivism-Based Electronic Physics Modules for Class X SMA, applying constructivist theory to electronic modules developed using the 4-D model. Based on the results of observations obtained through teacher interviews, the Physics LKS used by students are not yet interesting, and students' motivation to learn physics is low. In the material section, it starts with problems that are close to students' daily lives, they are guided to build their knowledge and find their own concepts about the material being studied. The results obtained, the electronic module developed with aspects assessed as a) purpose, b) rationale, c) module content, d) characteristics, e) suitability of language, and f) physical form, is very valid.

Another research was conducted by (Ardiansyah et al., 2023) with the title Developing Basic Physics Teaching Aids Based on Constructivism to Develop Generic Science Skills in High School Students applying constructivist theory to physics teaching aids developed with the 4-D model. The background to this research is due to the lack of complete physics teaching aids. Development carried out at the design stage or design of physics teaching aids on static fluid material. However, the relationship between the design of teaching aids and constructivist theory is not explained in detail. The results obtained show that constructivist-based teaching aids can build students' Generic Science Skills.

Other research was conducted by (Nana & Surahman, 2019) with the title Development of Digital Learning Innovation Using the Blended POE2WE Model in the Era of Industrial Revolution 4.0. The Prediction, Observation, Explanation, Elaboration, Write and Evaluation (POE2WE) learning model was developed from the POEW learning model and the Physics learning model with a Constructivist Approach. This model builds knowledge in a sequence of processes, namely predicting or predicting solutions to problems, conducting experiments to prove predictions, then explaining the experimental results obtained orally and in writing, making examples of applications in daily life, writing down discussion results and including evaluations of participants' understanding. educate both orally and in writing. The research results obtained from the development of blended learning innovations in Physics learning using the POE2WE model are categorized as new. The development of this model touches more on the realm of e-learning as an answer to the demands of the industrial revolution 4.0. However, this learning innovation is still in the development stage and still needs improvement or improvement in various aspects.

The conclusion of this text shows that various learning development methods based on constructivism theory have been evaluated positively in improving the quality of physics learning in high school. Constructivism-based electronic modules developed using the 4-D model are considered very valid in terms of objectives, content and characteristics, and are able to motivate students to learn by building their own concepts. Apart from that, constructivism-based physics teaching aids have also proven to be effective in building students' generic science skills, although a detailed explanation of their relationship to constructivist theory is not provided. Other research concerns the development of the POE2WE digital learning model, which combines blended learning and e-learning approaches, into a new innovation that meets the demands of the Industrial Revolution 4.0 era. This model allows students to build knowledge through cycles of prediction, observation, and evaluation, but still requires further improvement. Overall, the constructivist approach through various methods has succeeded in increasing student engagement and understanding, although there are several aspects that can still be improved.

c. Effectiveness of Constructivist Theory in Physics Learning

The effectiveness of the constructivist approach in teaching physics has been proven by various studies reviewed in this article. The application of learning models such as Predict-Observe-Explain (POE) and the use of digital media such as Bandicam to record and repeat learning material, shows positive results in increasing students' understanding of physics concepts. The POE method, in particular, has been proven to help students develop higher-order thinking skills because it allows them to predict, observe, and explain the physics concepts being studied. Research shows that a constructivist approach can improve learning outcomes, critical thinking skills, and student motivation. Based on research conducted by (Salmah et al., 2022) contained in table 1 with the title Effectiveness of Learning Based on a Constructivist Approach Using the Bandicam Application to Improve Conceptual Understanding of Class Bandicam is a screen recording tool that can record PC screen activity which is equipped with various features that can be accessed for free. The use of this learning media should be able to help students when studying independently. Media that can be stored means students can repeat material whenever and wherever they want. Learning media is able to connect the knowledge possessed by the teacher with the concepts that will be studied by students so that it can facilitate the learning of abstract physics concepts. The results of the research show that students' understanding of concepts after applying constructivist approach-based learning using the bandicam application on momentum and impulse material is in the good category.

The research conducted by M Fayakun and P Joko, "Efektivitas Pembelajaran Fisika Menggunakan Kontekstual (CTL) Dengan Metodepredict, Observe, Explain Terhadap Kemampuan Berpikir Tinggi," Jurnal Pendidikan Fisika Indonesia 11, no. 1 (2015): 49–58, https://doi.org/10.15294/jpfi.v11i1.4003. with the title Effectiveness of Physics Learning Using Contextual Models (CTL) with Predict, Observe, Explain Methods on High Level Thinking Abilities. Constructivist theory is found in the learning steps when applying a contextual approach. The results of research data analysis show that the contextual learning model using the POE method has a positive effect and is able to improve students' high-level thinking abilities compared to students who use conventional methods. The POE method is a scientific procedure that students can carry out. Scientific procedures are an effort to train students' high-level thinking abilities. The POE method is constructivist because students are given the freedom to think about the physics problems posed and students try to build their own knowledge through thinking, practicing and looking for explanations. The POE (Predict-Observe-Explain) method is a learning model that involves three main steps, namely prediction, observation and explanation. This learning model aims to: Develop students' life skills, Help students explore initial knowledge, Prove existing concepts directly, Identify students' knowledge and understanding of science concepts.

Another research was conducted by (Ritonga et al., 2021) with the title Using Adobe Flash with a Constructivist Approach in Increasing the Effectiveness of Understanding Physics Subject Material, researchers developed a waterfall model. Researchers developed Adobe Flash-based learning media with a constructivist approach. The result of this research is the need for special learning innovations for tests using digitalization technology, namely Adobe Macromedia Flash, in the sense that this research is still at the limited trial stage without validation from media experts. Research conducted by (Centaury, 2015) with the title Increasing Student Learning Activities through Constructivist Learning in General Physics Subjects obtained the results: applied constructivist learning can be used to increase student learning activities.

The conclusion from this statement is that physics learning based on a constructivist approach, with the help of various digital media, has proven to be more effective in increasing students' understanding of concepts compared to conventional methods. The use of the Bandicam application in physics learning on momentum and impulse material, as shown in the research of (Salmah et al., 2022), allows students to study independently, repeat material at any time, and visualize abstract physics concepts, so that student learning outcomes increase. Other research by Fayakun and Joko, "Efektivitas Pembelajaran Fisika Menggunakan Kontekstual (CTL) Dengan Metodepredict,

Observe, Explain Terhadap Kemampuan Berpikir Tinggi." which uses the POE (Predict-Observe-Explain) method in a contextual approach also shows that this model is able to improve students' high-level thinking abilities, because it encourages students to build knowledge independently through prediction, observation and explanation. Meanwhile, (Ritonga et al., 2021) shows that Adobe Flash-based learning media with a constructivist approach also has the potential to increase the effectiveness of understanding physics material, although the development of this media is still in the limited trial stage. Overall, a constructivist approach supported by digital technology can facilitate more interactive and effective learning. Overall, constructivism-based physics learning has a positive impact on student engagement, concept understanding, and critical thinking skills. Although some technological

innovations and learning methods still require further development, this approach overall has proven effective in improving student learning outcomes in the field of physics. Innovation continues to be needed to optimize physics learning, especially in facilitating understanding of complex and abstract concepts.

Conclusion

This research explores the application of constructivism theory in teaching physics and evaluates innovation and its effectiveness on learning outcomes. Constructivism emphasizes the active role of students in constructing knowledge through direct interaction with material. This approach is applied through various methods such as inquiry, experimentation, demonstration, and problem solving, which are proven to improve critical thinking skills and understanding of concepts. Technological innovations, such as digital simulations and electronic modules, also support constructivist learning. The results in this research are; 1) the principles of constructivism are relevant for teaching physics; 2) innovations in physics teaching strategies based on constructivism are mostly interactive and effective, 3) the constructivist approach is effective in improving students' physics learning outcomes.

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