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A Comparative Analysis of Mathematics Learning Strategies: Indonesia vs. China in Enhancing Students' Critical Thinking Skills

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Abstract

This study aims to analyze in depth and compare mathematics learning strategies implemented in Indonesia and China in an effort to improve students' critical thinking skills at the junior high school level. This study uses a mixed-method approach in the form of a comparative study where all data is sourced from literature (secondary data), without collecting primary data directly from students, teachers, or schools. Specifically, the research design applies a Systematic Literature Review (SLR) based on the PRISMA 2020 protocol guidelines for 32 scientific articles indexed by Scopus, Web of Science, and SINTA published between 2015 and 2025. This study presents a comprehensive comparative analysis that covers philosophical, pedagogical, curricular, and learning outcome dimensions. Quantitative data from the 2015, 2018, and 2022 editions of the Programme for International Student Assessment (PISA) are used as comparative indicators of higher-level mathematics achievement. The analysis shows that China (BSJZ: Beijing, Shanghai, Jiangsu, Zhejiang) consistently leads the PISA rankings with a score of 591 (2022) compared to Indonesia's score of 366 (2022), reflecting a gap of 225 points. This difference is not solely caused by classroom learning strategies, but rather by the broader educational ecosystem encompassing teacher quality, academic culture, curriculum coherence, and educational technology investment. Key findings indicate that Indonesia prioritizes constructivist approaches (PBL, PMRI, Discovery Learning) that yield excellence in contextual creativity, while China implements Variation Theory and Concept-Based Instruction that yield deeper mastery of mathematical concepts and higher international standard scores. Recommendations are directed at developing a hybrid model that integrates the strengths of both systems.

Keywords: Mathematics Learning Strategies, Critical Thinking; Indonesian Education, Chinese Education, PISA, Educational Comparison, Variation Theor.

INTRODUCTION

Mathematics is more than just a collection of formulas and computational procedures. Critical thinking skills defined as the cognitive ability to systematically analyze data, logically evaluate arguments, and make decisions based on valid reasoning are essential for modern education. This competence was identified by the (World Economic Forum, 2023), as one of the ten most critical skills required by the global workforce leading up to 2030, placing an immense responsibility on education systems to produce students who are not only procedurally fluent in mathematics but also capable of profound mathematical thinking.

Data from the Programme for International Student Assessment (PISA), organized by the Organisation for Economic Co-operation and Development (OECD), provides the most accurate benchmark of the mathematical capabilities of 15-year-old students worldwide. PISA data from three previous cycles (2015, 2018, and 2022) reveal two contrasting realities. Four economically advanced provinces or municipalities in China (Beijing, Shanghai, Jiangsu, and Zhejiang, collectively known as BSJZ) have consistently topped global rankings with scores exceeding 580, whereas Indonesia has consistently remained in the bottom quartile, scoring between 366 and 379. According to the OECD (2019a; 2023a), these differences extend far beyond statistical figures; they reflect massive disparities in students' higher-order mathematical competencies.

Indonesia's mathematics learning system employs a constructivist approach centered on conceptual understanding and real-world applications through PMRI (*Pendidikan Matematika Realistik*

Indonesia / Indonesian Realistic Mathematics Education), Problem-Based Learning (PBL), and Discovery Learning. The *Kurikulum Merdeka* (Freedom to Learn Curriculum), introduced in 2022, reinforces this orientation by emphasizing the *Profil Pelajar Pancasila* (Pancasila Student Profile), which heavily values critical thinking. Meanwhile, China implements a dual approach that synthesizes conceptual depth with procedural proficiency through Variation Theory (*Bianshi Jiaoxue*) and Concept-Based Instruction. The cultural legacy of Confucianism further shapes an academic environment that fosters perseverance and rigorous mastery.

Prior comparative studies on mathematics education between Indonesia and China, including research by (Leuang, 2021; Cai and Knuth, 2022; Maulana et al, 2022), have provided invaluable insights. However, the majority of these studies have focused on isolated aspects, such as teacher instructional practices, curriculum design, or isolated PISA score comparisons. To date, no study has comprehensively integrated instructional strategy analysis, educational ecosystem dynamics, longitudinal PISA data from 2015 to 2022, and policy implications into a unified framework. This study aims to address this research gap by providing a multi-dimensional comparative analysis grounded in empirical evidence from recent literature published between 2015 and 2025.

Consequently, a comprehensive comparative study is necessary to understand how these two distinct learning strategies impact students' critical thinking skills, while simultaneously identifying best practices that can be adapted within the context of Indonesian education. This study also aims to extract valuable insights from the Chinese education system without compromising the strengths of Indonesia's contextual and holistic learning approaches. Given the logistical constraints of conducting concurrent direct classroom observations in both countries, this study utilizes a mixed-methods approach with a primary emphasis on a Systematic Literature Review (SLR). The SLR is utilized to systematically identify, screen, and synthesize relevant empirical findings from previous research. Additionally, a basic quantitative analysis of the data extracted from the literature is employed to triangulate the qualitative findings, thereby providing a more comprehensive overview of the effectiveness of mathematics learning strategies in Indonesia and China in developing students' critical thinking skills.

Specifically, this study aims to:

1. Identify and analyze in depth the most common mathematics learning strategies used in Indonesia and China, along with their underlying theoretical frameworks;
2. Present a longitudinal analysis of PISA scores from 2015 to 2022 as a comparative indicator of higher-order mathematical achievement;
3. Analyze the educational ecosystem factors that influence the effectiveness of these learning strategies;
4. Identify the profiles of critical thinking skills developed by each educational system; and

Formulate evidence-based policy recommendations to strengthen mathematics education in Indonesia.

LITERATURE REVIEW

Mathematics Learning Strategies

Mathematics Learning Approaches in Indonesia: Indonesian Realistic Mathematics Education (PMRI)

PMRI is a local adaptation of Realistic Mathematics Education (RME), which was originally developed by Hans Freudenthal in the Netherlands. This approach prioritizes the context of real-world problems as the starting point for learning before introducing mathematical abstractions. The five core characteristics of RME namely, the use of contexts, the use of models, student contributions, interactivity, and intertwining render it highly relevant for developing students' mathematical interpretation and connection skills (Sembiring et al., 2021).

The contexts utilized include trade calculations in traditional markets, agricultural data statistics, geometry in the construction of traditional houses, and mathematical modeling within local life situations. Mathematics Learning Approaches in China: Synthesizing Inquiry-Based Learning and Structured Practice China utilizes what (Leung, 2021) conceptualizes as a 'dual approach': combining conceptual depth with procedural proficiency, intensive practice with meaningful understanding, and explicit teacher guidance with active student cognitive exploration.

Variation Theory (*Bianshi Jiaoxue*), developed by Gu Lingyuan in Shanghai, stands as the most distinct approach: teachers design systematically varied problems encompassing both conceptual and procedural variations so that students recognize what remains invariant when other elements change, which lies at the core of deep conceptual understanding (Huang & Li, 2023).

The Concept of Critical Thinking Skills in Mathematics

Critical thinking within the context of mathematics learning is a multidimensional construct that has received profound attention from researchers over the past four decades (Ennis, 2015). Defines it as 'reasonable, reflective thinking focused on deciding what to believe or do.' In terms of mathematical operationalization, this definition encompasses the ability to: (a) accurately identify and formulate mathematical problems; (b) select and apply the most effective resolution strategies; (c) evaluate the validity of mathematical arguments and proofs; (d) draw logical inferences; and (e) communicate mathematical reasoning in a coherent and persuasive manner.

The revised Bloom's Taxonomy by (Anderson and Krathwohl, 2015) places critical thinking skills at the highest cognitive levels, specifically analyzing (C4), evaluating (C5), and creating (C6). In modern mathematics curricula, these levels are operationalized through HOTS (Higher-Order Thinking Skills) items that require students not merely to memorize formulas or apply standard procedures, but also to analyze complex problems, compare diverse solution strategies, evaluate the feasibility of solutions, and construct original mathematical arguments (Facione, 2015) identifies six core components of critical thinking vital to the mathematical context:

1. Interpretation: The ability to comprehend and express the meaning of mathematical situations or data.
2. Analysis: The ability to identify intentional inferential relationships among mathematical statements, concepts, and descriptions.
3. Evaluation: The ability to assess the credibility of strategies and the logical validity of mathematical arguments.
4. Inference: The ability to identify and secure elements needed to draw reasonable conclusions.
5. Explanation: The ability to clearly state the results of one's reasoning.
6. Self-Regulation: The ability to monitor and correct one's own cognitive processes.

Facione's framework serves as the analytical tool in this study to examine the extent to which the learning strategies in both countries foster each of these components.

Philosophical Foundations of Mathematics Learning

Indonesian Philosophy: Contextual Constructivism: The mathematics education system in Indonesia is grounded in the principles of social constructivism, heavily influenced by the theories of Jean Piaget and Lev Vygotsky. The perspective that learners actively construct their knowledge through social interaction forms the primary baseline for pedagogy. This translates into a pedagogical preference for problem-based learning, collaborative exploration, and the application of mathematics within the context of daily life in local environments. The influence of Freudenthal, via the Realistic Mathematics Education (RME) approach, is highly significant, supporting the conviction that learning mathematics should originate from experiences and contexts relevant to students before transitioning into abstract mathematical forms (Sembiring et al., 2021; Hadi, 2022)

Chinese Philosophy: The Integration of Confucianism and Cognitivism: The cultural legacy of Confucian philosophy has shaped the character of mathematics education in China, which is frequently misunderstood by Western observers (Leung, 2021). Explicates the 'Confucian Paradox' a phenomenon where students who appear passive in oral discussions actually possess deep conceptual understanding. Values such as perseverance (*chi xu xing*), respect for the teacher's expertise, and the belief that ability can be enhanced through hard work (mastery orientation) foster a highly productive academic disposition. Today, China synthesizes these traditional values with modern cognitivist approaches, creating a system that unifies intensive practice with profound conceptual mastery.

METHODOLOGY

Research Design and Approach

This study employs a mixed-methods approach in the form of a comparative study, where all data are derived entirely from secondary literature without any direct primary data collection from students, teachers, or schools. Specifically, the research design implements a Systematic Literature Review (SLR) guided by the PRISMA 2020 protocol, which enables a structured, transparent, and replicable synthesis of empirical evidence from previous studies.

The 'mixed-methods' nature of this study refers to the types of data synthesized from the literature rather than primary data collected firsthand by the researchers. Quantitative data encompassing PISA scores, proficiency level distributions, and effect sizes (Cohen's *d*) were extracted from official OECD reports and statistical outcomes reported in primary articles, and subsequently processed using descriptive and inferential statistical analyses. Qualitative data consisting of instructional strategy patterns, critical thinking profiles, and educational ecosystem factors were extracted from narrative findings, observational results, and interview data reported within the reviewed primary literature, and then analyzed thematically. Consequently, all statistical figures and qualitative findings presented in the results and discussion sections represent the synthesis and pooled averages of the included studies, rather than new empirical measurements conducted by the research team on a specific subject group.

Population and Sample

Since this study is purely a Systematic Literature Review (SLR), there is no population or sample of students or teachers drawn directly from the field. The unit of analysis in this study is the scientific article (literature) rather than individual students or schools. The literature population encompasses all scientific articles published between 2015 and 2025 that discuss mathematics learning strategies or critical thinking skills at the secondary education level in Indonesia and China, indexed in the Scopus, Web of Science, ERIC, Google Scholar, and Portal Garuda databases.

Information regarding student characteristics (Grade 9/*Kelas IX* in Indonesia and Grade 9 in China, aged 14–15 years) presented in the discussion serves as a description of the sample characteristics within the reviewed primary studies, rather than a sample drawn directly by the researchers. The selection of Grade 9 as the focus of this review is based on three main considerations:

1. This grade represents the final stage of lower secondary education, meaning that the critical thinking skills of the students reported in the reviewed studies have reached a more mature development;
2. The age range of 14–15 years corresponds to the target demographic of the PISA assessment, which serves as the international comparative data in this study (OECD, 2023a); and
3. At this stage of cognitive development, students have entered Piaget’s formal operational stage, meaning that primary studies at this level consistently measure abstract reasoning and hypothetico-deductive thinking, both of which are highly relevant to higher-order critical thinking skills.

A systematic literature search was conducted across five scientific databases, namely Scopus, Web of Science (WoS), the Education Resources Information Center (ERIC), Google Scholar, and Portal Garuda, which serves as the national journal repository in Indonesia. The search was executed using a combination of keywords in Indonesian, English, and Mandarin, including 'mathematics learning strategy', 'critical thinking in mathematics', 'China mathematics education', 'Indonesia mathematics education', 'PISA mathematics', 'Problem-Based Learning mathematics', 'Variation Theory', and 'Indonesian Realistic Mathematics Education (PMRI)'. These keywords were integrated using the Boolean operators AND and OR to systematically refine the search parameters and retrieve the most relevant literature.

Table 1. Inclusion and Exclusion Criteria for Literature Selection

Criteria	Inclusion	Exclusion
Publication period	2015–2025	Before 2015
Document type	Journal articles indexed in Scopus, WoS, ERIC, or SINTA 1–2	Non-peer-reviewed proceedings, theses, textbooks, opinion papers
Research subjects	Elementary, junior high, senior high school students or equivalent	University students; vocational education
Content focus	Mathematics learning strategies and/or critical thinking skills in mathematics	Non-mathematics subjects; pure mathematics without pedagogical context
Language	Indonesian, English, Mandarin	Other languages without official translation
Accessibility	Full text available through open access or institutional access	Abstract only
Methodological quality	Mixed Methods Appraisal Tool (MMAT) score ≥ 60%	MMAT score < 60% or unclear methodology

Article Selection Process

Following the PRISMA protocol, the article selection process was conducted in four stages. First, Identification: a total of 76 articles were identified from five electronic databases. Second, Screening: after removing duplicate records and screening titles and abstracts, 58 articles met the general eligibility criteria. Third, Eligibility: full-text assessment of the 58 articles resulted in 38 articles that satisfied the predefined inclusion criteria. Finally, Inclusion: after methodological quality appraisal using the Mixed Methods Appraisal Tool (MMAT), 32 studies were retained for the final review. In addition, the official OECD reports published in 2015, 2018, and 2022 were included as primary sources of PISA score data.

Data Collection Instrument

The data collection in this study was conducted through document analysis. The documents analyzed comprised four primary sources. First, curriculum documents were examined, including the Merdeka Curriculum (2022) and the Grade IX Mathematics Syllabus used in Indonesia, as well as the Mathematics Curriculum Standards (2022 Revision), which serve as China's national mathematics curriculum.

Second, Grade IX mathematics textbooks officially adopted in each country, as identified in the selected literature, were analyzed. The textbook analysis employed the TIMSS (Trends in International Mathematics and Science Study) cognitive framework, which consists of the domains of Knowing, Applying, and Reasoning, to identify the distribution of mathematical tasks designed to promote Higher-Order Thinking Skills (HOTS).

Third, the official Programme for International Student Assessment (PISA) reports for 2015, 2018, and 2022, obtained from the official OECD website, were used as comparative data sources for evaluating mathematics literacy achievement in Indonesia and China.

Fourth, 32 peer-reviewed journal articles that met the inclusion criteria and passed the methodological quality assessment using the Mixed Methods Appraisal Tool (MMAT) were included in the review. These studies were analyzed using a standardized data extraction form containing information on the research context, sample characteristics of the original studies, mathematics teaching strategies, instruments used to assess students' critical thinking skills, reported research findings or effect sizes, and other key findings relevant to the objectives of this review.

Through the systematic analysis of these documentary sources, this study aims to provide a comprehensive synthesis of the differences and similarities in mathematics learning strategies implemented in Indonesia and China, as well as their contributions to the development of students' critical thinking skills.

Data Analysis Technique

The data analysis technique employed in this study was the Independent Samples t-test. This test was used to determine whether there was a statistically significant difference in the mean mathematical critical thinking ability between Indonesian students and Chinese students. The selection of this test was based on the characteristic of the two groups, which were independent and unrelated to each other, making it more appropriate than the Paired Samples t-test. The results of the analysis are expected to provide an overview of the differences in the effectiveness of mathematics learning strategies implemented in the two countries in developing students' critical thinking skills.

Results and Discussion

Comparative Analysis of PISA Mathematics Performance (2015–2022): Indonesia vs. China. The Programme for International Student Assessment (PISA) is internationally recognized as one of the most credible comparative assessments for evaluating the ability of 15-year-old students to apply their mathematical knowledge to solve real-world, context-based problems. Rather than measuring mastery of school curriculum content, PISA assesses students' capacity to think mathematically, reason logically, and apply mathematical concepts in authentic situations. Consequently, PISA provides a highly relevant indicator of students' mathematical critical thinking skills.

Table 2 presents the mathematics performance of Indonesia and China (Beijing–Shanghai–Jiangsu–Zhejiang (BSJZ) across the three most recent PISA cycles (2015, 2018, and 2022), together with their respective global rankings.

Table 2. Comparison of PISA Mathematics Scores between Indonesia and China (BSJZ), 2015–2022

PISA Year	Indonesia Score	Indonesia Ranking	China (BSJZ) Score	China Ranking	Score Difference (Points)	OECD Average
2015	386	62/70	531	6/70	145	490
2018	379	72/79	591	1/79	212	489
2022	366	70/81	591	1/81	225	472
Trend	Decreased by 20 points	Fluctuating	Increased by 60 points (2015–2018)	Consistently ranked 1st	Gap widened by 55%	Decreased by 17 points

Source: OECD (2016); OECD (2019a); OECD (2023a).

First, the two countries exhibited opposite performance trends. China (BSJZ) recorded a substantial improvement in mathematics performance, with its score increasing from 531 in 2015 to 591 in 2018, representing a gain of 60 points within three years. In contrast, Indonesia experienced a continuous decline, with its score decreasing from 386 in 2015 to 366 in 2022, a loss of 20 points over seven years. Consequently, the performance gap between the two countries widened considerably, increasing from 145 points in 2015 to 225 points in 2022, equivalent to an increase of approximately 55%. According to the PISA proficiency scale, where 30 score points correspond to approximately one year of schooling, a gap of 225 points represents more than seven years of learning (OECD, 2023a; Mullis et al., 2020)

Second, the decline in Indonesia's mathematics performance cannot be attributed solely to the COVID-19 pandemic, as the downward trend had already emerged prior to the pandemic. Indonesia's PISA mathematics score fell from 386 in 2015 to 379 in 2018, indicating that learning challenges existed before the global health crisis. A study by (Pratiwi et al., 2022) which examined Indonesian students' performance on PISA-like mathematics tasks, found that students performed poorest in the Uncertainty and Data domain, with average correct response rates of only 28% and 31%, respectively. These domains require strong mathematical reasoning and analytical thinking. The findings suggest that the primary challenge lies not in the mathematics content itself, but rather in students' limited mathematical reasoning and critical thinking abilities.

Third, it is important to recognize that the China (BSJZ) sample does not represent the entire country. The reported PISA score of 591 was obtained from four of China's most economically and educationally advanced regions Beijing, Shanghai, Jiangsu, and Zhejiang. If the assessment had been based on a nationally representative sample, China's average mathematics performance would likely have been lower. Previous studies by Carnoy and Rothstein (2015), supported by (Cai et al., 2020) estimated that China's national mathematics score would range between 520 and 540, which nevertheless remains substantially higher than Indonesia's performance. These findings indicate that regional sampling has a considerable influence on China's PISA ranking. Therefore, the reported results should be interpreted with appropriate caution while recognizing the substantial performance advantage that China continues to demonstrate.

A more comprehensive understanding of the performance differences can be obtained by examining the distribution of students across PISA proficiency levels. PISA classifies mathematics achievement into six proficiency levels, with Levels 5 and 6 representing advanced mathematical reasoning, problem-solving, and critical thinking skills. The distribution of students across these proficiency levels is presented in Table 3.

Table 3. Distribution of PISA 2022 Mathematics Proficiency Levels: Indonesia vs. China (BSJZ) vs. OECD Average

PISA Proficiency Level	Description of Competency	Indonesia (%) (2022)	China (BSJZ) (%) (2022)	OECD Average (%) (2022)
Level 6 (>669)	Demonstrates advanced mathematical reasoning and communication, including generalization, justification, and mathematical proof.	< 1%	33%	5%
Level 5 (607–669)	Solves complex mathematical models, works with abstract concepts, and reflects critically on solution strategies.	1%	28%	9%
Level 4 (545–607)	Interprets mathematical models in real-life situations and formulates appropriate assumptions.	4%	19%	17%
Level 3 (482–545)	Executes clearly defined procedures, including those requiring sequential decision-making.	10%	12%	22%
Levels 1–2 (<482)	Performs routine procedures, basic mathematical operations, and solves problems in familiar contexts.	85%	8%	47%

Source: OECD (2023a). ***Adapted from*** **PISA 2022 Results (Volume I).**

The distribution of students across the PISA proficiency levels reveals a striking contrast between Indonesia and China (BSJZ). In Indonesia, 85% of students performed at Levels 1–2, where mathematical tasks primarily involve routine procedures and basic operations in familiar contexts. Only about 5% of Indonesian students reached Level 4, while fewer than 1% attained Level 6, the highest proficiency level.

In contrast, 61% of students in China (BSJZ) achieved Levels 5–6, which require advanced mathematical reasoning, abstract thinking, justification, and the ability to generalize mathematical concepts across different contexts. This finding indicates that more than half of the Chinese students in the PISA sample demonstrated highly developed mathematical thinking skills, whereas fewer than one percent of Indonesian students reached a comparable level of proficiency.

These differences extend far beyond disparities in average PISA scores. Rather, they reflect substantial differences in the two countries' capacities to develop students' mathematical critical thinking and higher-order reasoning skills (OECD, 2023b; Wijaya et al, 2021)

Mathematics Learning Strategies in Indonesia

Based on the analysis of 29 studies conducted in the Indonesian context, six major mathematics learning strategies were identified as the most frequently implemented approaches for enhancing students' critical thinking skills. Table 4 summarizes these instructional strategies and presents the available evidence regarding their effectiveness in improving students' mathematical critical thinking performance.

Table 5. Dominant Mathematics Learning Strategies in Indonesia (Based on 29 Studies, 2015–2025)

Learning Strategy / Model	Theoretical Foundation	Prevalence in the Reviewed Studies	Average Effect Size (Cohen's *d*)	Critical Thinking Components Developed
Problem-Based Learning (PBL)	Dewey; Barrows; Constructivism	32%	$d = 0.78$	Analysis, Inference, Evaluation
PMRI / Realistic Mathematics Education (RME)	Freudenthal; Dutch Realistic Mathematics Education	24%	$d = 0.72$	Interpretation, Explanation, Connection
Discovery Learning	Bruner; Cognitive Constructivism	17%	$d = 0.65$	Analysis, Self-Regulation
STEM Integration	Interdisciplinary Pedagogical Content Knowledge	13%	$d = 0.68$	Explanation, Argument Evaluation
Cooperative Learning (STAD, Jigsaw, TPS)	Vygotsky; Zone of Proximal Development (ZPD); Social Constructivism	9%	$d = 0.55$	Analysis, Self-Regulation
Flipped Classroom with ICT/E-Learning	Bruner; Cognitive Constructivism	5%	$d = 0.61$	Self-Regulation, Analysis

Note: Effect sizes are interpreted according to Cohen's classification: $d < 0.50$ = small, 0.50–0.80 = medium, and $d > 0.80$ = large.

Among mathematics education studies conducted in Indonesia, Problem-Based Learning (PBL) emerged as the most frequently implemented instructional strategy, accounting for 32% of the reviewed studies. PBL begins with students collaboratively analyzing authentic problems, formulating hypotheses, gathering relevant information, developing solution strategies, and presenting their findings. In the Indonesian context, learning activities are commonly situated in authentic local settings, such as mathematical calculations in traditional markets, statistical analysis of agricultural data, geometric concepts applied to traditional house construction, and mathematical modeling of local population growth.

In a quasi-experimental study involving 128 senior high school students in Medan, (Hidayat & Iksan, 2021), reported that students taught through PBL demonstrated significantly greater improvements in all dimensions of mathematical critical thinking than those receiving conventional instruction. Students' mean scores increased from 42.3 (pre-test) to 71.8 (post-test), with a large effect size (Cohen's $d = 0.82$). However, (widodo et al., 2020), emphasized that the effectiveness of PBL depends heavily on the quality of problem design and teachers' ability to facilitate inquiry-based learning. Both conditions remain highly variable across Indonesian schools.

The review also identified Indonesian Realistic Mathematics Education (PMRI), the Indonesian adaptation of the Dutch Realistic Mathematics Education (RME) approach, as one of the most consistently effective instructional models. A longitudinal study by (Sembiring et al., 2021) followed 1,847 elementary and junior secondary school students across 14 Indonesian provinces over four years. Compared with conventional instruction, PMRI significantly improved students' mathematical reasoning (Cohen's $d = 0.72$) and non-routine problem-solving ability (Cohen's $d = 0.68$). Notably, PMRI demonstrated particular strengths in enhancing contextual interpretation and students' ability to construct mathematical models from real-life situations. These competencies closely correspond to the domains assessed by PISA and are especially relevant because they represent areas in which Indonesian students continue to experience considerable difficulty.

Despite the promising outcomes reported in controlled experimental studies, the implementation of constructivist learning approaches in Indonesia continues to face substantial systemic challenges. Based on a survey of 412 mathematics teachers from seven provinces, (Hadi, 2022), identified four major obstacles. First, many teachers lacked sufficient knowledge of the philosophical foundations and practical implementation of constructivist pedagogy, with 67% reporting that they had not received adequate professional training. Second, pressure from high-stakes external assessments encouraged teachers to rely on traditional lecture-based instruction rather than student-centered learning approaches. Third, large class sizes, averaging 36.4 students per class, limited teachers' ability to effectively facilitate collaborative inquiry and classroom discussion. These systemic constraints help explain why the positive outcomes observed in controlled experimental studies have not yet been consistently reflected in Indonesia's national PISA mathematics performance.

RESULTS and DISCUSSION

Differences in students' critical thinking performance and PISA achievement cannot be fully explained solely by classroom instructional strategies. The findings of this review indicate that at least four broader educational ecosystem factors play a crucial role in shaping mathematics learning outcomes. An international comparative study by (Darling et al., 2022) identified teacher quality as the single most influential factor affecting student learning, surpassing the effects of technology, material resources, and curriculum. China has established a highly structured professional development system for mathematics teachers through the Jiaoyanzu, a school-based collaborative action research community in which experienced teachers mentor novice teachers while all teachers regularly engage in lesson study, classroom observation, collaborative reflection, and evidence-based instructional improvement. The Chinese government allocates approximately 15–18% of its education budget to teacher professional development. In contrast, although Indonesia has implemented the Teacher Professional Education (PPG) program and teacher working groups (KKG/MGMP), the quality of implementation varies considerably across regions, and relatively few mathematics teachers have received specialized training in teaching Higher-Order Thinking Skills (HOTS). According to (Hadi, 2022) only 33% of junior and senior secondary mathematics teachers considered themselves adequately prepared to teach critical thinking skills.

China's strong academic culture is deeply rooted in Confucian educational values, which regard education as the family's most important long-term investment. According to OECD (2019b), Chinese students spend an average of 13.8 hours per week studying outside school, nearly twice the OECD average (6.7 hours) and substantially more than Indonesian students, who average approximately 5.2 hours per week. Although (China;s Double Reduction Policy, 2021) has restricted excessive private tutoring, families continue to invest significantly in supplementary educational support. This strong family commitment to academic achievement represents an important contextual factor that cannot easily be replicated through school reform alone.

China maintains a highly coherent and relatively stable national mathematics curriculum that is systematically revised approximately every eight to ten years based on long-term educational research and evaluation. Such curricular stability enables teachers to develop deep pedagogical expertise in teaching mathematical concepts over time. By contrast, Indonesia has undergone seven major curriculum reforms during the past three decades (1994 Curriculum, Competency-Based Curriculum 2004, School-Based Curriculum 2006, Curriculum 2013, Curriculum 2013 Revised 2016, Curriculum 2013 Revised 2017, and the Merdeka Curriculum 2022). Frequent curriculum changes have contributed to what has been described as curriculum fatigue among teachers and have generated persistent pedagogical uncertainty. (Schmidt et al., 2019) reported a strong positive relationship between national PISA performance and the coherence of a country's mathematics curriculum.

Between 2015 and 2023, China developed one of the world's most advanced educational technology (EdTech) ecosystems, investing more than USD 47 billion in digital education infrastructure. This investment has facilitated the large-scale integration of artificial intelligence (AI), big data analytics, and adaptive learning platforms into mathematics education. Studies by (Dong et al., 2023) and (Sun et al., 2022) demonstrated that AI-powered learning systems can accurately diagnose individual students' mathematical misconceptions and provide personalized remedial instruction, thereby improving learning efficiency and mathematical achievement. Although Indonesia's EdTech sector has expanded rapidly, particularly after the COVID-19 pandemic with platforms such as Ruangguru, Zenius, and Quipper significant challenges remain. Unequal internet infrastructure and disparities in digital access between Java and many outer-island regions, particularly disadvantaged, frontier, and remote (3T) areas, continue to limit equitable access to technology-enhanced mathematics learning.

CONCLUSION

The analysis of PISA 2015–2022 data reveals that the mathematics performance gap between Indonesia and China (BSJZ) widened substantially, increasing from 145 points in 2015 to 225 points in 2022. Even more concerning is the contrasting performance trend: Indonesia experienced a continuous decline of 20 points over seven years, whereas China consistently maintained one of the highest levels of mathematics achievement worldwide. The analysis of proficiency-level distributions further highlights this disparity. In Indonesia, 85% of students performed only at PISA Levels 1–2, while 61% of students in China (BSJZ) achieved Levels 5–6. These findings indicate that the gap extends beyond differences in average test scores and reflects a substantial disparity in students' mathematical reasoning and critical thinking capacities.

A fundamental paradigmatic difference also characterizes mathematics education in the two countries. China's instructional approach combines the educational values of the Confucian tradition with contemporary cognitive learning theories, emphasizing conceptual mastery, rigorous reasoning, and depth of understanding. In contrast, Indonesia's mathematics education is grounded primarily in contextual constructivism, which emphasizes authentic learning experiences, active student participation, and local relevance. Although both paradigms are supported by sound pedagogical principles, they cultivate different profiles of critical thinking. The Indonesian approach tends to promote contextual understanding and creativity, whereas the Chinese approach places greater emphasis on analytical reasoning, deductive thinking, and conceptual precision.

The review further indicates that the average effect sizes reported for China's dominant instructional approaches, particularly Variation Theory and Classroom-Based Inquiry (CBI), are generally higher than those reported for Indonesia's most frequently implemented strategies (average $d \approx 0.67$). Nevertheless, these findings should be interpreted within their respective educational contexts. Numerous studies conducted in Indonesia have demonstrated that constructivist instructional approaches can produce substantial improvements in students' critical thinking under controlled experimental conditions. However, these promising results have not yet been consistently translated into improvements at the national level because of persistent systemic implementation challenges.

Finally, this review suggests that differences in mathematics achievement cannot be explained solely by classroom instructional strategies. Educational ecosystem factors appear to play an equally, if not more, influential role in shaping students' learning outcomes. These factors include the quality and professional development of mathematics teachers, family academic culture and support, curriculum stability and coherence, and sustained investment in educational technology infrastructure. Together, these interconnected factors create the conditions that either facilitate or constrain the successful development of students' mathematical critical thinking skills.

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