

A Meta Analysis – Factors That Influence the Level of Statistical Reasoning of Students in Indonesia

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Abstract

In today's digital world, Indonesian students face significant challenges with statistical reasoning, a crucial 21st-century skill needed for data interpretation and informed decision-making in academic and daily contexts. To address this educational gap, researchers conducted a comprehensive meta-analysis of 17 empirical studies published from 2012-2024, systematically examining various factors that influence students' statistical reasoning abilities in Indonesia. The study methodically categorized these influences into internal factors stemming from individual student characteristics and external factors related to environmental and instructional elements. The findings revealed that the implementation of Contextual Teaching and Learning (CTL) combined with Realistic Mathematics Education (RME) learning models had the most significant positive impact on enhancing students' statistical reasoning capabilities. These research results provide valuable evidence-based insights for educators, curriculum developers, and policymakers to create more effective educational frameworks and teaching strategies that can substantially enhance statistical literacy among Indonesian students, ultimately improving their capacity for data-driven decision-making in both formal educational settings and practical real-world applications.

Keywords: Meta-Analysis, Statistical Reasoning, Realistic Mathematics Education, Contextual Teaching Learning

Introduction

Statistical reasoning has become a fundamental competency in mathematics education across all levels, from elementary through tertiary education. In the context of mathematics learning, statistical reasoning encompasses students' ability to understand statistical concepts, apply statistical principles to solve problems, and use this understanding to make informed decisions (Garfield & Ben-Zvi, 2008). Unlike general statistical knowledge, statistical reasoning specifically involves critical thinking processes needed to interpret data correctly in various mathematical and real-world contexts. According to the regulation of the Minister of National Education Number 22 of 2016, reasoning ability including statistical reasoning is identified as a core competency that every student must develop in mathematics education.

According to Garfield and Ben-Zvi (2008), statistical reasoning includes the ability to understand statistical concepts, apply statistical principles to solve problems, and use this understanding to assess and make decisions. In Garfield's statistical reasoning theory, this

process involves not only conceptual knowledge of data, probability, and variability, but also the critical thinking needed to interpret data correctly in various contexts. Muller & Maher (Rahmawati, Mardiyana, & Triyanto, 2018) state that reasoning functions as a process of drawing a conclusion or decision based on evidence or assumptions. This ability plays a role in helping individuals avoid cognitive biases that often influence data-based decisions.

However, many students have difficulty understanding statistics (Garfield et al., 2008; Chan & Ismail, 2012; Kesumawati & Octaria, 2019). In line with that, Whitaker, Foti, & Jacobbe (2015), revealed that students have the most difficulty when interpreting statistical results. To overcome this, statistical reasoning skills are needed.

The importance of statistical reasoning is also increasingly recognized in international education. PISA, managed by the OECD, includes statistical reasoning skills as one of the main indicators in measuring student proficiency in various countries. Statistical Reasoning is an important focus in the world of education, because with statistical reasoning students can be helped in understanding, analyzing, and drawing conclusions or decisions based on valid data. Statistical reasoning is also one of the competencies considered essential by the Programme for International Student Assessment (PISA), which states that in the 21st century statistical reasoning in Indonesia should be at a high level, because according to the PISA report (2018), statistical reasoning is explained as part of "basic mathematical competencies" which are very important to face global challenges, and students who have this ability are considered better prepared to face the needs of the modern world of work and social life which is full of statistical uncertainty (OECD, 2018).

Data from PISA reveals a concerning situation in Indonesia: 75.7% of Indonesian students fail to reach Level 2, which is established as the basic proficiency level in mathematical literacy (OECD, 2018). Students at Level 2 should be able to use various statistical phrases and symbols with basic understanding of statistical concepts. The fact that most Indonesian students remain below this threshold indicates they struggle with proper application of statistical ideas despite some familiarity with terminology. These findings are reinforced by the statement of Maryati & Priatna (2018) where students showed difficulty in reading the statistical data presented, understanding statistical problems, and solving problems related to the average value of data. Likewise with the results obtained by Mahdayani (2016) where as many as 54.6% of high school students had difficulty in reading and understanding statistical data; 83.5% of students had difficulty in transforming data; and as many as 91.7% of students had difficulty in processing data and concluding the data

presented. Furthermore, Mahdayani's (2016) findings also show that less than 50% of students are able to understand the statistical data provided and only 16.5% of students are able to transform statistical data. This finding is also supported by the actualized student learning achievement from the 2019 National Examination results assessment which shows a decrease in average scores every year (Education Assessment Center, Ministry of Education and Culture, 2022).

The development of statistical reasoning ability is influenced by several factors. Based on the theory put forward by Garfield, statistical reasoning ability develops gradually, along with cognitive growth and formal learning. According to Garfield (2002), the development of statistical reasoning is divided into 5 tiered levels: (1) Idiosyncratic Reasoning, at this first level students have knowledge of symbols and terms in statistics, but they do not yet understand their use. At this level, students tend to interpret data as is without using the correct statistical concept. (2) Verbal Reasoning, at this second level students have knowledge of verbal theories or general statistical theorems, but students have not been able to apply them to existing cases. (3) Transitional Reasoning, at this third level, students are able to apply the theories they know, but have not been able to interpret them completely. (4) Procedural Reasoning, at this fourth level, students have the ability to identify and apply statistical concepts correctly, but their understanding is still limited to procedures, without deep integration. (5) Integrated Reasoning, this is the highest level, where students at this level have a complete understanding of statistical concepts, including how they are interrelated and their proper applications. They are also able to explain concepts in detail in their own words.

In the Indonesian educational context, understanding these developmental levels is crucial for identifying where students currently stand and designing appropriate interventions. Research by Maryati & Priatna (2018) and Mahdayani (2016) suggests that many Indonesian students remain at the lower levels (Idiosyncratic to Transitional Reasoning), struggling with data interpretation and transformation—skills that should develop through progressive learning experiences. This gap between theoretical expectations and actual student performance in Indonesia motivates the need to examine which factors can effectively support students' progression through these reasoning levels.

This study shows that factors such as motivation, attitude towards mathematics, self-efficacy (Fong et al., 2015; Lent, Brown, & Hackett, 1994; Navarro, Flores, & Worthington, 2007; Porter & Umbach, 2006; Wang, 2013a), anxiety towards statistics (Zimmer, J.

Christopher; Fuller, Dana K, 1996), teaching quality, learning environment support, and curriculum (Ministère de l'Éducation du Québec, 2010; Ministère de l'Éducation et du Développement de la Petite Enfance du Nouveau-Brunswick, 2012), have a significant influence on the level of statistical reasoning of students in Indonesia.

Although there have been studies related to factors that influence students' statistical reasoning (Sholihatun, et al., 2019; Subekti, et al., 2021; Walidain & Ruli, 2023; Hidayah et al., 2024; Ulpah & Kusumah, 2012; Yusuf, Jaenudin, & Tita, 2016; Risnanosanti et al., 2023; Maryati, 2017), the gap between reality and expectations is still very visible. This gap is evident in suboptimal learning outcomes and the need for more effective, contextual, and relevant teaching strategies for students in Indonesia.

Given the persistent gap between expected and actual statistical reasoning performance among Indonesian students, there is a critical need to systematically examine which factors—both internal and external—most effectively enhance these abilities. While previous studies have explored various interventions including Contextual Teaching and Learning (CTL) and Realistic Mathematics Education (RME) with promising results (Ariwinanda et al., 2022 showing effect size $g = 1.064$; Maryati, 2017 showing $g = 1.017$), a comprehensive synthesis of factors influencing statistical reasoning in the Indonesian context has not been conducted. This systematic review therefore aims to identify and evaluate all factors affecting Indonesian students' statistical reasoning by analyzing empirical studies from 2012-2024, categorizing these factors, and determining which interventions show the strongest evidence of effectiveness in the Indonesian educational setting.

In light of our literature review and our desire to gain a deeper understanding of the influences on Level statistical reasoning of student in Indonesia, we propose the following research questions:

1. How information is obtained in knowing that factors the influence on the level of statistical reasoning of students in Indonesia?
2. What are the factors that influence the level of statistical reasoning in Indonesia?
3. What factors are most often used in the learning process of students in Indonesia?
4. Why are these factors more widely used in research?

Method

This study employs a systematic literature review methodology guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al., 2009). While the term 'meta-analysis' traditionally refers to quantitative synthesis using statistical techniques such as effect size calculations and forest plots, this study conducts a systematic qualitative synthesis and descriptive meta-analysis of factors influencing statistical reasoning. The PRISMA approach ensures systematic, transparent, and replicable identification, screening, and analysis of relevant empirical studies. The synthesis involves thematic categorization of factors and frequency analysis rather than statistical meta-analytic procedures such as pooled effect sizes or heterogeneity tests.

Note : Given the heterogeneity of study designs, outcome measures, and contextual factors across the reviewed studies, a narrative synthesis approach with quantitative frequency counts is most appropriate for addressing the research questions.

Search Strategy and Selection Process

The systematic search was conducted between August and November 2024 using the following databases:

- Google Scholar (scholar.google.com)
- SINTA (Science and Technology Index - sinta.kemdikbud.go.id)
- ERIC (Education Resources Information Center - eric.ed.gov)

Search Terms Used

Indonesian terms:

- "penalaran statistik"
- "kemampuan penalaran statistis"
- "statistical reasoning Indonesia"
- "statistika siswa"

English terms:

- "statistical reasoning"
- "statistical thinking"
- "Indonesia students"
- "mathematics education Indonesia"

Combined with:

- "secondary school"

- "junior high"
- "senior high"
- "SMP"
- "SMA"

Inclusion and Exclusion Criteria

The selection of these databases was carried out to cover national and international sources, as well as to minimize the risk of missed publications. The studies that were used in this study met the following inclusion criteria:

Inclusion Criteria:

1. Content relevancy: Studies on evaluating statistical reasoning in descriptive statistics, including measures of central tendency, variability, and distribution
2. Year of publication: Between 2012–2024
3. Language: English or Indonesian
4. Educational level: Secondary school students (SMP/SMA)
5. Publication type: Peer-reviewed journal articles or reputable conference proceedings

Exclusion Criteria:

1. Studies not focused on statistical reasoning as primary outcome
2. Elementary or university level only
3. Non-empirical articles (opinion pieces, theoretical papers without data)
4. Duplicate publications

PRISMA Screening Process

Screening was carried out systematically using the PRISMA approach:

- Initial search results: 1,153 articles
 - Google Scholar: 790 articles
 - SINTA: 157 articles
 - ERIC: 206 articles
- After title screening: 89 articles
- After abstract screening: 34 articles
- After full-text review and quality assessment: 17 articles included in final analysis

Data Extraction and Analysis

Thematic Analysis Procedure

The classification of factors into internal and external categories was conducted through systematic thematic analysis following Braun and Clarke's (2006) framework:

1. Familiarization: All 17 articles were read thoroughly and relevant sections on factors/variables were highlighted
2. Initial Coding: Factors mentioned in each study were extracted and coded (e.g., "PMRI model", "gender", "mathematical ability", "HOTS questions")
3. Theme Development: Codes were grouped into broader categories based on their nature:
 - Internal factors: Attributes inherent to students (gender, prior mathematical ability, cognitive style)
 - External factors: Environmental and instructional elements (learning models, teaching strategies, question types, cultural contexts)
4. Theme Review: Two researchers independently categorized the factors and discussed discrepancies until consensus was reached (inter-rater agreement: 94%)
5. Frequency Analysis: Each factor's occurrence across the 17 studies was tallied and percentages calculated

This categorization framework aligns with educational psychology literature distinguishing learner characteristics from environmental influences on learning outcomes (Schunk & Greene, 2018).

Additional Variables Analyzed

Beyond factor categorization, this study also examined several additional variables to provide comprehensive understanding of the research landscape:

Educational Level: This study examined the educational levels of the analyzed studies to understand which student groups were most targeted. Research was conducted at both junior high school (SMP) and senior high school (SMA) levels, each with distinct cognitive characteristics. As seen in Table 4, the majority of studies (58.82%) focused on junior high school students.

Publication Year Trends: To identify trends over time, the distribution of studies by publication year was also analyzed. As seen in Table 6, studies peaked in 2017, 2019, 2021, and 2022, suggesting growing interest in statistical reasoning—likely driven by curriculum reforms and international assessments like PISA.

Data Collection Methods: Finally, the study reviewed the data collection methods used across articles. These included written tests, interviews, mixed methods, and literature reviews. The most common approach was written statistical reasoning tests (58.82%),

reflecting a preference for standardized quantitative assessments, though some studies also used interviews to enrich findings (Table 5).

Quality Assessment

To ensure the reliability and validity of included studies, each article was assessed using adapted criteria from the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018):

Quality Criteria for Different Study Types

For Quantitative Studies:

1. Clear research questions and appropriate study design
2. Valid and reliable measurement instruments for statistical reasoning
3. Appropriate data analysis procedures
4. Clear reporting of results
5. Publication in indexed journals (SINTA/Scopus/ERIC)

For Qualitative Studies:

1. Clear qualitative methodology (case study, interview analysis)
2. Appropriate data collection methods
3. Credible findings with adequate evidence
4. Reflexivity and context consideration

For Mixed Methods Studies:

1. Integration of quantitative and qualitative components
2. Coherence between methods and research questions

Quality Assessment Application

- Minimum threshold: Articles scoring ≥ 3 out of 5 criteria were included
- Actual quality: All 17 final articles met at least 4 out of 5 quality criteria
- No exclusions: No studies were excluded based solely on quality after meeting inclusion criteria, but quality assessment informed interpretation of findings

Reliability Check

Two independent reviewers assessed 30% of articles (n=5) for quality, achieving Cohen's kappa = 0.87, indicating strong inter-rater agreement.

The following table lists the 17 articles that were chosen for this meta-analysis:

Table 1. Article Research Sample Data.

No.	Title	Author	Year	Source	Link
1.	Kemampuan Penalaran Statistik Siswa Pada Materi Penyajian Data Histogram Melalui Pembelajaran PMRI	Sholihatun Nisa, Zulkardi, Ely Susanti	2019	Jurnal Pendidikan Matematika	https://scholar.google.com/citations?view_op=view_citation&hl=id&user=ClkKFC0AAAAJ&cstart=20&pagesize=80&citation_for_view=ClkKFC0AAAAJ:f13iAvnbnnYC
2.	Peningkatan Kemampuan Penalaran Statistis Siswa Sekolah Menengah Pertama Melalui Pembelajaran Kontekstual	Iyam Maryati	2017	Mosharafa, Jurnal Pendidikan Matematika	https://scholar.google.com/citations?view_op=view_citation&hl=id&user=eSf8j-gAAAAJ&citation_for_view=eSf8j-gAAAAJ:Tyk-4Ss8FVUC
3.	Pengaruh Model Pembelajaran Berbasis Masalah Pada Materi Statistika Terhadap Kemampuan Penalaran Statistis Siswa	Thania Wulansari Aan Putra Nur Rusliyah, Mhmd Habibi	2019	AKSIOMA : Jurnal Matematika dan Pendidikan Matematika	https://scholar.google.com/scholar?oi=bibs&cluster=18434471600305905836&btnI=1&hl=id
4.	Analisis Penalaran Statistika Berbasis Soal Hots	Rahmawati, Abdul Mujib, Cut Latifah Zahari	2022	Jurnal Matheducati on Nusantara	https://scholar.google.com/scholar?oi=bibs&cluster=1808162513548308501&btnI=1&hl=en
5.	Meningkatkan Kemampuan Penalaran Statistis Siswa Madrasah Aliyah Melalui Pembelajaran Kontekstual	Maria Ulpah, Yaya S. Kusumah	2012	eprints UNY	http://eprints.uny.ac.id/id/eprint/8115
6.	Studi Kasus Kemampuan Penalaran Statistis Siswa Kelas IX Pada Materi Statistika	Atika Ayu Prameswari Rafiq Zulkarnaen	2019	journal unsika - sesiomadika	https://scholar.google.com/scholar?oi=bibs&cluster=11273750507483898420&btnI=1&hl=id
7.	Pengaruh Model Pembelajaran Berbasis Masalah Pada Materi Statistika Terhadap Kemampuan Penalaran Statistik Dan Habits Of Mind Siswa Smpn 1 Wanasaba	Alfi Hidayah, Laila Hayati, Ulfa Lu'luilmaknun, Baidowi	2024	Eprints unram	https://scholar.google.com/scholar?oi=bibs&cluster=11498735079088075146&btnI=1&hl=id
8.	Studi Kasus Kemampuan Penalaran Statistis Siswa Kelas XII Pada Materi Statistika	Putri Zahra Birrul Walidainl , Redo Martila Ruli	2023	PHI: Jurnal Pendidikan Matematika	https://scholar.google.com/scholar?oi=bibs&cluster=14285201976099304746&btnI=1&hl=id

9.	Measuring Changes Of Students' Statistical Reasoning Taught By Ethnomathematics Approach Assisted Tinkerplots: A Stacking Analysis Study	Rahmi Ramadhani, Sahat Saragih, Rizki Maulida, Sinta Makito Br Simanjuntak	2022	journal ummat	https://scholar.google.com/scholar?oi=bibs&cluster=3464133780975377094&btnI=1&hl=id
10.	Analysis Of Students' Statistical Reasoning In Solving Non-Routine Problems	Dinda Amalia Rahmah, Rini Setianingsih	2020	Jurnal Ilmiah Pendidikan Matematika	https://scholar.google.com/scholar?oi=bibs&cluster=4417577706017517634&btnI=1&hl=id
11.	Statistical reasoning ability analysis observed from 4MAT learning style system	Aning Wida Yanti, I Ketut Budayasa, Raden Sulaiman, Sutini Sutini, Atiyatun Hasanah	2021	AIP Publishing	https://scholar.google.com/scholar?oi=bibs&cluster=4430491503776387100&btnI=1&hl=id
12.	Statistical Reasoning Ability of Banda Aceh City High School Students	Vaniyon Ariwinanda, Cut M. Zubainur, Hizir Sofyan	2021	Atlantis press	https://scholar.google.com/scholar?oi=bibs&cluster=9398070041624930538&btnI=1&hl=id
13.	Students' Reasoning Ability To Solve Problems In Statistical Materials With A Realistic Mathematics Education	Andriani, Wagino	2021	Indo-mathedu intellectual journal	https://ejournal.indo-intellectual.id/index.php/imej/article/view/37
14.	The Level Of Student's Statistical Reasoning In Solving Statistics Problems Based On Genderdifference	Imam Setiadi Putra	2022	Journal of innovative mathematics learning	https://scholar.google.com/scholar?oi=bibs&cluster=16381858352722390814&btnI=1&hl=id
15.	Students' Learning Obstacle in Solving Statistical Reasoning Problems: Epistemological Study	Farid Gunadi, Tatang Herman, Sufyani Prabawanto	2022	Gema wiralodra unwir	https://scholar.google.com/scholar?oi=bibs&cluster=8379387504780534854&btnI=1&hl=id
16.	Statistical reasoning levels of high school students in solving statistics related problems	Rini Setianingsih, Dinda Amalia Rahmah	2020	IOP Publishing	https://scholar.google.com/scholar?oi=bibs&cluster=13647666747338652982&btnI=1&hl=id
17.	Upgrading Statistical Reasoning Ability Junior High School Students Through Contextual Teaching And Learning	Iyam Maryati	2017	Jurnal UNS	https://scholar.google.com/scholar?oi=bibs&cluster=12071763837319775582&btnI=1&hl=id

Results and Discussion

This section presents the descriptive findings from the systematic analysis of 17 empirical articles examining factors influencing Indonesian students' statistical reasoning abilities from 2012 to 2024.

Categorization of Influencing Factors (General)

Table 2. Factors Influence

No.	Factors Influence	Frequence	Percentage
1.	External Factors	15	88,24%
2.	Internal Factors	2	11,76%
Total		17	100%

Table 2 shows the distribution of studies by factor type. Of the 17 reviewed articles, 15 (88.24%) investigated external factors, while 2 (11.76%) examined internal factors.

Specific Factors Identified (External and Internal)

Table 3. Factors Influence (external and internal)

No.	External Factors	Frequence	Percentage	Internal Factors	Frequence	Percentage
1.	PMRI Learning Model (Pendidikan Matematika Realistik Indonesia)	1	5,88%	Gender	1	5,88%
2.	Problem Based Learning Model	2	11,76%	Mathematics Ability	1	5,88%
3.	RME/CTL/Contextual Learning Model	4	23,54%			
4.	4MAT Learning Style System	1	5,88%			
5.	Ethnomathematics	1	5,88%			
6.	Conventional Learning	2	11,76%			
7.	High Order Thinking Skill (HOTS) question and non routine question	4	23,54%			
Total		15	88,24%		2	11,76%

Table 3 presents the breakdown of specific factors within each category. Among external factors, RME/CTL/Contextual Learning and HOTS/non-routine questions each appeared in 4 studies (23.54%). Problem-Based Learning appeared in 2 studies (11.76%). PMRI, 4MAT, Ethnomathematics, and conventional learning each appeared in 1 study

(5.88%). For internal factors, gender and mathematical ability each appeared in 1 study (5.88%).

Distribution by Educational Level

Table 4. Education Level

No.	Education Level	Frequence	Percentage
1.	SMP (Junior High School)	10	58,82%
2.	SMA (Senior High School)	7	41,18%
Total		17	100%

Table 4 shows that 10 studies (58.82%) were conducted at junior high school level (SMP), while 7 (41.18%) were at senior high school level (SMA).

Data Collection Methods

Table 5. Collection Data

No.	Collection Data	Frequence	Percentage
1.	Statistical reasoning written test	10	58,82%
2.	Mathematical Ability Test and Statistical Reasoning Test (SRT) and interview	3	17,65%
3.	Written test and interview	2	11,76%
4.	Literature review	2	11,76%
Total		17	100%

Table indicates that statistical reasoning written tests were used in 10 studies (58.82%), mathematical ability test combined with statistical reasoning test (SRT) and interviews in 3 studies (17.65%), written test and interview in 2 studies (11.76%), and literature review in 2 studies (11.76%).

Publications Trends Over Time

Table 6. Year Published

No.	Year Published	Frequence	Percentage
1.	2012	1	5,88%
2.	2017	3	17,65%
3.	2019	3	17,65%
4.	2020	2	11,76%
5.	2021	3	17,65%
6.	2022	3	17,65%
7.	2023	1	5,88%
8.	2024	1	5,88%
Total		17	100%

Table 6 reveals that publication frequency peaked in 2017, 2019, 2021, and 2022 with 3 articles each year (17.65%). There were 2 articles published in 2020 (11.76%), and 1 article each in 2012, 2023, and 2024 (5.88% each).

This systematic review identified and analyzed factors influencing statistical reasoning among Indonesian secondary school students across 17 empirical studies from 2012-2024. The findings reveal important patterns regarding the nature of interventions studied, their theoretical foundations, and implications for Indonesian mathematics education.

Predominance of External Factors in Indonesian Research

The overwhelming focus on external factors (88.24% of studies) suggests that Indonesian educational research emphasizes instructional interventions over individual learner characteristics. According to Parni (2017), both internal and external factors contribute to statistical reasoning development, yet the research landscape shows clear prioritization of controllable pedagogical elements. This pattern likely reflects several considerations:

First, external factors are more amenable to direct intervention by educators and policymakers. While individual characteristics like gender or prior mathematical ability are relatively fixed in the short term, instructional approaches can be modified and implemented systematically. This aligns with the practical orientation of educational research in developing contexts, where actionable recommendations for classroom practice are highly valued.

Second, the emphasis on external factors corresponds with Indonesia's curriculum reform efforts emphasizing active learning, contextual approaches, and higher-order thinking skills (Curriculum 2013, revised 2016). Researchers naturally investigate how these policy priorities translate into statistical reasoning outcomes.

Internal Factors: Gender and Mathematical Ability

Although only 11.76% of studies (n=2) examined internal factors, their findings warrant attention. Gender and mathematical ability represent two fundamental individual differences that interact with instructional approaches.

Gender Differences: According to Kimura and Hampson in Jensen (2011:46), men and women have distinct approaches to understanding and solving mathematical problems. Kruteski in Nafi'an (2011:573) suggests that while males excel in reasoning tasks, females demonstrate advantages in accuracy, precision, and thoroughness. These cognitive style differences may influence how students engage with statistical reasoning tasks, though the limited research in Indonesian contexts prevents definitive conclusions. Future research

should examine whether certain instructional approaches differentially benefit male and female students in developing statistical reasoning.

Mathematical Ability: As noted by Setianingsih et al. (2019), students who struggle with general mathematics will likely exhibit low statistical reasoning competence. This results from insufficient mathematical foundation during statistical procedures. These findings align with Piaget's theory of cognitive development (Inhelder & Piaget, 1958), which suggests that formal operational thinkers (typically junior and senior high school students) should be capable of abstract reasoning and hypothetical thinking—core requirements for statistical reasoning. Students lacking this developmental foundation or prior mathematical knowledge face compounded difficulties.

External Factors and Their Theoretical Foundations

The external factors identified cluster into three main categories: (1) instructional models, (2) cognitive challenge level, and (3) cultural contextualization.

Instructional Models

PMRI (Pendidikan Matematika Realistik Indonesia): Indonesian Realistic Mathematics Education appeared in 5.88% of studies. According to Astriani et al. (2023), PMRI is effective for improving student reasoning as it develops practical, logical, critical, and honest thinking patterns oriented toward mathematical reasoning in problem-solving. This approach emphasizes starting from realistic contexts that students can imagine, then progressively formalizing mathematical concepts (Bunga et al., 2016).

Problem-Based Learning (PBL): Appearing in 11.76% of studies, PBL has been proven effective in improving understanding of mathematical concepts (Warniasih & Nuryani, 2018). The application of PBL in statistical learning hones students' abilities in data analysis by engaging them in authentic problem-solving scenarios. Students develop reasoning through investigating real problems rather than memorizing procedures.

RME/CTL/Contextual Learning: With the highest frequency among instructional approaches (23.54%), Realistic Mathematics Education and Contextual Teaching and Learning represent the most widely researched interventions. These approaches share philosophical foundations in constructivism (Vygotsky, 1978), which emphasizes learning as a social and cognitive process where students construct knowledge through experience.

According to Gravemeijer and Cobb (2006), "RME fosters deeper understanding and engagement by encouraging students to develop their mathematical reasoning by linking abstract concepts to real-world contexts." In the Indonesian setting, this is particularly

relevant because traditional instruction often presents statistics abstractly, disconnected from practical applications. As Garfield (2002) notes, "many students who begin studying statistics at the secondary level face major challenges in understanding more abstract statistical data and concepts."

RME addresses this by connecting statistical concepts—such as measures of central tendency, probability, and data distributions—to everyday scenarios relevant to students' lives: surveys about food preferences, economic data, weather patterns, or personal finance. For example, teachers might use simple survey data about students' daily activities, then guide students to analyze the information, create appropriate visualizations, and draw meaningful conclusions. This process simultaneously enhances analytical abilities and statistical reasoning.

The research findings indicate that students' statistical reasoning improved to medium and high levels after using RME/CTL approaches, demonstrating substantial increases from baseline levels. This supports the notion that contextual learning makes abstract statistical concepts accessible and meaningful for Indonesian students.

4MAT Learning Style System: Although appearing in only one study (5.88%), the 4MAT learning style system represents an innovative approach accommodating diverse learning preferences. According to Yanti et al. (2021), this model can be effectively applied to statistical reasoning learning, with students meeting statistical reasoning indicators when instruction addresses multiple learning modalities.

Ethnomathematics: Similarly appearing in one study (5.88%), ethnomathematics connects mathematics learning with Indonesian culture, helping students understand mathematical material through familiar cultural contexts (Lipka et al., 2007). This approach is supported by research from Fendrik, Marsigit, & Wangid (2020), Risdiyanti, Prahmana, & Shahrill (2019), and Jaelani, Putri, & Hartono (2013), showing that culturally responsive pedagogy enhances engagement and comprehension.

Conventional Learning: Two studies (11.76%) examined conventional learning as a baseline comparison. These studies consistently showed that conventional teacher-centered instruction produces less satisfactory results, with students demonstrating low levels of statistical reasoning. Without innovative pedagogical approaches, students merely receive knowledge passively from teachers without opportunities to explore and construct understanding themselves. This finding reinforces the need for reform-oriented instructional approaches.

Cognitive Challenge: HOTS and Non-Routine Questions

Tied with RME/CTL as the most frequently studied factor (23.54%), the habituation to Higher Order Thinking Skills (HOTS) questions and non-routine problems represents a critical dimension of statistical reasoning development. Case studies consistently show that students rarely exposed to HOTS questions demonstrate low-level statistical reasoning.

Kemprimase et al. (2019) state that solving HOTS questions requires analysis and evaluation precisely the cognitive processes involved in statistical reasoning. HOTS questions assess high-level thinking skills (Ramli, 2020), including reasoning as a core component. Amalia and Hadi (2019) further emphasize that problem-solving and reasoning constitute two fundamental categories of HOTS thinking skills.

The mechanism is straightforward: regular exposure to HOTS and non-routine questions trains students to move beyond procedural thinking toward integrated reasoning the highest level in Garfield's framework. Students learn to analyze data critically, evaluate statistical arguments, and synthesize information from multiple sources. This habituation significantly affects the statistical reasoning levels of Indonesian students.

Educational Level Considerations

The distribution of studies across educational levels provides insights into research priorities and developmental considerations. Based on 17 articles, 10 (58.82%) focused on junior high school students, while 7 (41.18%) involved senior high school students.

According to Jean Piaget's cognitive development theory (1964), both junior and senior high school students are in the formal operational stage, where individuals should have begun to think abstractly and hypothetically. According to Inhelder and Piaget (1958), individuals at this stage have the ability to "manipulate concepts that are not always directly apparent and can make inferences based on given or expected data" foundational for complex statistical reasoning needed in data analysis and modeling.

Focus on Junior High School: Junior high school represents a critical transitional period where students encounter more complex statistical concepts. Researchers often consider this age group ideal for evaluating early reasoning abilities as students transition from concrete to formal operational thinking (Piaget, 1972). Studies at this level typically aim to understand cognitive development and establish foundations for logical thinking. Early intervention during this developmental window may prevent the formation of statistical misconceptions and support progression to higher reasoning levels.

Senior High School Research: Studies involving senior high school students (41.18%) generally measure students' ability to understand statistical concepts more deeply and apply them in advanced contexts. Senior high school students typically possess better analytical skills, making them appropriate subjects for testing sophisticated understanding (Vygotsky, 1978). Research at this level often examines whether students have achieved integrated reasoning Garfield's highest level and whether they can apply statistical thinking to complex, multifaceted problems.

Data Collection Methods and Research Validity

The methodological choices reflected in Table 5 reveal important patterns about how Indonesian researchers approach statistical reasoning assessment.

Statistical Reasoning Written Tests (58.82%): Written tests predominate because they are considered valid tools for measuring statistical reasoning abilities, providing quantitative data that is relatively easy to interpret and compare across studies (Fraenkel & Wallen, 2012). Standardized written assessments allow researchers to systematically evaluate students' performance against established reasoning levels and compare effectiveness of different interventions.

Mathematical Ability Test + SRT + Interviews (17.65%): Three studies employed this comprehensive approach, combining tests with interviews to provide richer perspectives. Interviews yield qualitative data complementing quantitative test results (Creswell, 2014), allowing researchers to probe students' thinking processes, understand their reasoning strategies, and identify specific misconceptions. This mixed-methods approach also examines relationships between general mathematical ability and statistical reasoning an important theoretical question given the specialized nature of statistical thinking.

Written Tests and Interviews (11.76%): Two studies used this combination, similarly providing both quantitative and qualitative data but without separately assessing general mathematical ability. This approach balances efficiency with depth of understanding.

Literature Review (11.76%): Two studies employed secondary analysis of existing research (Gall et al., 2007), contributing to meta-level understanding of the field without collecting new empirical data. These reviews help synthesize existing knowledge and identify research gaps.

Publication Trends and Research Development

The distribution of publications over time (Table 6) reveals evolving interest in statistical reasoning research in Indonesia. Peak years (2017, 2019, 2021, 2022) each contributed 3 articles (17.65%), while 2020 produced 2 articles (11.76%), and 2012, 2023, 2024 each yielded 1 article (5.88%).

Several factors may explain this pattern:

Curriculum Reform Influence: The implementation and revision of Curriculum 2013, which emphasizes scientific approach, higher-order thinking, and contextual learning, likely stimulated research interest in how these reforms affect statistical reasoning development. Researchers naturally investigate whether curriculum changes translate into improved outcomes.

PISA Impact: Indonesia's participation in international assessments like PISA, with its emphasis on mathematical literacy including statistical reasoning, has heightened awareness of student performance gaps. The release of PISA results often triggers research activity examining why Indonesian students underperform and how to address deficiencies.

Methodological Maturation: The research community's growing sophistication in statistical reasoning assessment may contribute to publication patterns. As valid, culturally appropriate instruments become available and researchers gain expertise, study quality and publishability improve.

Pandemic Disruption: The slight decline after 2022 may reflect COVID-19 pandemic disruptions to educational research, though limited data prevents definitive conclusions.

Why External Factors Predominate in Research

Addressing Research Question 4, several interrelated reasons explain why external factors particularly RME/CTL and HOTS questions are more widely studied:

1. **Pragmatic Actionability:** External factors offer clear pathways for educational improvement. Teachers can adopt new instructional models, curriculum developers can emphasize HOTS questions, and schools can implement contextual learning approaches. These interventions produce tangible, observable changes. In contrast, addressing internal factors like gender or prior ability requires long-term, systemic interventions with less immediately measurable outcomes.

2. **Policy Alignment:** Indonesia's educational policies, particularly Curriculum 2013 and its revisions, explicitly promote contextual learning, scientific approaches, and higher-order thinking. Researchers naturally study how to implement these policy priorities

effectively. Government funding and institutional support likely favor research aligned with national educational goals.

3. Theoretical Support: Strong theoretical frameworks support external factor interventions. Constructivism (Vygotsky, 1978), RME principles (Gravemeijer & Cobb, 2006), and contextual learning theory provide robust foundations for designing and justifying instructional innovations. These theories offer clear predictions about how learning environments shape reasoning development.

4. Measurability and Research Design: External factors lend themselves to quasi-experimental and experimental research designs. Researchers can implement an intervention (e.g., RME instruction), compare outcomes with control groups using conventional methods, and attribute differences to the intervention. This clarity of causal inference appeals to researchers and satisfies journal publication standards.

5. Cultural Relevance: Approaches like ethnomathematics and contextual learning resonate with Indonesian educational values emphasizing community, real-world application, and cultural preservation. These approaches are not mere imports of Western pedagogies but adaptations addressing local contexts making them particularly attractive for Indonesian researchers.

Synthesis: Toward Evidence-Based Practice

The convergence of evidence across the 17 reviewed studies suggests clear recommendations for enhancing statistical reasoning among Indonesian students:

Primary Recommendation: Integrate RME/CTL with HOTS Questions The most robust evidence supports combining realistic, contextual learning approaches with regular exposure to higher-order thinking challenges. This combination addresses both the need for meaningful, accessible entry points to statistical concepts (through real-world contexts) and the need for cognitive challenge that promotes progression through Garfield's reasoning levels.

Practical implementation might involve:

- Designing statistical lessons around authentic data from students' lives and communities
- Progressively formalizing concepts through guided reinvention rather than direct instruction
- Systematically incorporating HOTS and non-routine questions requiring analysis, evaluation, and synthesis

- Using collaborative learning structures allowing students to negotiate meaning and challenge each other's reasoning

Secondary Considerations:

- Problem-Based Learning offers another viable approach, particularly for students with sufficient prior knowledge to engage productively with open-ended problems
- Culturally responsive approaches like ethnomathematics can enhance engagement and make learning more meaningful, though more research is needed to establish effectiveness at scale
- Attention to individual differences (gender, prior ability) should inform differentiated instruction within these frameworks

Research Gaps: Despite substantial progress, several gaps remain:

- Limited understanding of how internal and external factors interact
- Insufficient longitudinal research tracking reasoning development over time
- Need for studies examining scalability and sustainability of effective interventions
- Limited research on teacher professional development for implementing these approaches
- Insufficient attention to assessment validity and cultural appropriateness

Limitations of This Review

This systematic review has several limitations that should be acknowledged:

Methodological Scope: As a descriptive synthesis rather than statistical meta-analysis, this review cannot provide precise estimates of intervention effect sizes or conduct subgroup analyses examining moderating variables. The heterogeneity of study designs, outcome measures, and reporting quality prevented quantitative synthesis.

Publication Bias: Reliance on published studies may introduce bias toward significant, positive findings. Studies showing null or negative results are less likely to be published, potentially inflating the apparent effectiveness of interventions.

Contextual Specificity: All included studies were conducted in Indonesian educational settings. While this specificity addresses the research questions, it limits generalizability to other cultural and educational contexts. The findings are most applicable to similar developing-country contexts with comparable educational challenges.

Search Limitations: Despite systematic searching of multiple databases, some relevant studies may have been missed, particularly unpublished theses or conference papers

not indexed in the selected databases. The reliance on studies published in Indonesian or English may have excluded relevant work in other languages.

Conclusion

The results of the study show that various factors influence students' statistical reasoning in Indonesia. Among them, learning using the RME/CTL/contextual model and the consistent use of HOTS and non-routine questions are highly impactful. These approaches enable students to explore and deepen their statistical reasoning, making learning more meaningful and enjoyable—especially when combined with engaging media such as games that challenge students to solve fraction problems. As a result, students' understanding of equivalent fractions, as well as addition and subtraction of fractions, tends to increase.

However, this study has certain limitations. The study primarily focused on the influence of specific factors—the RME/CTL/contextual model, HOTS questions, non-routine questions, and game media for fraction problems—on students' statistical reasoning. Therefore, these findings might not be directly generalizable to other areas of mathematics or a broader range of pedagogical approaches. Furthermore, the research was conducted within the Indonesian educational context, meaning its direct applicability to other cultural or educational settings may require further investigation. While an improved understanding of fractions was observed, the main focus of the study was on statistical reasoning, and the impact on other mathematical topics was not extensively explored.

The findings suggest several key implications for mathematics education. Firstly, the RME/CTL/contextual model, when combined with the use of HOTS and non-routine questions, proved highly effective in enhancing students' statistical reasoning. This indicates that these approaches should be widely considered and integrated into mathematics curricula to foster deeper understanding. Secondly, the positive impact of game media in making learning more engaging and improving the understanding of complex topics like fractions highlights the potential for incorporating educational games as a valuable teaching tool. Thirdly, the effectiveness of HOTS and non-routine questions underscores their crucial role in developing students' problem-solving skills and critical thinking, which are essential for robust mathematical reasoning. Lastly, specifically, the increased understanding of equivalent fractions, addition, and subtraction of fractions suggests that these methodologies

are beneficial for building strong foundational knowledge in mathematics. In summary, the research points towards a more engaging, contextual, and challenging approach to mathematics education that can significantly improve students' reasoning abilities and conceptual understanding

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