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Does the Ethno-Physics-based Problem Based Learning Model Improve Students' 21st Century Thinking Skills? Meta-analysis

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Abstract: This study aims to determine the effectiveness of ethno-physics-based project-based learning model to improve students' 21st century thinking skills. Inclusion criteria in this study are research published in 2022-2024, research must be experimental or quasi-experimental methods, research obtained through Google Scholar, ScienceDirect, Wiley, ERIC, ProQuest, Fronteins and Web of Science databases, research must be relevant and consist of 1229 students. Data analysis in this meta-analysis with the help of JSAP application. The analysis of 24 studies concluded that the resulting random effect size value was 1.05 (high effect size category) with 95% confidence level. This finding explains that the ethno-physics-based project-based learning model can improve students' 21st century thinking skills. This research can also provide new information related to the application of problem-based learning model in the future.

Keywords: Ethno-physics; Meta-analysis; Problem Based Learning; 21st Century Thinking

Introduction

21st century thinking skills are important skills that must be possessed by students in facing global challenges in the modern era (Cantaş et al., 2024; Feyza & Seyda, 2023; Oktay et al., 2023). 21st century skills consisting of critical, creative, collaborative, and problem-solving skills must be possessed by students in today's learning. In the midst of the rapid development of technology and information, students are not only required to master the material theoretically (Maxnun et al., 2024), but also be able to apply this knowledge in complex and dynamic real situations. With these higher-order thinking skills, students can face problems analytically, find innovative solutions, and work together in teams, which is a provision to contribute productively in society and the world of work (Fajri et al., 2023; Nanda et al., 2023; Widyaningtyas et al., 2024).

Furthermore, 21st century thinking skills are also important to support lifelong learning. In the era of the Industrial Revolution 4.0, changes occur very quickly, so students need to have the ability to adapt to technology and the environment that continues to evolve (Oktay et al., 2023; Orhan Özen & Özen, 2022). By honing critical and creative thinking skills, students can be better prepared to face unprecedented challenges and make better decisions in a variety of contexts (Novitra et al., 2021). Thus, an education that focuses on developing 21st-century thinking skills not only helps students achieve academic success, but also prepares them to become independent, innovative, and highly competitive individuals at the global level (Tadege et al., 2022; Toheri et al., 2020).

The Industrial Revolution 4.0 is characterized by the integration of advanced technologies such as artificial intelligence, Internet of Things (IoT), big data, and automation in various sectors of life, which fundamentally changes the way humans work,

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communicate, and learn (Wibowo, 2023). In the context of education, this revolution demands learning that is more adaptive, innovative, and relevant to real life. Traditional approaches that focus on memorization and one-way methods are no longer adequate to prepare students for the challenges of the modern world. Students must be equipped with critical thinking skills, problem-solving skills, and strong digital literacy in order to adapt quickly to ever-evolving technological changes (Priyambodo et al., 2023; Wijayanto et al., 2023).

Innovative learning is needed to encourage students to think [21]st century in everyday life. Furthermore, the ability of the [21]st century requires students to be able to master learning technology, so learning materials need to be adjusted to technological developments and industry needs (Hansen & Bertel, 2023; Yaşar et al., 2023). By utilizing digital technologies in the learning process, such as simulation, project-based learning, and the use of big data, students can be better prepared to face future challenges and be able to contribute significantly to an increasingly globally connected work environment and society (Ichsan et al., 2023; Solissa et al., 2023; Zulyusri et al., 2023).

A major problem related to students' 21st-century abilities is the lack of emphasis on critical, creative, and collaborative thinking skills in the traditional education system (Festiyed et al., 2022; Hamdani et al., 2022; Zulkifli et al., 2022). Many schools still focus on a learning approach oriented towards memorization and achievement of academic grades, so students lack the opportunity to develop higher-order thinking skills. This makes it difficult for students to adapt to real challenges outside of the classroom, especially when it comes to complex problem-solving, data-driven decision-making, and working in teams to achieve innovative solutions (Oral & Erkilic, 2022). As a result, graduates are often unprepared to face the demands of the world of work and modern life that increasingly relies on 21st-century skills. Furthermore, students are less able to integrate technology and learning that is relevant to real life in the educational process (Diniyyah et al., 2022; Illene et al., 2023). Technology that continues to develop rapidly in the era of the Industrial Revolution 4.0 requires students to have strong digital literacy and the ability to adapt quickly to changes. However, many schools have not been able to optimally facilitate technology-based learning, both due to limited resources and because there has been no adequate curriculum adjustment (Zainil et al., 2023). This makes students unaccustomed to using technology to think critically or collaboratively, making them less able to compete in an increasingly digital and connected global era. Therefore, it is necessary to have a learning model that is able to encourage students' 21st century thinking skills, one of which is through the problem-based learning model (Ilma et al., 2023).

Problem based learning is student-centered learning, where students are invited to solve complex real problems as a means to develop their knowledge and skills. In the problem-based learning model, students not only play a passive role in receiving information, but also as active and collaborative problem solvers (Fajri et al., 2023; Toheri et al., 2020). They work in teams to identify problems, seek relevant information, and come up with solutions based on a critical understanding of the problem. Thus, the problem-based learning model not only helps students understand the material in depth, but also hones critical thinking, communication, collaboration, and problem-solving skills that are needed in the 21st century (Nanda et al., 2023; Widyaningtyas et al., 2024).

Furthermore, problem-based learning models provide a more relevant learning context to real life, which encourages students to relate academic concepts to practical applications in the world around them (Wibowo, 2023). Because the problems faced in the problem-based learning model are often related to real issues, students are more motivated to learn and see the practical value of the knowledge they have acquired. This learning model also increases students' confidence in solving complex problems, considering that they are given space to experiment, make decisions, and reflect on their learning process (Cantaş et al., 2024). With a combination of knowledge development, skills, and contextual relevance, PBL is a highly effective learning model to equip students to face the challenges of the 21st century. The problem based learning model can be integrated with ethnophysics.

Ethnophysics is an approach in physics learning that integrates local culture with physics concepts to create a more contextual and relevant understanding for students. This approach utilizes natural phenomena or technologies that exist in the daily lives of local people as a real example in explaining the principles of physics. By linking scientific concepts to cultural knowledge and practices (Sudarmin et al., 2023), Ethno-Physics helps students understand physics in a more meaningful way, while also appreciating their cultural heritage. In addition to increasing students' engagement and motivation to learn, this approach also bridges the gap between modern science and local traditions, providing insight that physical science is not a discipline separate from everyday life, but rather something that can be found in every aspect of their cultural environment (Jon et al., 2023).

Ethno-Physics-based Problem Based Learning (PBL) is an innovative approach that combines real problem solving with local cultural context in physics learning. In this model, students are invited to solve problems drawn from physical phenomena that occur in their surroundings, which are associated with local cultural traditions or practices (Winarto et al., 2022). This approach not only helps students understand physics concepts in a more in-depth and relevant way, but also improves critical thinking, collaboration, and creativity skills through a problem-solving process that focuses on the cultural context they are familiar with. By integrating the problem-based learning and Ethno-Physics models, students not only learn science in a scientific framework, but also appreciate their local cultural values, so that learning becomes more meaningful, contextual, and sustainable.

Research by Hmelo-Silver (2000) confirms that students who engage in problem-based learning are not only better able to analyze and solve complex problems, but also actively engage in group discussions, which encourages collaborative skills and communication skills. In addition, research by Loyens et al. (2012) found that problem-based learning models increase students' intrinsic motivation to learn, as they are faced with real problems that require active engagement, critical thinking, and deep reflection. PBL has proven effective in a variety of educational contexts, including science and technology, in honing the skills needed in the 21st century. Research by Sefa Dei (2022) also emphasizes that connecting learning with the local cultural context not only makes science more accessible to students, but also encourages the critical thinking skills needed to understand how science operates in everyday life. By combining problem-based learning and ethno-physics models, this research has the potential to produce an effective learning model in improving 21st century thinking skills, while strengthening students' understanding of the relevance of science in their cultural context. The research gap is that many studies on the application of problem based learning models based on local wisdom have not been found how large the effect size of ethn-physics-based problem based learning models is in encouraging students' 21st century skills. Therefore, a meta-analysis was carried out to obtain a deep conclusion on the application of the model in learning. Based on this, this study aims to determine the effectiveness of ethno-physics-based project-based learning models to improve students' 21st-century thinking skills.

Method

This study uses a meta-analysis approach to determine the effect size of ethno-physics-based problem-based learning model on students' 21st-century thinking ability. Meta-analysis is a research approach that evaluates previous research statistically to reach a conclusion (Hukom, 2023; Nurtamam et al., 2023; Tamur et al., 2020; Zulyusri et al., 2023). The meta-analysis research procedure is determining the research inclusion criteria, collecting data and coding, analyzing the data statistically. As seen in Figure 1

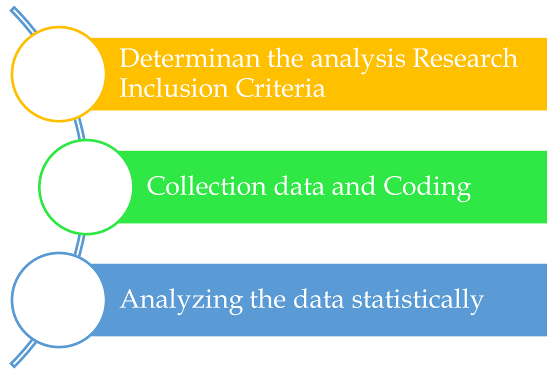

Figure 1. Prosedure Meta-analysis

Eligibility Criteria

In the process of searching for data through the Google Scholar, ScienceDirect, Wiley, ERIC, ProQuest, Fronteins and Web of Science databases, the research must meet several inclusion criteria, namely 1) the research is published in the 2022-2024 range, 2) the research is published in a journal indexed by SINTA, Scopun or Web of Science, 3) The research must use experimental classes of Ethno-Physics-based problem-based learning models and other classes of conventional learning models, 4) All studies must have complete data to calculate the effect size value dan 5) Student Research Sample SD, SMP dan SMA. From the data search, 24 studies were obtained that met the inclusion criteria published in 2022-2024 which can be seen in Table 2.

Data Collection

To obtain valid research data related to ethno-physics-based problem-based learning models to improve students' 21st-century thinking skills collected from Google Scholar, ScienceDirect, Wiley, ERIC, ProQuest, Fronteins and Web of Science databases and frontenists. The keywords for data search are "Problem Based Learning Model", "Problem based learning based on Ethno-Physics"; "Students' 21st Century Thinking Ability", "The influence of problem-based learning models"; and the influence of ethno-physics-based problem-based learning on the ability of ABDA-21 students (critical, creative, collaborative and communicative)".

Statistical Analysis

Data analysis in this study calculates the effect size value of each study analyzed. The effect size value in this study is to calculate the effect of the ethno-physics-based problem-based learning model to improve students' 21st-century thinking skills. According to Borenstein et al. (2021) the stages of data analysis in the meta-analysis can be seen in (Figure 1.). Furthermore, the criteria for the effect size value in the study can be seen in Table 1.

Table 1. Category Effect Size Value

Effect Size	Category
0.0≤ES≤ 0.2	Low
0.2≤ES≤ 0.8	Medium
ES≥ 0.8	High

Source: (Bachtiar et al., 2023; Borenstein et al., 2021; Tamur et al., 2020)

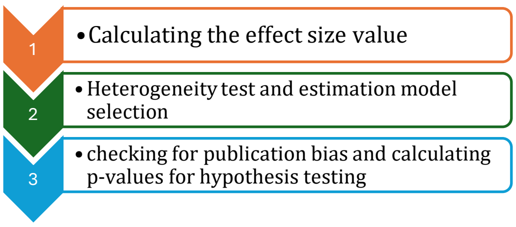

Figure 1. Data Analysis Procedure

Result and Discussion

Based on the results of data search through the database, 24 studies/articles met the inclusion criteria. The effect size and error standard can be seen in Table 2.

Based on Table 2, the effect size value of the 24 studies ranged from 0.49 to 2.91. According to Borenstein et al. (2021) of the 24 effect sizes, 6 studies (25%) had medium criteria effect sizes and 18 studies (75%) had high criteria effect size values. Furthermore, 24 studies were analyzed to determine an estimation model to calculate the mean effect size. The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 2. Effect Size and Standard Error Every Research

Code Journal	Years	Effect Size	Standard Error
R1	2024	1.07	0.42
R2	2024	2.91	0.59
R3	2024	1.42	0.36
R4	2022	0.93	0.33
R5	2022	1.52	0.42
R6	2022	1.18	0.35
R7	2022	1.04	0.30
R8	2023	0.73	0.27
R9	2024	0.97	0.37
R10	2023	1.13	0.39
R11	2023	0.66	0.22
R12	2023	0.72	0.18
R13	2023	0.81	0.29
R14	2023	0.89	0.25
R15	2024	1.06	0.40
R16	2024	1.34	0.34
R17	2022	1.70	0.30
R18	2022	2.30	0.51
R19	2022	1.52	0.44
R20	2023	0.57	0.15
R21	2023	0.49	0.22
R22	2024	0.76	0.29
R23	2022	1.09	0.37
R24	2024	1.38	0.30

Table 3. Fixed and Random effect

Parameters	Q	df	p
Omnibus test of Coefficients Model	72.552	1	< 0.001
Test of Residual Heterogeneity	143.961	23	< 0.001

Based on Table 3, a Q value of 143,96 was obtained higher than the value of 72,552 with a coefficient interval of 95% and a p value of 0.001 <. The findings can be concluded that the value of 24 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail safe N (FSN) test (Borenstein et al., 2021; Hukom, 2023; Ichsan et al., 2023; Tamur et al., 2020). The results of checking publication bias with funnel plot can be seen in Figure 2.

Based on Figure 2, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail Safe N (FSN) test. The results of the Rosenthal Fail Safe N calculation can be seen in Table 4.

Based on Table 4, the Fail Safe N value of 2504 is greater than the value of 5k + 10 = 5(24) + 10 = 130, so it can be concluded that the analysis of 24 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test the hypothesis through the random effect model. The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Based on Table 5, the results of the analysis with the random effect model obtained a lower limit value of 0.87 and an upper limit of 1.22 and a mean effect size value of 1.050. The effect size category in this study is included in the high category. Furthermore, the results of the Z test to determine the significance were obtained 11.56 and the p value < 0.01, so it can be concluded that the application of ethno-physics-based problem-based learning model can improve students' 21st century thinking skills dibandingkan model konvensional.

Table 4. Fail Safe N

File Drawer Analysis			
	Fail Safe N	Target Significance	Observed Significance
Rosenthal	2504	0.050	< 0.001

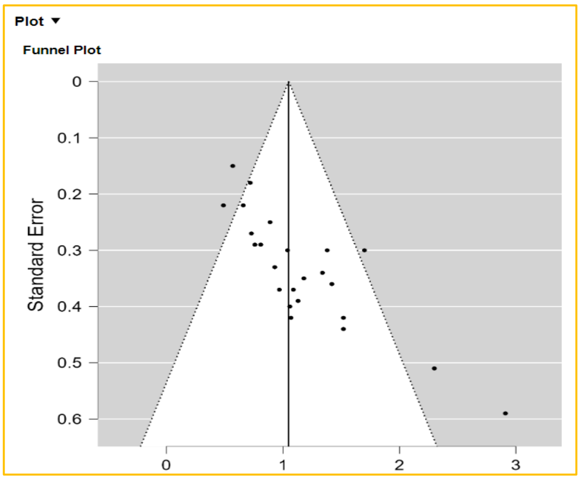

Figure 2. Funnel Plot

Table 5. Summary/ Mean Effect Size

Coeficient	Effect Size	Standard Error	z	p	Coeficient Interval 95 %	
					Lower	Upper
Intercept	1.050	0.089	11.56	< 0.01	0.87	1.22

This research is in line with Yustina et al., (2022) The Ethnoscience-based problem-based learning model can encourage 21st century thinking skills consisting of students' creative and critical thinking skills in learning. These findings are in accordance with (Hamzah et al., 2022; Hatipoğlu, 2023) The application of the Problem Based Learning model can increase interest and motivation which can stimulate the thinking ability of 21st century students in school. The ethno-physics-based problem-based learning model helps students learn about local wisdom that helps students think critically, creatively and communicatively in learning and helps students solve a problem in life. Therefore, ethno-physics-based problem-based learning models help students learn physics more easily by interacting directly with nature (Alviya et al., 2023; Rattanakha & Chatwattana, 2023).

Problem based learning model: students learn more actively and creatively in solving a problem in learning activities (Kök & Duman, 2023; Rahma et al., 2024). Furthermore, the application of ethno-physics-based problem-based learning models will help their learning process be more interesting and innovative, making it easier for students to understand physics learning materials or concepts and helping to improve students' 21st-century thinking skills. 21st century thinking skills that are important in practicing students' soft skills and hard skills in solving a physics problem (Farizi, 2019; Gök & Boncukçu, 2023; Ningsih et al., 2023).

Conclusion

The results of this study show that the application of ethno-physics-based probelm based learning model has a positive influence on the thinking ability of 21st-century students in school compared to conventional models. Although the mean effect size value is 1.05 with a high influence category on the thinking ability of 21st century students. These findings provide important information that ethno-physics-based problem-based learning models are effective in improving students' 21st-century thinking skills in their physics learning at school.

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Author Contributions

This research consists of two authors, the first author Adwitya Rezky Septian contributed in collecting, selecting and analysing and interpreting research data. The second author, Heru Kuswanto, contributed in providing input, additions and suggestions for this research.

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Conflicts of Interest

The authors declare no conflict of interest.

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