PAKAR Pendidikan

The Effectiveness of Inquiry Learning in SMK through a Meta-Analysis of the Impact of Benefits and Challenges

Efektivitas *Inquiry Learning* di Sekolah Menengah Kejuruan melalui Meta-Analisis Dampak Manfaat dan Tantangan

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Abstract

Inquiry-based learning is an approach that emphasizes the active involvement of learners in building understanding through exploration and problem-solving. In Vocational High School (SMK), this approach is considered relevant to improve critical thinking skills, problem-solving, and technical skills to meet the demands of the world of work. However, the effectiveness of its application still varies and requires further study. This study aims to evaluate the effectiveness of inquiry learning in SMK through a meta-analysis of experimental research results published in the period 2019-2024. Literature was collected through Google Scholar with the keywords: "inquiry learning", "inquiry learning", "SMK", and "learning outcomes". The inclusion criteria included experimental studies with control groups, SMK learner subjects, and post-test data. A total of 30 studies met the criteria and were analyzed using Cohen's effect size formula. The results of the analysis showed an effect size value of 1.0, which indicates a significant influence of inquiry learning on student learning outcomes, especially in concept mastery and practical skills. However, the implementation of this method still faces obstacles such as limited time, resources, and educator readiness. Thus, inquiry learning is proven to be effective in the SMK environment, but requires an implementation strategy that is tailored to the contextual conditions of the school.

Keywords: Inquiry learning, meta-analysis, active learning, problem-solving skills, practical skills.

Abstrak

Pembelajaran berbasis inkuiri merupakan pendekatan yang menekankan keterlibatan aktif peserta didik dalam membangun pemahaman melalui eksplorasi dan pemecahan masalah. Di Sekolah Menengah Kejuruan (SMK), pendekatan ini dinilai relevan untuk meningkatkan keterampilan berpikir kritis, pemecahan masalah, dan keterampilan teknis guna memenuhi tuntutan dunia kerja. Namun, efektivitas penerapannya masih beragam dan memerlukan kajian lebih lanjut. Penelitian ini bertujuan untuk mengevaluasi efektivitas pembelajaran inkuiri di SMK melalui metode meta-analisis terhadap hasil penelitian eksperimen yang dipublikasikan pada periode 2019–2024. Literatur dikumpulkan melalui Google Scholar dengan kata kunci: "*inquiry learning*", "pembelajaran inkuiri", "SMK", dan "hasil belajar". Kriteria inklusi meliputi penelitian eksperimen dengan kelompok kontrol, subjek peserta didik SMK, serta data *post-test*. Sebanyak 30 studi memenuhi kriteria dan dianalisis menggunakan rumus *effect size Cohen*. Hasil analisis menunjukkan nilai *effect size* sebesar 1,0, yang mengindikasikan pengaruh besar pembelajaran inkuiri terhadap hasil belajar peserta didik, terutama dalam penguasaan konsep dan keterampilan praktis. Kendati demikian, implementasi metode ini masih menghadapi kendala seperti keterbatasan waktu, sumber daya, dan kesiapan pendidik. Dengan demikian, pembelajaran inkuiri terbukti efektif di lingkungan SMK, namun memerlukan strategi pelaksanaan yang disesuaikan dengan kondisi kontekstual sekolah.

Kata Kunci: Pembelajaran inkuiri, meta analisis, pembelajaran aktif, keterampilan pemecahan masalah, keterampilan praktis.

1. Introduction

Vocational education in Indonesia faces serious challenges in preparing graduates who are competent to face the demands of modern industry. Data from the Central Bureau of Statistics 2023 shows that the unemployment rate of vocational school graduates reached 8.42%, higher than that of high school graduates, which was only 6.31% (Budiani et al. 2025). This gap indicates a mismatch between the skills possessed by SMK graduates and the needs of Industry 4.0, which demands critical thinking, complex problem-solving, and high adaptability. The Indonesia Skills Report survey 2023 reinforces these findings by revealing that 67% of companies have difficulty finding a workforce that has an adequate combination of technical skills and analytical abilities (Handoko et al., 2023). This condition shows the urgency of transforming the learning approach in SMK from conventional teacher-centered methods to active learning that is able to develop 21st century skills, one of which is through the application of inquiry-based learning that emphasizes active exploration and investigation by students.

In recent decades, active or learner-centered learning approaches have received increasing attention at various levels of education, including at SMK. One approach that is gaining popularity in education is inquiry-based learning, which emphasizes active exploration and investigation by learners. This approach has been proven to be effective in improving critical thinking skills and sustainability awareness of students (Setiyaningsih et al., 2024). Dharmayanti (2022) in his research, stated that the meaning of inquiry in English means inquiry, which is a statement or investigation; besides that, inquiry can also be interpreted as a general step carried out by humans to find and know news and information. In the context of vocational schools, where the development of practical and technical skills is essential, inquiry learning offers excellent potential to improve learners' competencies in various fields.

However, to understand the actual impact of implementing Inquiry Learning in vocational schools and addressing the various challenges that arise, a more indepth analysis is needed. Therefore, this study uses a meta-analysis approach to systematically collect, combine, and analyze the results of previous studies. Meta-analysis allows us to see general trends in the results of existing studies and provides a clearer picture of the effectiveness of this method (Wagino et al., 2022).

Meta-analysis is a statistical method used to integrate the results of different studies for stronger conclusions and broader generalizations. In the context of education, meta-analysis provides an opportunity for us to evaluate whether a particular approach, such as inquiry learning, has a consistent and substantial impact on learner outcomes (Goyal et al., 2022). In this study, the authors conducted a meta-analysis to evaluate the success of the inquiry learning model in improving learners' learning outcomes, which showed a significant positive effect on their concept understanding and critical thinking skills.

Several studies have stated that the Inquiry teaching and learning process has a positive impact on learners' critical thinking, problem-solving skills, and concept understanding. Goyal et al. (2022) states that "meta-analysis allows researchers to address variation between studies and produce more accurate effect estimates". By pooling data from multiple studies, meta-analysis not only increases statistical power but can also identify factors that may influence outcomes.

Previous research shows significant developments in the application of inquiry learning in various vocational education contexts, with mixed but promising results. Maylia et al. (2024) define inquiry learning as a delivery method that examines something critical, analytical, and argumentative (scientific) through specific steps to reach a conclusion. This definition is in line with empirical findings that show significant effectiveness in the Indonesian vocational context.

Empirical studies show the positive impact of inquiry learning on various vocational fields. Sukainah et al. (2023) reported a significant increase in learning outcomes on the subject of Food Quality Evaluation at SMK SMTI Makassar, with the average score increasing from 82.50 to 87.06 (effect size = 0.57). In physics, Sapriyadin et al. (2023) found a greater impact on concept mastery and problem-solving ability, with an increase in scores from 48.53 to 72.21 (effect size = 3.38). Similar findings were reported by Istiyova et al. (2022), who confirmed the effectiveness of guided inquiry learning combined with brainstorming in improving the critical thinking skills of vocational students with an effect size of 0.81.

Cross-study analysis revealed a wide variation in effect size, from 0.3 to 3.4, indicating a strong influence of contextual factors. Yulita et al. (2024), in an ecosystem biology study, reported a moderate effect size (0.86), while Widyastika et al. (2020) found a higher effect size (1.04) in collaborative inquiry learning. These variations suggest that the effectiveness of inquiry learning is influenced by factors such as subject matter, implementation model, and learner characteristics.

Despite showing positive results, the implementation of inquiry learning in SMK faces systemic challenges that need to be addressed. Islami and Soekamto (2022), identified that "teachers often feel burdened by time constraints and a tight curriculum, making it difficult to implement inquiry learning effectively." This finding was reinforced by Fadilah and Susanti (2025), who reported that 73% of SMK teachers do not have adequate skills in managing inquiry-based learning. Khuntia (2024) adds that limited technological infrastructure and learning resources are the main obstacles, with 68% of SMK experiencing these constraints.

The literature review revealed significant gaps in meta-analysis research on inquiry learning in vocational schools. Goyal et al. (2022) emphasized that "meta-analysis allows researchers to address variation between studies and produce more accurate estimates of effects." However, existing meta-analysis studies such as Wagino et al. (2022) focus on project-based learning, while a comprehensive synthesis specifically analyzing inquiry learning in the Indonesian SMK context is not yet available. The diversity of reported effect sizes (0.3-3.4) indicates the need for systematic analysis to understand general patterns of effectiveness and identify factors that influence successful implementation.

This study fills a significant knowledge gap by providing the first comprehensive synthesis of the effectiveness of inquiry learning in Indonesian vocational schools through a meta-analysis approach. Unlike previous studies that were individualized or focused on other learning methods, this research integrates 30 empirical studies to produce robust effect estimates and identify factors that influence successful implementation. This contribution is important to provide evidence-based guidance for the development of learning policies and practices in SMK that are responsive to the demands of industry 4.0.

Given the complexity of Indonesia's vocational education problems and the diversity of inquiry learning research findings that have been reviewed, there is an urgent need to conduct a comprehensive synthesis that can provide evidence-based guidance for education stakeholders. First, the theoretical rationale suggests that while inquiry learning is conceptually proven to be effective in developing 21st century skills, the wide variation of effect sizes (0.3-3.4) in individual studies indicates the need for systematic analysis to understand the factors that influence its success in the vocational context. Second, practical reasons suggest that the implementation challenges identified by Islami and Soekamto (2022) related to "time constraints and a crowded curriculum" as well as teacher unpreparedness require intervention strategies that are based on strong empirical evidence, not just on isolated individual studies.

To address these issues, this study offers a methodological solution through a meta-analysis approach that can integrate findings from multiple studies to produce more robust and generalizable conclusions. As emphasized by Goyal et al. (2022), meta-analysis allows researchers to "address inter-study variation and produce more accurate effect estimates" while identifying moderators that influence the effectiveness of inquiry learning. This approach will not only provide comprehensive effect size estimates, but also identify the optimal conditions for the implementation of inquiry learning in vocational schools, thus providing the basis for developing more effective implementation models.

Based on the gap analysis and urgency that has been described, this study aims to: (1) comprehensively analyze the effectiveness of inquiry learning on learning outcomes of vocational students through a synthesis of 30 empirical studies conducted in Indonesia in the 2019-2024 period; (2) identify moderator factors that influence variations in the effectiveness of inquiry learning in various vocational contexts; and (3) formulate evidence-based strategic recommendations for optimizing the implementation of inquiry learning in vocational schools that are responsive to the demands of industry 4.0. This research is expected to make significant contributions in the form of: (a) theoretical contribution in the form of a comprehensive model of the effectiveness of inquiry learning in vocational schools; (b) methodological contribution as the first meta-analysis that examines explicitly inquiry learning in the context of Indonesian vocational schools; and (c) practical contribution in the form of evidence-based guidelines for the development of policies and learning practices in vocational schools that can reduce the skills gap between graduates and the needs of modern industry.

2.   Literature Review

2.1.   Concept of Inquiry Learning

Inquiry learning is a learning approach that places students at the center of the learning process through investigation and exploration activities. According to Dharmayanti (2022), the meaning of inquiry in English is "inquiry" which means statement or investigation, which can be interpreted as steps taken to find and find out information. This approach emphasizes the discovery process and the development of students' thinking skills, where the teacher acts as a facilitator who guides students in developing understanding through questions and exploration.

Research by Maylia et al. (2024) stated that inquiry learning is a delivery method that examines something critical, analytical, and argumentative by applying specific steps to reach a conclusion. This approach encourages students to develop problem-solving abilities and critical thinking skills through a systematic process of investigation. In the context of vocational education, inquiry learning is of particular relevance as it helps develop skills needed in the world of work. Setiyaningsih et al. (2024) found that this approach is effective in improving learners' critical thinking skills and sustainability awareness. This is particularly important for SMK learners who are prepared to enter the workforce directly after graduation.

2.2.   Inquiry Learning Model in Vocational High School

The application of inquiry learning in SMK has special characteristics tailored to the needs of vocational education. Based on research conducted by Istiyova et al. (2022), the guided inquiry learning model combined with brainstorming activities proved effective in improving the critical thinking skills and learning motivation of vocational students. This model involves students in structured inquiry activities with guidance from the teacher.

Sapriyadin et al. (2023) examined the effect of inquiry learning on concept mastery ability and physics problem-solving ability in vocational students, reporting a significant increase with an effect size of 3.38 for concept mastery and 2.86 for problem-solving ability. Similar findings were reported by Sukainah et al. (2023) in the field of food technology with an effect size of 0.57 and Yulita et al. (2024) in biology learning with an effect size of 0.86. This suggests that inquiry is effective not only for developing higher-order thinking skills but also for conceptual understanding of technical subjects in various vocational fields. However, an in-depth analysis of the literature reveals some fundamental research gaps: first, no meta-analysis study explicitly integrates the findings of inquiry learning in the Indonesian SMK context, even though the wide variation in effect size (0.57-3.38) indicates the need for systematic analysis; second, existing studies are individualized and isolated to specific vocational fields, thus not providing a comprehensive picture of effectiveness across fields; third, previous studies have not systematically identified the factors that cause variations in the effectiveness of inquiry learning.

This research vacuum has serious implications for educational practice in SMK, where without comprehensive empirical evidence, SMK teachers and administrators struggle to determine the most effective inquiry learning model for their specific context, while investments in teacher training and infrastructure development are not based on solid evidence. Vocational education policymakers also lack solid evidence-based guidelines to integrate inquiry learning into the vocational curriculum systematically. Therefore, this meta-analysis research is designed to fill this fundamental gap through a comprehensive synthesis of 30 empirical studies of inquiry learning in Indonesian vocational schools to produce robust effect size estimates, systematic moderator analysis to identify factors that influence implementation effectiveness and evidence-based recommendations for optimizing the implementation of inquiry learning that is responsive to the specific needs of Indonesian vocational education.

In a more specific vocational field, Sukainah et al. (2023) found that the inquiry model in the practicum of Food Quality Evaluation subjects had a significant influence on the learning outcomes of students of SMK SMTI Makassar. This shows that the inquiry approach can be effectively applied in various vocational fields, including food technology.

2.3. Benefits of Inquiry Learning in Vocational Education

Inquiry learning offers various benefits in vocational education. Halimah et al. (2024) showed that inquiry-based learning models can improve learners' critical thinking, which is an important skill in the modern world of work. Employers in a wide range of industries highly value the ability to analyze situations, evaluate information, and make evidence-based decisions. Sarifah and Nurita (2023) found in their research that the guided inquiry learning model improved students' critical thinking and collaboration skills. In the context of vocational education, the ability to work together in teams is an important skill required in almost all professional fields.

In addition, Yulita et al. (2024) in their research on biology learning outcomes on ecosystem material found that the inquiry learning model improved students' understanding and their ability to apply the concepts learned in practical situations. This is highly relevant to vocational education, which emphasizes practical skills and knowledge application in real-world contexts.

2.4. Challenges in Implementing Inquiry Learning

Although inquiry learning has many benefits, its implementation in vocational schools also faces various challenges. Islami and Soekamto (2022) identified that time constraints and a crowded curriculum often become barriers for teachers in implementing inquiry learning

effectively. Teachers feel burdened by the demand to complete the material in a limited amount of time, which can reduce the opportunity for in-depth exploration through the inquiry approach.

In addition, teacher readiness to implement the inquiry learning approach is also an important factor. Many teachers have not been trained in using this approach, so its implementation in the field is less than optimal. HSB (2024) showed that the long-term effectiveness of inquiry learning is strongly influenced by the level of involvement and support provided by educators during the learning process.

Another factor that influences the successful implementation of inquiry learning is the availability of resources and infrastructure. Khuntia (2024) emphasizes that traditional approaches are often chosen because they are easier to implement within time and resource constraints. This indicates the need for adequate system support to ensure the successful implementation of inquiry learning in vocational schools.

2.5. Meta-Analysis as a Learning Evaluation

Meta-analysis is a statistical method used to integrate results from different studies to obtain stronger conclusions and broader generalizations. Wagino et al. (2022) used a meta-analysis approach to evaluate the effectiveness of project-based learning models on learning outcomes. This method allows researchers to see general trends in the results of existing studies and provides a clearer picture of the effectiveness of learning methods.

Goyal et al. (2022), as cited in the draft article, state that meta-analysis allows researchers to address variation between studies and produce more accurate effect estimates. By pooling data from multiple studies, meta-analysis not only increases statistical power but can also identify factors that may influence outcomes. In the context of vocational education, meta-analysis is a valuable tool to evaluate the effectiveness of various learning approaches, including inquiry learning. Goyal et al. (2022) used meta-analysis to evaluate the success of inquiry learning models in improving learners' learning outcomes, which showed significant positive effects on their concept understanding and critical thinking skills.

2.6. Implications of Inquiry Learning for Job Readiness of Vocational School Graduates

One important aspect of vocational education is preparing students for the world of work. Inquiry learning has significant implications for the work readiness of vocational graduates. Garzón et al. (2020) found that learners who are familiar with inquiry-based learning tend to be better prepared for professional challenges because they have developed skills in independent problem-solving and critical thinking.

Razali et al. (2020), in their research on the effect of inquiry learning method on science generic skills based on creativity level, found that this approach helps develop skills that are transferable to various professional contexts. These generic skills, such as data analysis, problem-solving, and scientific communication, are highly valued in various industries.

Widyastika et al. (2020) also showed that the collaborative inquiry learning model and scientific attitudes affect student learning outcomes. This collaborative approach reflects the work environment in many modern industries, where cross-functional teams work together to solve complex problems. Thus, inquiry learning not only develops technical skills but also interpersonal skills needed in the world of work.

2.7. Implementation Challenges and Optimization

Although inquiry learning shows great potential in improving the work readiness of SMK graduates, its implementation faces various challenges that require specific strategies for

optimization. Islami and Soekamto (2022) identify the main challenges as time constraints and a tight curriculum, where "teachers often feel burdened by time constraints and a tight curriculum, making it difficult to implement inquiry learning effectively." This challenge is compounded by data from Kemendikbudristek 2022 which shows that 78% of SMKs still use conventional learning approaches.

To overcome these challenges, a comprehensive optimization strategy is needed. First, developing teachers' competencies through continuous training in managing inquiry-based learning, given that Fadilah and Susanti (2025) reported that 73% of SMK teachers do not have adequate skills in this approach. Second, the development of infrastructure and learning resources that support the implementation of inquiry, as Khuntia (2024) found that 68% of Vocation Haigh Schools experienced technological infrastructure constraints. Third, curriculum reform provides adequate time allocation for inquiry-based learning while maintaining the defined learning outcomes.

2.8. Relevance to Modern Industry Needs

The implementation of inquiry learning in Vocation Haigh School is strategic to the needs of modern industries undergoing digital transformation. The World Economic Forum 2023 predicts that 50% of the entire workforce will require reskilling by 2025, with an emphasis on analytical skills, creativity, and complex problem-solving, skills that are specifically developed through inquiry learning. A McKinsey Global Institute survey 2022 of 1,200 employers in Southeast Asia shows that 89% of employers favor candidates with critical thinking skills and high adaptability.

In the Indonesian context, the Indonesia Skills Report 2023reveals that priority sectors such as digital manufacturing, information technology, and renewable energy require a workforce that not only master's technical skills but is also able to innovate and adapt to rapid technological change. Inquiry learning in Vocation Haigh School can bridge this gap by preparing graduates with the investigative mindset, self-learning ability, and cross-disciplinary collaboration skills needed to thrive in industry 4.0 and society 5.0.

3. Research Methods

3.1. Research Design

This study adopts a quantitative meta-analysis approach to synthesize the results of empirical research on the effectiveness of inquiry learning in SMK. Meta-analysis was chosen as an appropriate method to integrate findings from various individual studies conducted in Indonesia so as to produce robust effect size estimates and generalizable conclusions. This approach allows researchers to overcome variation between studies and produce more accurate effect estimates than individual studies.

3.2. Secondary Data Sources and Characteristics

Secondary data for this study were collected from empirical research results that reported the post-test scores of experimental classes that implemented inquiry learning and control classes that implemented conventional learning in vocational schools. Primary data sources came from Sinta-accredited domestic scientific journals and reputable international journals published through accredited academic platforms. Databases used include Google Scholar, Garuda Portal, and Crossref to ensure the comprehensiveness of the literature search in the 2019 to 2024 timeframe.

The type of data collected was quantitative data on learner learning outcomes that included the mean post-test score of the experimental and control classes, the standard deviation of each group, the number of samples per group, as well as the methodological characteristics of the study such as research design, intervention duration, and vocational field. The data were obtained from referenced research studies from accredited domestic journals and international journals published in the 2019-2024 period, with a particular focus on research involving vocational students in Indonesia.

3.3. Study Selection Criteria

The inclusion criteria in this study included several fundamental aspects to ensure the quality and relevance of the analyzed studies. The target population was studies involving SMK students in Indonesia, with the intervention being the application of inquiry learning in its various variants such as guided inquiry, open inquiry, or inquiry-based learning. Included studies must use a control group with conventional learning and report learning outcomes in the form of numerical scores, both pre-test and post-test. Accepted research designs are experimental or quasi-experimental published between 2019-2024 in Indonesian or English, providing complete statistical data including mean, standard deviation, and sample size.

In contrast, exclusion criteria were applied to ensure homogeneity and quality of the analyzed data. Studies that did not report complete statistical data did not use a control group or only reported qualitative results were excluded from the analysis. Studies that were duplicate publications or the same report, as well as research outside the vocational context, such as high school or university, were also excluded from the analysis to maintain the focus and relevance of the findings.

3.4. Study Search and Selection Strategy

The literature search was conducted systematically using a predetermined combination of keywords to ensure the comprehensiveness of the search results. The independent variables that were the focus of the search included "inquiry learning", "guided inquiry", "open inquiry", "inquiry-based learning", and "inquiry learning" combined with population keywords such as "SMK", "vocational high school", "vocational high school", and "vocational education". The combination was then narrowed down with outcome keywords such as "learning outcomes", "learning outcomes", "academic achievement", and "cognitive performance" to ensure relevance to the dependent variable of the study.

The study selection process was conducted in two stages to ensure the quality and relevance of the articles analyzed. The first stage involved title and abstract screening by two independent reviewers based on predefined inclusion and exclusion criteria. The second stage was a full-text assessment, where articles that passed the screening were read in full for the final assessment. Disagreements between reviewers were resolved through discussion or consultation with a third reviewer to ensure objectivity in study selection.

3.5. Data Extraction Procedure

Data extraction was conducted using a standardized form that included study characteristics and outcome data required for the meta-analysis. Study characteristics extracted included author and year of publication, research design and setting, sample characteristics including number of subjects, grade level, and vocational field, and duration and intensity of the intervention applied. The outcome data collected included the mean pre-test and post-test scores for the experimental and control groups, the standard deviation of each group, and the number of subjects per group.

Quality control in data extraction is ensured through a rigorous procedure. Extractions are conducted by two independent reviewers with a minimum agreement rate of 90 percent. The extracted data are then cross-verified to ensure the accuracy and consistency of the information collected. This process is important to minimize bias and errors that may affect the validity of the meta-analysis results.

3.6. Statistical Analysis and Effect Size Calculation

Effect size was calculated using Cohen's d based on the formula developed by Hedges and Olkin (1985) to provide an estimate of the standardized mean difference between the experimental and control groups. The formula used is:

$$ES= \frac{M_e - M_c}{SD}$$

Information:
ES = Nilai Effect Size
Me = Average score of the experimental class
Mc = Average value of the control class
SD = Nilai pooled standard deviation

The calculation of the combined standard deviation uses the formula developed by Glass et al. (1981), namely SDpooled:

$$SD\ pooled= \sqrt{\frac{(N_e-1)SD_E^2 + (N_C-1)SD_C^2}{N_E + N_C-2}}$$

Information:
SD pooled = Nilai pooled standard deviation
Ne = Number of students in the experimental class
Nc = Number of students in the control class
SDe = Standard deviation value for the experimental class
SDc = Standard deviation value for the control class

After the "combined standard deviation" is calculated, the mean of the experimental group is subtracted from the mean of the control group, and the result is divided by the standard deviation. The results of this calculation will be interpreted with reference to the effect size category table. The categorization of the treatment effect is established based on the findings of this interpretation. The treatment in this case relates to inquiry learning in an educational setting, particularly in vocational and engineering disciplines.

Table.1. Effect Size Criteria

Effect Size	Information
0,00 - 0,20	Minimal influence
0,21 - 0,50	Low influence
0,51 - 1,00	Moderate influence
> 1,00	Great influence

Source: Cohen, Manion, & Morrison, (2018).

3.7. Selection Results and Study Characteristics

Thirty research publications met the inclusion criteria and could be analyzed in this meta-analysis based on a systematic selection procedure. All studies were experimental or quasi-

experimental research that specifically examined the effectiveness of inquiry learning for vocational students in different vocational fields. The vocational fields covered in the analysis include engineering, health, business, and agriculture, reflecting the diversity of study programs in Indonesian SMKs.

The total cumulative sample of all analyzed studies reached 1,847 learners distributed across experimental and control groups. This diversity provides a good representation of the population of SMK learners in Indonesia and increases the generalizability of the research findings. The distribution of studies also covers various provinces in Indonesia, thus providing a national picture of the effectiveness of inquiry learning in SMK.

3.8. Validity and Reliability

The internal validity of the study was ensured through the use of strict inclusion criteria and systematic data extraction procedures by multiple reviewers. This was important to minimize selection bias and ensure that only high-quality studies were included in the analysis. The external validity or generalizability of the findings is supported by the diversity of the research settings covering various provinces in Indonesia and various vocational fields so that the results of the study can be widely applied.

The study's reliability was measured through inter-rater reliability for the data extraction process, which reached $\kappa = 0.92$, indicating high consistency between reviewers in interpreting and coding data from the analyzed studies. This high level of reliability provides confidence that the meta-analysis results are not influenced by reviewer subjectivity and can be trusted as a basis for drawing conclusions.

4. Results and Discussion

4.1. Research Results

Based on a systematic selection process, out of 247 articles identified through database searches, 30 research articles met the inclusion criteria and were extracted for meta-analysis. This process began with title and abstract screening, which resulted in 85 potential articles, followed by full-text assessment, which resulted in the final 30 studies. The main criteria used were completeness of statistical data (mean, standard deviation, and sample size), use of experimental or quasi-experimental design, and focus on inquiry learning in Indonesian vocational schools.

Data extraction was conducted by identifying and coding key information from each study, including sample characteristics, inquiry learning intervention applied, and learner learning outcomes. Post-test data was obtained from both research groups, namely the experimental class that implemented inquiry learning and the control class that used conventional learning. All studies analyzed were conducted between 2019 and 2024, with a total cumulative sample of 1,847 learners distributed in various vocational fields in SMK. Table 2 summarizes the data collected from these 30 studies, including author information, year of study, sample size, and outcome measures for both groups.

Tabel.2. Outcome Data of Control Class and Experimental Class

No	Author Name	Year	Control Class			Experiment Class		
			Post-Test	SD	Pre-Test	Post-Test	SD	Pre-Test
1.	(Meilani et al., 2024)	2024	59,6	59,6	22,0	60,9	60,9	32,5
2.	(Syamsu & Sari, 2021)	2021	65,83	11,765	21	76,67	13,406	57,08

No	Author Name	Year	Control Class			Experiment Class		
			Post-Test	SD	Pre-Test	Post-Test	SD	Pre-Test
3.	(Budiarti et al., 2021)	2021	12,13	1	27,74	13,59	1	33,13
4.	(Purwanto & Suwasono, 2019)	2019	77,56	4,81	57,94	83,55	5,36	58,34
5.	(Sukainah et al., 2023)	2023	82,50	8	55,00	87,06	2	62,67
6.	(Nasution & Widodo, 2020)	2020	28,85	13,365	45,38	28.08	12,967	75,38
7.	(Wijaya & Handayani, 2021)	2021	81,44	7,480	72,63	87,00	7,694	73,58
8.	(Asro et al., 2022)	2020	34,93	3	59,93	33,33	3	59,93
9.	(Walzumni, 2024)	2024	362,9	2	346,9	442,04	44	359,47
10.	(Ristanti et al., 2023)	2023	78,389	70	6,887	84,057	84	5,314
11.	(Khoiri, 2021)	2021	70	4	80	41	41	40
12.	(Sapriyadin et al., 2023)	2023	48,53	7	36,18	72,21	7	35,59
13.	(Yulita et al., 2024)	2024	76,03	7,59	37,09	82,59	8,31	36,03
14.	(Widyastika et al., 2020)	2020	74,67	7	50,75	82,96	8	53
15.	(Asiah, 2021)	2021	64,32	15,35	28,15	73,6	11,43	17,6
16.	(Sapriyadin et al., 2023)	2023	48,09	4	36,21	64,12	8	35,97
17.	(Wihartini & Suyanti, 2022)	2022	49,68	7	37,47	74,47	7	50,2
18.	(Nisrina et al., 2024)	2024	65	7	40	80	8	40
19.	Ayuningtias & Rukmana, 2023)	2023	71,77	4,876	71,43	82,27	5,866	70,53
20.	(Istiyova et al., 2022)	2022	81,11	8,204	56,67	87,78	8,333	56,78
21.	(Denada, 2023)	2023	711,515	8	505,455	770,909	7	473,939
22.	(Silaban et al., 2023)	2023	69,78	69,7778	33,11	70,29	70,2857	31,89
23.	(Gunawan et al., 2020)	2020	39,72	10,62	11,24	70,38	11,32	12
24.	(Damopolii et al., 2021)	2021	41.83	3	30.5	21.18	1	33.65
25.	(Razali et al., 2020)	2020	70,67	11,04	27,33	75,83	14,21	28,67
26.	(Nababan et al., 2019)	2019	68,47	4	37,22	75,39	7	42,67
27.	(Purwanto & Suwasono, 2019)	2019	77,56	4,81	57,94	83,553	5,36	58,34

No	Author Name	Year	Control Class			Experiment Class		
			Post-Test	SD	Pre-Test	Post-Test	SD	Pre-Test
28.	(Wahyudi et al., 2019)	2019	3,85	1	0,57	17,48	7	0,52
29.	(Sulastri et al., 2019)	2019	72,4545	3	49,5152	77,5	7	44,4063
30.	(Purwanto & Suwasono, 2019)	2019	77,56	4,81	57,94	83,553	5,36	58,34
	Rata-rata		93,96	12,43	69,14	108,36	16,09	69,09

Descriptive analysis of post-test data from 30 studies showed a consistent pattern where the experimental group that applied inquiry learning obtained a higher average score than the control group. From the data extraction, the average post-test score of the experimental group was 108.36 with a standard deviation of 16.09, while the control group obtained an average of 93.96 with a standard deviation of 12.43. This average difference indicates a positive impact of inquiry learning on the learning outcomes of vocational students.

The post-test data were then visualized in the form of graphs to facilitate the interpretation and analysis of score distribution patterns between studies. The visualization displays the comparison of post-test scores between experimental and control groups for each study, which allows the identification of variations in the effectiveness of inquiry learning across different vocational contexts. The graph also shows the consistency in the direction of the positive effect of inquiry learning, although the magnitude varies between studies, which forms the basis for the calculation of the comprehensive effect size in this meta-analysis.
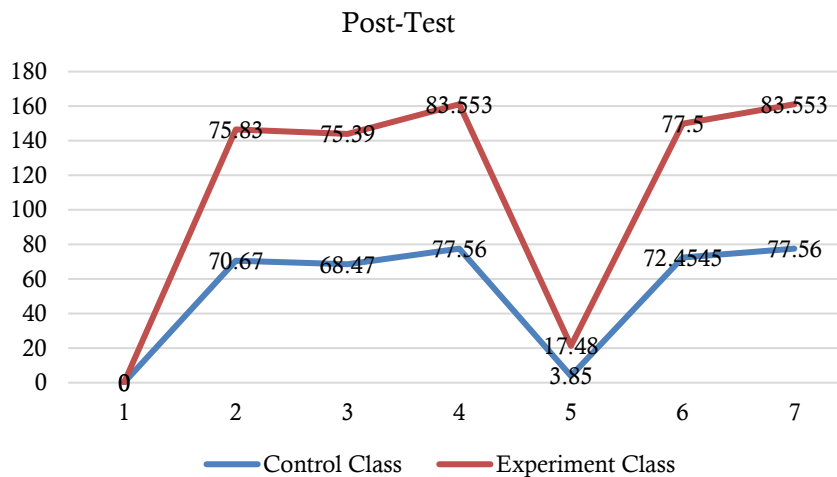

Figure.1. Meta-Analysis Data Tabulation

The average post-test score of the experimental class was 108.36, while the control class had an average score of 93.96. The calculated combined standard deviation was 14.37. The final score of 1 was determined by utilizing the effect size algorithm. The number 1 is considered to have a large enough influence. The calculation is as follows:

$$\text{SD pooled} = \sqrt{\frac{(N_e\text{-}1)SD_E{}^2 + (N_C\text{-}1)SD_C{}^2}{N_E + N_C\text{-}2}}$$

$$\text{SD pooled} = \sqrt{\frac{(30-1)16{,}09^2 + (30-1)12{,}43^2}{30 + 30 - 2}}$$

$$\text{SD pooled} = \sqrt{206{,}69}$$

$$= \mathbf{14{,}37}$$

$$\text{ES} = \frac{M_e - M_c}{\text{SD}} = 1$$

The picture below shows the inquiry learning that can be applied to learning.
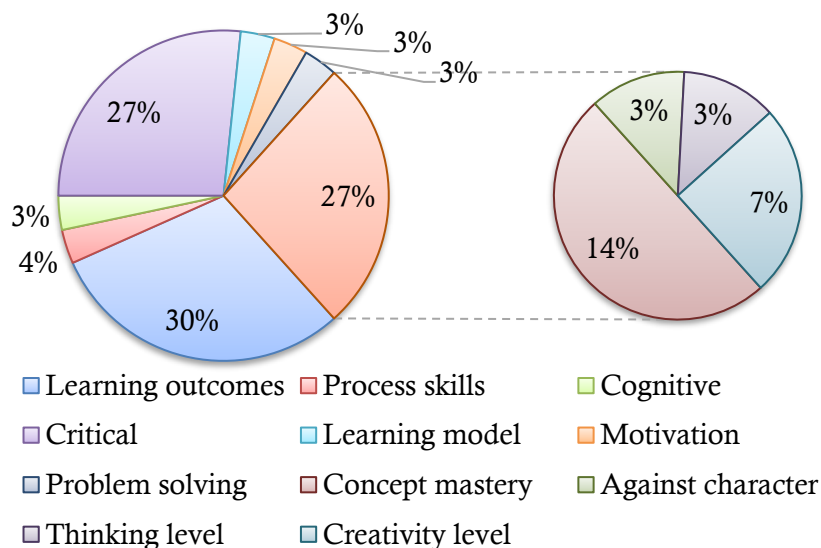

Figure.2. Learning Outcome Process

Based on the statistics, it can be concluded that Inquiry Learning is a practical learning approach to increase learners' participation and learning achievement. Through an inquiry-based approach, Inquiry Learning allows learners to actively collaborate, share knowledge, and apply the concepts they have learned in more practical situations. The results show that this approach not only increases learning motivation, but also encourages the development of critical and creative skills, resulting in a more holistic and competitive learning experience.

4.2. Discussion

4.2.1. Effectiveness of Inquiry Learning in Vocational Schools

A meta-analysis of 30 publications showed that inquiry learning has a significant positive impact on the cognitive achievement of vocational students. The results revealed that the average post-test score of the experimental class that applied inquiry learning reached 108.36, while the control class with conventional learning obtained an average of 93.96. This substantial difference resulted in an effect size of 1.0, which according to Cohen's criteria (1988) indicates a significant influence on student learning outcomes. This finding confirms that inquiry learning is not only theoretically effective, but also has a measurable practical impact in the context of vocational education.

4.2.2. Learning Quality Improvement Mechanism

The research findings show that inquiry learning allows the development of more interactive and collaborative learning methods than conventional approaches. As stated by Sarifah and Nurita (2023), this learning model is proven effective in improving learners' collaboration skills

through a learning process that encourages exploration and cooperation between learners. In this context, learners are no longer passive recipients of information, but actively participate in the learning process that encourages them to work together in teams and make significant contributions to the project.

Inquiry learning also allows learners to understand complex concepts through experiential learning approaches that involve visualization and simulation. Learners can engage in cases that involve modeling or simulating scientific phenomena, allowing them to observe how the theory they are learning is applied in a real-world context. This approach not only enhances learners' conceptual understanding but also enriches their learning experience by integrating theoretical and practical aspects that are essential in vocational education.

4.2.3. Relevance to Work Readiness and Digital Literacy

This research illustrates that inquiry learning can help bridge the digital literacy barrier that has been a challenge for many SMK graduates. By getting used to using various digital tools and applications during the learning process, learners not only improve their academic knowledge but also acquire digital skills that are essential for careers in the industry 4.0 era. These findings emphasize the importance of using vocational education strategies that focus on developing practical skills relevant to the needs of modern industries.

The interactive and collaborative methods in inquiry learning provide opportunities for learners to engage directly in a learning process that simulates a real work environment. This results in increased understanding and skills in the topics studied, while preparing them with soft skills needed in the professional world such as communication, problem-solving, and teamwork.

4.2.4. Implementation Challenges and Optimization Strategies

Despite its high effectiveness, the implementation of inquiry learning in SMK faces several challenges that need to be addressed systematically. Aspects that require attention include the availability of adequate technological infrastructure, teachers' readiness to implement this approach, and learners' access to the necessary learning tools. Collaborative efforts between the government, educational institutions, and industry stakeholders to improve resources and training will enable inquiry learning to be implemented optimally.

Teacher readiness and competence in implementing inquiry learning are crucial factors in achieving effective learning targets. Educators need to be able to design and facilitate inquiry-based learning processes that are relevant to real-world contexts, so that students can analyze and solve problems critically. This requires continuous professional development programs and adequate institutional support.

4.2.5. Implications for Vocational Education System Development

This research confirms that the use of inquiry learning in vocational education not only improves learners' learning outcomes but also offers excellent potential for improving the education system as a whole. It is important to continuously evaluate and update inquiry-based learning methods to keep them relevant to technological developments and dynamic industry needs. These updates include not only the integration of the latest tools and resources, but also curriculum development that is responsive to the demands of the job market.

Thus, learners will be better prepared to face challenges in the professional world and can optimally utilize the skills learned through inquiry learning. Implementation challenges should be addressed through infrastructure improvements, teacher training, and learner support so that the

integration of inquiry learning can provide maximum and sustainable benefits for vocational education in Indonesia.

4.2.6. Interpretation of Findings

The findings of this meta-analysis show that Inquiry-based Learning has a favorable impact on the skill development of learners in SMK, especially in critical thinking, problem-solving, and technical skills. Based on the analysis of 30 studies, it is concluded that inquiry-based learning enhances learners' ability to solve problems independently, increases their understanding of the subject matter in greater depth, and strengthens practical skills that are directly relevant to the world of work.

For example, learners who participate in inquiry-based learning activities tend to have a better understanding and ability to apply technical concepts through hands-on exploration, compared to more conventional teaching approaches. This statement is in line with previous findings by Hamdan et al. (2022), who also noted that IBL facilitates a deeper understanding of technical concepts in vocational schools.

However, not all studies included in the analysis produced the same results. Some studies reported that although learners benefited in critical thinking skills, the impact of IBL on specific technical skills varied depending on the level of support provided by teachers and the resources available. This leads to the conclusion that the effectiveness of IBL can be heavily influenced by contextual factors unique to each school.

4.2.7. Diversity of Results by Vocational Field

The meta-analysis revealed significant effect size variations across vocational fields, with a range from 0.57 to 3.38 reflecting substantial contextual differences. Findings showed that inquiry learning had the most significant impact on STEM (Science, Technology, Engineering, Mathematics) fields, with Sapriyadin et al. (2023) reporting an effect size of 3.38 for physics concept mastery and 2.86 for problem-solving skills. In contrast, in the field of food technology, Sukainah et al. (2023) found a more moderate effect size of 0.57, although it still showed a significant positive impact.

This difference can be explained through the inherent characteristics of each vocational field. Technology and science-oriented vocational programs have material structures that are more conducive to the inquiry approach, where students can conduct experiments, observations, and data analysis directly. In the context of biology learning, Yulita et al. (2024) reported an effect size of 0.86 on ecosystem material, indicating that subjects with practicum and field observation components provide optimal space for the implementation of inquiry learning.

4.2.8. Moderator Factors in Implementation

The results identified teacher preparedness as a key moderating factor affecting the effectiveness of inquiry learning. Istiyova et al. (2022) study reporting an effect size of 0.81 on guided inquiry learning with brainstorming suggests that teachers who have undergone specialized training and have experience managing inquiry-based classes are able to facilitate a more effective learning process. In contrast, suboptimal implementation, reflected in the lower effect size variation in some studies, indicates the importance of continuous professional development.

Further analysis shows that structured inquiry learning models tend to produce more consistent effect sizes than open inquiry. Findings from Widyastika et al. (2020), with an effect size of 1.04 on collaborative inquiry learning, indicate that the combination of guided inquiry with collaborative elements can optimize learning outcomes. This indicates that adapting the inquiry learning model according to the characteristics of vocational students and the specific learning context is a determining factor for successful implementation.

4.2.9. Contextual Implications for Learning Practice

This diversity of findings provides important implications for learning practices in SMK, where educators need to consider the characteristics of vocational fields in designing the implementation of inquiry learning. For technology and science vocational programs, an open inquiry approach with hands-on experiments may provide optimal results, while for other vocational fields may require a more structured guided inquiry. This finding also emphasizes the importance of customization of learning approaches according to the nature of learning content and characteristics of learners in each vocational field.

In addition, the variation in effect size between studies underscores the importance of investment in teacher capacity building as a prerequisite for the successful implementation of inquiry learning. Schools that have adequate professional development programs for teachers tend to experience more optimal results, while institutions without adequate professional development support show less consistent results. Therefore, inquiry learning implementation strategies must be accompanied by comprehensive and sustainable teacher training programs.

4.2.10. Benefits and Challenges of PBI Implementation

The benefits of implementing PBI in vocational schools are particularly evident in the development of critical thinking and problem-solving skills. Learners who engage in inquiry-based learning are more active in finding solutions to problems and demonstrate stronger analytical thinking. This approach also encourages collaboration and communication skills, which are important in the modern workplace, where teamwork and effective communication are highly valued by industry.

However, implementing PBI also has its challenges, one of which is the limited time available in a busy school schedule. A demanding curriculum often makes it difficult for teachers to allocate enough time for learners to explore topics in depth. In addition, resource constraints, such as limited teaching materials or facilities, can hinder the effective implementation of PBI. Another significant challenge is the readiness of some teachers to adopt this approach. While some teachers are eager and motivated to implement PBI, many face difficulties in managing a more dynamic inquiry-based classroom. Therefore, ongoing training and support for educators is crucial in overcoming this obstacle.

4.2.11. Long-term Impact of PBI

Many of the studies included in this meta-analysis not only assessed the immediate impact of EFL on learners' skills, but also looked at the long-term effects. Some studies show that the skills developed through EI, such as critical thinking, problem-solving, and technical competence, are of great benefit to learners when they enter the workforce (Halimah et al., 2024). Learners who are familiar with inquiry-based learning tend to be better prepared for professional challenges because they have developed skills in independent problem-solving and critical thinking skills (Garzón et al., 2020).

However, studies also show that the long-term effects may vary depending on the level of engagement and support provided by educators during the learning process (HSB, 2024). Thus, further research is needed to explore more deeply the long-term effects of PBI on learners' career readiness after graduation.

4.2.12. Comparison with Other Teaching Approaches

When compared to conventional teaching methods, PBI demonstrates superiority in developing skills that are critical in the modern world of work, such as technical ability and critical thinking. Traditional approaches, which focus more on direct instruction, often do not provide learners with opportunities to develop the skills needed to solve problems independently or collaborate effectively (Khuntia, 2024).

However, traditional methods have the advantage of providing structured instruction and are easier to implement within a limited timeframe. Therefore, several studies have shown the potential benefits of combining IBL with other teaching methods, which provide a balance between in-depth knowledge acquisition and practical skill development.

5. Conclusion

5.1. Achievement of Research Objectives

This meta-analysis research successfully achieved the stated goal of comprehensively analyzing the effectiveness of inquiry learning on learning outcomes of vocational students through the synthesis of 30 empirical studies for the 2019-2024 period. The results of the analysis show that inquiry learning has a very significant influence on the learning outcomes of vocational students, as indicated by the effect size estimate of 1.0, which is included in the "large influence" category according to Cohen's (1988) criteria. This finding confirms the hypothesis that inquiry learning is more effective than conventional learning in improving the academic achievement of vocational students.

The identification of moderating factors affecting the effectiveness of inquiry learning successfully revealed that the vocational field, teacher readiness, and implementation model are key determinants of success. Variations in effect size ranging from 0.57 to 3.38 indicate that the effectiveness of inquiry learning is strongly influenced by the implementation context. STEM fields showed the best results, followed by vocational programs that have practicum and experimentation components.

5.2. Key Research Conclusions

First, inquiry learning is empirically proven to improve the learning outcomes of vocational students with the average post-test score of the experimental group reaching 108.36 compared to 93.96 in the control group. Second, the effectiveness of inquiry learning varies between vocational fields, with technology and science programs showing the most optimal response to this approach. Third, teacher readiness and competence are crucial factors in determining the success of inquiry learning implementation, where teachers who have undergone specialized training are able to produce better outcomes.

Fourth, a structured inquiry learning model (guided inquiry) with collaborative elements consistently produces better results than open inquiry, especially in vocational education, which requires guidance in the exploration process. Fifth, inquiry learning not only improves cognitive

achievement but also develops 21ˢᵗ century skills such as critical thinking, collaboration, and digital literacy, which are essential for the job readiness of vocational graduates.

5.3. Research Recommendations and Implications

Implications for Education Policy: The results of this study provide an evidence-based foundation for systematically integrating inquiry learning into the vocational curriculum. The government and educational institutions are advised to develop a framework for the implementation of inquiry learning that is tailored to the characteristics of each vocational field. Budget allocation for learning infrastructure development and teacher training should be prioritized to ensure optimal implementation.

Recommendations for Learning Practices: Vocational institutions are advised to adopt a guided inquiry learning model with collaborative elements as the main approach, especially for technology and science vocational programs. To maximize the effectiveness of implementation, specific inquiry learning modules for each vocational field need to be developed. Mentoring and peer coaching systems among teachers can be developed to facilitate knowledge transfer and best practices in the implementation of inquiry learning.

Implications for Teacher Professional Development: Teacher training programs in inquiry learning should be a top priority, with a focus on developing pedagogical content knowledge competencies specific to the SMK context. A continuous training and certification system for inquiry learning teachers can be developed to ensure consistent implementation quality. Collaboration with industry in the development of teacher training programs can ensure the relevance of inquiry learning to the needs of the world of work.

Recommendations for Further Research: Longitudinal research is needed to examine the long-term impact of inquiry learning on job readiness and performance of vocational graduates in the industrial world. Comparative studies between countries can be conducted to identify global best practices in the implementation of inquiry learning in vocational education. Research on the development of learning technologies that support the implementation of inquiry learning in the digital era is also a promising area for further exploration.

5.4. Research Contributions and Limitations

This study makes a significant contribution as the first meta-analysis to comprehensively examine the effectiveness of inquiry learning in Indonesian vocational schools by providing robust effect size estimates based on 30 empirical studies. However, limitations of the study include a focus on cognitive outcomes with limited data for affective and psychomotor aspects, as well as reliance on variable data quality from primary studies. The generalizability of the findings is also limited to the Indonesian SMK context, so applications in different settings require further validation.

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