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The Effectiveness of the CIPP Evaluation Model in Science Learning in the Era of the Industrial Revolution 4.0

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Abstract
This study aims to determine the effectiveness of the CIPP model in evaluating science learning in students in the 4.0 revolution era. This research is a type of quantitative research with a meta-analysis approach. The inclusion criteria in this study are 1) the research was published in 2022-2024; 2) research must be indexed by the Science Technology Index (SINTA) or Scopus; 3) research was obtained through the Google Scholar, Mendeley, and ERIC databases; 4) The research must be relevant and report complete data to calculate the effect size value—data analysis through statistical analysis with the help of JSAP applications. The analysis results of 20 publications obtained a summary effect size value ($d = 0.861$; $p < 0.001$). Effect size is included in the category of very high effect size. These findings conclude that using the CIPP model has a positive effect on the evaluation of science learning in students compared to other evaluation models. No publication bias was found in this meta-analysis study, so it can be scientifically accounted for.

Keywords: *Evaluation; CIPP Model: Science Learning; Meta-analysis*

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Introduction
The Industrial Revolution 4.0 has brought great changes in various aspects of life, including education. In this era, technologies such as Artificial Intelligence (AI), big data, and the Internet of Things (IoT) have opened up new opportunities for education to develop more dynamically and interactively (Asnur et al., 2024). In science education, for example, the use of technology allows for wider access to various sources of information, visualization of complex scientific concepts, as well as a more in-depth learning experience through virtual simulations (Zulfadhli & Kamarudin, 2024; Dzo'ul Milal et al., 2020). This encourages science learning to be more relevant and engaging, where students not only understand the theory, but can also apply it in real-world contexts. Technology also allows for more efficient collaboration and communication, providing a richer and more holistic learning experience (Adnan et al., 2021).

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However, the development of this technology also requires a more accurate and thorough evaluation of learning. With AI and big data technology, educators now have access to more detailed student learning data, so they can track learning progress, understand individual student needs, and make more precise adjustments to learning methods(Ali et al., 2024; Wantu et al., 2024). Additionally, IoT allows for real-time data collection that provides an actual picture of student activity and engagement during the learning process. (Agustina & Mukhtaruddin, 2019).

Educational evaluation has an important role in ensuring the quality and relevance of the learning applied, especially in facing the demands of the Industrial Revolution 4.0 era that continues to develop (Zulkifli et al., 2022; Khalid et al., 2020). Evaluation is a tool to assess the effectiveness of teaching methods and strategies, including the extent to which learning outcomes meet the increasingly complex needs of students (Ampong, 2020). Not only does it function to measure the final results, but the evaluation also includes an analysis of various factors that support learning, such as context, resources, and the application process. Through a thorough evaluation, educators can identify successes and aspects that need to be improved, so that learning is not only focused on academic achievements, but also on developing student competencies in accordance with the times (Harding, 2012).

More than that, educational evaluation is an important source of information for decision-making at the school, institutional, and government levels (Chen & Ruannakarn, 2024; Oflaz et al., 2022). Accurate evaluation data helps stakeholders to assess the relevance of the curriculum, the effectiveness of teaching methods, and the suitability of learning strategies to the needs of the community. In the midst of rapid technological advances and changing skills needs, evaluation serves as a tool to ensure that the education system is able to equip students with 21st century skills, such as critical thinking, collaboration, and digital literacy (Nurhayati et al., 2024). Thus, the evaluation not only aims to assess student achievement, but also directs education to remain responsive and adaptive to change, so as to prepare a generation that is ready to face future challenges.

Furthermore, educational evaluation faces several fundamental problems that affect its effectiveness in assessing and developing the quality of learning. One of the main problems is the evaluation approach that still focuses too much on the final result or cognitive achievement, such as test scores or tests (Khaksar et al., 2023; Keskin & Yazar, 2020). This leads to assessments of other important aspects, such as students' critical thinking skills, creativity, and interpersonal skills, often overlooked. In fact, in the era of the Industrial Revolution 4.0, these skills are crucial to help students adapt and succeed in a constantly changing world. Excessive reliance on standardized tests also has the potential to limit teachers' room for innovation in developing more varied and interactive learning methods, which can ultimately have an impact on student motivation and participation in the learning process (Putro et al., 2024).

In addition, the limitations of technology and infrastructure are obstacles in the implementation of effective and comprehensive educational evaluation. Many schools, especially in remote areas or with limited resources, do not yet have access to technology that allows for real-time, data-driven evaluations(Divayana et al., 2017; Kang, 2020). This hinders the ability of educators and institutions to monitor student development on an ongoing basis, and to make timely adjustments to learning strategies. These limitations also limit the use of data to support more holistic evaluations, which include the affective and social aspects of students. The lack of training and development for educators in the use of technology for evaluation is also a problem, resulting in evaluations that are often less than optimal in describing the real needs and potential of students(Basaran et al., 2021; Chen & Ruannakarn, 2024). Therefore, there is a need for an evaluation model that is effective in measuring student learning, namely the evaluation of the CIPP model.

The CIPP (Context, Input, Process, Product) evaluation model is a holistic and comprehensive evaluation method in assessing learning effectiveness(Bilan et al., 2021; Aziz

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et al., 2018). This model is designed to see and analyze various important aspects that affect the quality of education, so that it can provide a complete picture of the success of a program or learning method (Setiawan et al., 2024). In the context aspect, the CIPP model assesses the learning goals and needs to be achieved, as well as the relevance of the program to the conditions and challenges faced by students. This aspect is important to ensure that learning is designed according to the needs and characteristics of students as well as real situations faced in the field. With the right understanding of the context, learning programs can be better directed to achieve significant and relevant outcomes (Rezaee & Shokrpour, 2011; Santiyadnya, 2021; Divayana et al., 2017).

The Input aspect in the CIPP model evaluates the resources used, such as facilities, teaching staff, and teaching materials, as well as the learning strategies applied. It aims to ensure that all available resources are optimal and support the effectiveness of the learning process(Basaran et al., 2021). In the Process aspect, this model evaluates the implementation or implementation of the learning itself, assessing whether the method used is running according to plan and whether there are obstacles during the implementation(Iqbal et al., 2022; Adedokun-Shittu & Shittu, 2013). Finally, the Product aspect evaluates the final learning outcomes, namely the extent to which the learning program or method is able to achieve the goals that have been set. By evaluating these four aspects, the CIPP model allows for a thorough evaluation of learning, from planning to final results, so that areas that need to be improved or maintained can be identified for more effective learning (Rezaee & Shokrpour, 2011).

The CIPP evaluation model is effective for evaluating the student learning process on the independent curriculum (Setiawan et al., 2024); Santiyadnya, 2021) serta dapat mengevaluasi pembelajaran di perguruan tinggi (Li & Hu, 2022). In addition, the CIPP evaluation model is effective in evaluating service learning standards in schools (Harding, 2012; Sopha & Nanni, 2019; Darma, 2019). However, there are many studies related to the CIPP learning model, there has been no research related to the effectiveness of the CIPP model in science learning. Therefore, a meta-analysis is needed to determine the effectiveness of the CIPP model in science learning. Based on this, this study aims to evaluate the effectiveness of the CIPP model to evaluate science learning in students in the 4.0 revolution era.

Methodology

This study uses a meta-analysis approach to determine the effect size of effectiveness of the CIPP model to evaluate science learning in students in the 4.0 revolution era. Meta-analysis is a research approach that evaluates previous research statistically to reach a conclusion (Tamur et al., 2020; Abdullah et al., 2024; Noh et al., 2014)The meta-analysis research procedure is 1) determining the research inclusion criteria, 2) collecting data and coding, and 3) analyzing the data statistically, as can be seen in Figure 1.

Figure 1. Meta-analysis Prosedure

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 1) the research was published in 2022-2024; 2) research must be indexed by the Science Technology Index (SINTA) or Scopus; 3) research was obtained through the Google Scholar, Mendeley and ERIC databases; 4) The research must be relevant and report complete data to calculate the effect size value,. From the data search, 20 studies were obtained that met the inclusion criteria published in 2021-2024 which can be seen in Table 2.

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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, Mendeley dan ERIC The keywords for data search are " evaluation"; "CIPP evaluation model"; "Effectiveness of CIPP model evaluation on science learning"; "Science learning".

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 effectiveness of the CIPP model to evaluate science learning in students in the 4.0 revolution era. According to (Borenstein et al., 2007) 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: (Borenstein et al., 2007; Bachtiar et al., 2023; Tamur et al., 2020)

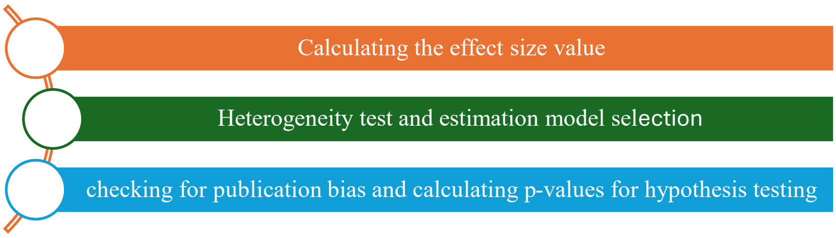

Figure 1. Data Analysis Procedure

Publication Bias Review

Checking publication bias in this purchase is through funnel plot analysis and the Rosenthal Fail-Safe N test. The results of checking publication bias with the plot funnel can be seen in Figure 2.

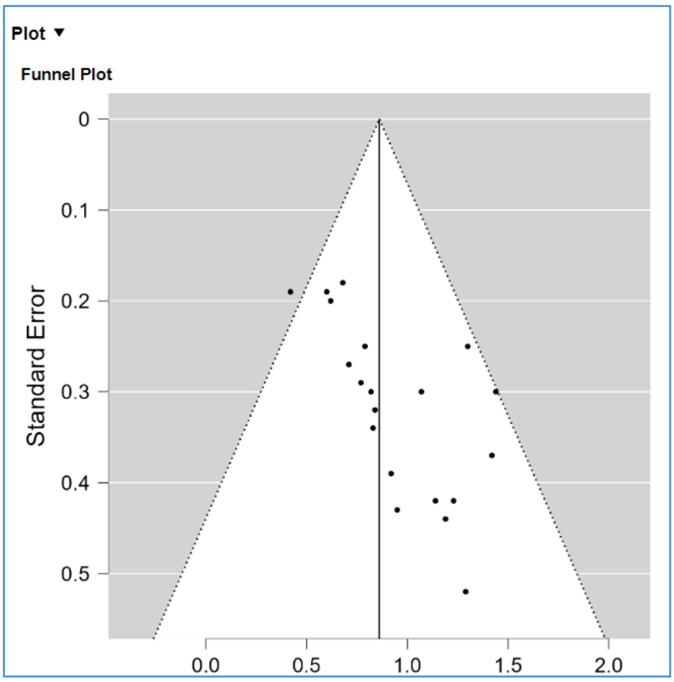

Figure 2. Funnel Plot

DOI: 10.31004/obsesi.v8i6.6227

Result and Discussion

Based on the Google Scholar database search results, Mendeley and ERIC were obtained, 20 studies/articles met the inclusion criteria. The effect size and error standard can be seen in Table 2.

Table 2. Effect Size and Standard Error Every Research

Code Jurnal	Years	Countries	Effect Size	Standard Error
AP1	2021	Indonesia	0.82	0.30
AP2	2021	China	0.77	0.29
AP3	2023	China	1.14	0.42
AP4	2023	Indonesia	0.92	0.39
AP5	2023	China	1.19	0.44
AP6	2023	Inggris	1.07	0.30
AP7	2021	Mesir	0.62	0.20
AP8	2024	Malaysia	0.84	0.32
AP9	2024	Filipina	0.71	0.27
AP10	2024	China	0.60	0.19
AP11	2024	Indonesia	1.30	0.25
AP12	2022	Indonesia	1.23	0.42
AP13	2022	Indonesia	1.42	0.37
AP14	2021	Spanyol	0.42	0.19
AP15	2024	India	0.95	0.43
AP16	2024	India	0.79	0.25
AP17	2024	Pakistan	1.44	0.30
AP18	2024	Indonesia	0.68	0.18
AP19	2021	USA	1.29	0.52
AP20	2021	Indonesia	0.83	0.34

Based on Table 2, the effect size value of the 20 studies ranged from 0.42 to 1.44. According to Borenstein et al., (2007) Of the 20 effect sizes, 7 studies had medium criteria effect sizes, and 13 studies had high criteria effect size values. Furthermore, 20 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 3. Fixed and Random effect

	Q	df	p
Omnibus test of Coefficients Model	62.997	1	< 0.001
Test of Residual Heterogeneity	102.972	19	< 0.001

Based on Table 3, a Q value of 102.972 was obtained, higher than the value of 62.997 with a coefficient interval of 95% and a p-value of 0.001 <. The findings show that the value of the 20 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 the Rosenthal fail-safe N (FSN) test (Tamur et al., 2020; Badawi et al., 2022; Ichsan et al., 2023b; Borenstein et al., 2007; Kahraman, 2023). The results of checking publication bias with Rosenthal Fail-Safe N can be seen in Table 4.

Based on Table 4, the Fail Safe N value of 1369 is greater than the value of 5k + 10 = 5(20) + 10 = 110, so it can be concluded that the analysis of 20 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test

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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.

Table 4. Fail-Safe N

File Drawer Analysis			
	Fail-Safe N	Target Significance	Observed Significance
Rosenthal	1369	0.050	< 0.001

Table 5. Summary/ Mean Effect Size

Coefficient						
	Effect Size	Standard Error	z	p	Coeficient Interval 95%	
					Lower	Upper
Intercept	0.861	0.274	11.662	< 0.01	0.716	1.007

Table 5, the results of the analysis of the summary effect value of 0.861 with a standard error of 0.274 with a 95% confidence level lower 0.716 and upper 1.007. These findings show that the application of the CIPP model has a positive influence on evaluating student science learning in schools with a value ($z = 11.662$; $p < 0.001$) included in the high effect size category. The Context, Input, Process, Product (CIPP) model emerges as an evaluation approach that is able to assess all aspects of learning from start to finish, thus providing a comprehensive picture of program effectiveness (Iqbal et al., 2022). This approach allows for a deeper understanding of the factors that affect the quality of science education in the face of the needs of the 4.0 Revolution which demands technology-based competencies (Chen & Ruannakarn, 2024; Keskin & Yazar, 2020).

The CIPP evaluation model helps teachers and institutions understand the environment and needs of science learning in accordance with the Revolution 4.0. This evaluation involves an analysis of educational goals, skills needed, and challenges faced by students and educators(Bilan et al., 2021). Through context analysis, institutions can ensure that the curriculum and programs implemented are in line with global trends, in particular digital skills, problem-solving, and technology adaptation that are essential for this era(Putro et al., 2024; Chen & Ruannakarn, 2024).The evaluation of the CIPP model focuses on the quality of resources that support learning, including facilities, technology devices, and the capacity of educators to integrate technology in science learning(Ratnaya et al., 2022). This assessment helps institutions to determine whether the available resources are sufficient to meet educational standards in the era of Revolution 4.0. The availability of adequate technology and training for educators is a crucial aspect, because without strong input support, learning goals relevant to Revolution 4.0 are difficult to achieve (Ekiz, 2022).

Furthermore, CIPP evaluates the teaching methods and strategies applied during the learning process. This includes the application of technology-based learning methods, such as the use of simulations, virtual laboratories, as well as project-based learning that can hone students' skills in solving real problems. Evaluation of this process is essential to ensure that the approach used is truly effective in equipping students with Revolution 4.0 skills, such as collaboration, communication, and data analysis skills.

The last stage, namely Product, aims to evaluate the final result of the learning process(Görkem Erdogan & Mede, 2021). Through the measurement of results, CIPP allows the evaluation of the achievement of students' competencies in science, both in terms of material understanding and technological skills developed during the learning process. This product evaluation provides a clear picture of whether the learning program has successfully achieved its goals and whether students are ready to face the challenges of modern industry

(Oflaz et al., 2022). If the results show gaps, improvements are needed in the previous stages. Overall, the application of the CIPP model in the evaluation of science learning in the era of Revolution 4.0 brings many benefits, especially in improving learning programs that are responsive to change (Khaksar et al., 2023; Li & Hu, 2022; Putro et al., 2024). By evaluating from various perspectives, the model not only assesses the final result but also the process and supporting factors. This helps educational institutions to make continuous improvements so that students can gain learning experiences that are relevant to the times (Nurhayati et al., 2024).

Conclusion

From the results of the meta-analysis, it can be concluded that the analysis of 20 publications obtained a summary effect size value ($d = 0.861$; $p < 0.001$). Effect size is included in the category of very high effect size. These findings conclude that using the CIPP model positively affects the evaluation of science learning in students compared to other evaluation models. No publication bias was found in this meta-analysis study, so it can be scientifically accounted for. The CIPP model can ensure that every aspect of learning, from curriculum adjustments, resource readiness, and implementation of technology-based methods to the achievement of student competencies, can be assessed comprehensively. The implication is that educational institutions can use these findings to strengthen the quality of learning programs by being more adaptive to industry changes, especially in developing technological skills and problem-solving in students. Thus, the CIPP model increases the effectiveness of science learning and helps shape students who are ready to compete in a high-tech work environment. CIPP evaluation model in subjects other than science is used to determine the consistency of its effectiveness in different educational contexts. In addition, integrating industry 4.0-based learning technologies, such as artificial intelligence and big data, into CIPP evaluations can provide deeper insights into how technology can support the learning evaluation process. Further research can also consider the perspectives of various stakeholders, such as teachers, students, and policymakers, to obtain a more comprehensive picture of the application of this model in supporting the quality of education in the digital age.

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