frontiers | Frontiers in Education

TYPE Perspective
PUBLISHED 18 June 2025
DOI 10.3389/feduc.2025.1493737

OPEN ACCESS

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RECEIVED 09 September 2024
ACCEPTED 29 May 2025
PUBLISHED 18 June 2025

CITATION
Kodirun, Kadir, Busnawir and Indrawati WO (2025) Senior high school students' competence in logical operation and logical reasoning.
Front. Educ. 10:1493737.
doi: 10.3389/feduc.2025.1493737

Senior high school students' competence in logical operation and logical reasoning

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The research suggests that the framework of logical operations and inference patterns remains unfinished even in adulthood. While various logical models exist beyond the classical true-or-false reasoning model, secondary school students must primarily understand and apply classical reasoning rules. In mathematics, proof, reasoning, and refutation are essential due to the frequent use of logical operations in the subject. This study assessed general logical knowledge and operations within mathematical contexts through classroom tests involving 448 students from 10 public schools and four vocational schools. The students performed best on tasks requiring correct conclusions (69.02%), followed by interpreting "at most"/"at least" (63.41%), with the lowest success rate in negation tasks (29.91%), including negating "at least," "exists," and "for every". The results reveal that accurate interpretation was not dominant across all logical operations for these students. Students performed best on geometric problems (70.05%), followed by algebra, statistics, and calculus problems, with the lowest success rate in calculus-related logical problems (28.04%). Statistical tests showed no significant gender differences in performance; however, according to human capital theory, students with teachers as parents performed significantly better.

KEYWORDS

logical operation, logical reasoning, high school student, classroom testing, mathematical context

1 Introduction

Senior high schools typically serve as settings where students begin to perceive reality through a scientific lens. They engage in the "intellectual life" of their peers and develop social skills by interacting with more experienced individuals (Fauzi, 2022). When learning is considered as enculturation in its broadest sense, it means immersing oneself in the community's culture and adopting its habits, skills, methods, and tools, thus integrating into the cultural practices of that group or society (Simanjuntak et al., 2023; Odden and Rochat, 2004). Consequently, secondary school acts as a gateway for the scientific field and the broader field relating to science.

In the present day information-driven community, the significance of science and research has risen, highlighting the need for higher education students to develop advanced cognitive skills. To participate effectively in scientific inquiry, students must foster critical thinking, a thorough grasp of epistemology, research capabilities, evidence-based reasoning, and an understanding of context (Murphy et al., 2005). As noted by Heino et al. (2021), students should be adept at selecting relevant information, making research-based judgments, understanding knowledge creation processes, assessing the credibility of information sources, and applying reasoning skills, all of which are aspects of critical thinking. These higher-order thinking abilities are vital for 21st-century citizens, as they can be applied across various disciplines, contexts, jobs, and industries (Mukhlis et al., 2023; Hasan and Pardjono, 2019;

Thornhill-Miller et al., 2023). Critical thought process, problem-solving, and complex reasoning have been the focus of increasing research in higher education over recent decades (Rosalina and Sundari, 2022; Thornhill-Miller et al., 2023; Karaca-Atik et al., 2023). These widely studied generic skills are based on fundamental logical processes.

Both critical and logical thinking support students' understanding across various fields (Cresswell and Speelman, 2020; Sobhanzadeh et al., 2021). According to multiple studies, Debrenti and Bordás (2023) highlight the importance of formal reasoning across all educational levels. This is because, in addition to the natural sciences, the social sciences also necessitate deductive reasoning, an understanding of causal relationships and their components such as excluding and controlling variables, creating and utilizing formal models, and applying logical reasoning. Throughout their school years, students' intellectual abilities are nurtured and enhanced through various means. One key goal of mathematics education is the proper application of logical operations, which contributes to the overall development of thinking skills (Cresswell and Speelman, 2020). Everyone is able to perform mathematical proofs and derive additional conclusions from them by using basic logical procedures.

In mathematics and science, formal logic and fundamental logical processes are crucial, yet informal logic is used in everyday conversations. We employ the informal logic of the language before acquiring formal logic. It is evident that common sense reasoning and non-mathematical language do not adhere to the conventions and standards of mathematical logic (Bergwall, 2021). The initial step in using formal logic norms and rules across different contexts is to determine the linguistic register required for thinking. This is important because the semantic content of the context, or the mental images it generates, influences our understanding of the topic and our interpretation of logical operations, whether they adhere to formal logic rules or everyday language (Tamba, 2021).

In addition to helping students succeed academically in science and math, students who possess excellent reasoning skills and operational logic abilities are also crucial for the growth of critical thinking abilities and the ability to make logical decisions in daily life (Sulistiani and Masrukan, 2016; Mutmainnah et al., 2025). Therefore, understanding and applying operational logic is an important investment in the education of high school students, which will later support their success in various aspects of life (Muhammad et al., 2024).

Research into Indonesian senior high school students' competencies in logical operations and reasoning has yielded several insights that highlight both strengths and areas for improvement. Notably, while many students demonstrate a solid understanding of basic logical principles, there is often a gap when it comes to applying these concepts in more complex, real-world scenarios. A few papers about logical reasoning in mathematics were discovered in Indonesia. Assessing logical thinking skills was one of them. The logical thinking skills of 205 eleventh graders from four public high schools in Ketapang Regency, West Kalimantan, were evaluated by a survey. Although the available summary lacked particular data, the study's goal was to profile these skills (Aditya, 2024). According to another study on students' reasoning skills by Isnani et al. (2020), students frequently make the mistake of answering Real Analysis questions incorrectly. However, this research also reveals other mistakes like misconceptions, carelessness, or simply writing the question (Isnani et al., 2020; Isnani et al., 2020).

A study examined the connection between Biology learning outcomes and critical thinking abilities in Malang senior high school students. Critical thinking accounted for 73.9% of the variance in learning outcomes, according to the study's significant correlation findings (Mite and Corebima, 2017). A research was conducted in Bengkulu, and the purpose of this study carried out in Bengkulu was to evaluate the critical thinking abilities of high school pupils. The study helps to comprehend regional differences in critical thinking competencies, even though the summary did not go into detail about the precise results (Fitriani et al., 2022). Besides that, research on the area of reasoning in language learning had also been conducted in West Sumatra. This study examined the reasoning patterns and logical fallacies of 30 senior high school students in an English as a Foreign Language (EFL) classroom in West Sumatra. The research analyzed students' higher-order thinking skills through HOTS-based questions related to descriptive texts (Selpia and Setyarini, 2020). The Indonesian government's educational policies have emphasized the development of critical thinking skills as a part of logical and mathematical reasoning among secondary school students to enhance national competitiveness.

Some Indonesian experts are also interested in personality traits when it comes to mathematical reasoning. A study examined the relationship between personality types—more especially, the guardian personality—and senior high school students' aptitude for mathematical reasoning. The study, which was carried out in East Lombok, sought to characterize reasoning abilities and pinpoint the reasons behind problem-solving mistakes (Akrom and Triyanto, 2021). These studies collectively highlight a concerted effort within Indonesia to assess and enhance logical and critical thinking skills among senior high school students, acknowledging their importance in academic success and overall cognitive development.

Another one was on the difficulties in Higher-Order Thinking Skills (HOTS). This research involving high school students identified challenges in solving HOTS problems, particularly in mathematics. Students exhibited errors in comprehension, transformation, process skills, and encoding, highlighting difficulties in understanding problem keywords and applying appropriate strategies (Hadi et al., 2018).

Collectively, these studies show that although attempts are being made to improve Indonesian senior high school students' logical reasoning and higher-order thinking abilities, difficulties still exist in reaching proficiency. To effectively assist kids' cognitive development, addressing these issues calls for curriculum improvements and focused interventions.

Research on assessing student performance, especially in logical reasoning and logical operation, in Kendari secondary education is limited. To close this gap, we looked at a relatively limited portion of academic enculturation material to gauge students' proficiency in fundamental logical reasoning and operating skills. Our study aimed to identify the kinds of logical tasks and operations that are hard to interpret and solve, as well as the extent to which the mathematical context affects problem comprehension and accurate solution. One focus of our study was to determine whether the mathematical context in which a logical operation task is presented influences the proportion of correct responses. Additionally, we aimed to investigate how factors

such as participants' age, gender, parental education, and involvement in teacher training impacted their problem-solving abilities.

The region in this research, Kendari City, is one of the most diverse peripheral areas of the nation in terms of ethnicity. The region highly values traditional customs, and its residents have strong connections to the land and their community. District new student selection process is common since secondary education institutions in this region are finding it difficult to handle the youth's study-driven population to prestigious school and in the region. The rise of non-traditional student groups, such as those originating in lower socioeconomic backgrounds, diverse cultural contexts, and low-income families, has led to the creation pertaining "to the 12-year mandatory education program." This initiative is designed to foster cohesion among the region's varied population (Margiyanti and Maulia, 2023).

Using the questioner created by Wijaya et al. (2014), a conceptual replication study was conducted that partially replicated their findings and posed new probes (van der Kleij, 2019). Due to the "nationalization" of educator training program, most of schools in are being places for prospective teaching practice so that students have an important position in the school, not just in teacher education policies. To assess the initial findings related to academic achievement of students on logical tasks integrated into distinct mathematical situations across a distinct population and educational environment, we developed four hypotheses.

> *Hypothesis #1:* The gender of students does not affect their performance on logical thinking tasks.
>
> *Hypothesis #2:* Students' age affects their performance on logical thinking tasks, with older students anticipated to perform better than their younger counterparts.
>
> *Hypothesis #3:* The educational attainment of students' parents is believed to affect students' performance on logical thinking tasks, with those having parents with higher levels of education performing better than those with less educated parents.
>
> *Hypothesis #4:* The success in solving a logical task is affected by both the characteristics of the task and the context in which it is introduced.

2 Methods

This study is considered a conceptual replication because it replicates many of the methodological aspects from previous research published in both print and online journals (Debrenti and Bordás, 2023). Study population was distinct from that of the original study in terms of geography and educational attainment to evaluate whether the findings held true outside the confines of the original investigation. This technique is known as the "scaling out model of exploration" (Misfeldt et al., 2024).

To maintain data comparability, the study employed the same research design and, for the most part, the same statistical methods as the original study. However, some aspects of the original approach were altered or supplemented. Additionally, the study investigated whether the characteristics of the logical operations or the task context affected performance, aiming to gain a deeper understanding of how performance relates to variations among logical problems. This was compared to how parental education, as an independent variable, affected student performance in relation to the findings of the original study.

2.1 Participants

Data were gathered from August to December 2023. The study involved senior high school students from 10 public schools and four vocational schools. Purposive sampling was used to select participants, and the students completed the test under the oversight of a school teacher.

The survey included 448 students: 314 (70%) were girls, and 134 (30%) were boys. Among the participants, 75% attended public schools, while 25% were enrolled in vocational schools. In terms of age distribution, 200 participants were under 16 (44.64%), and 248 were 16 or older (55.36%). Most respondents (over 90%) were from public schools, with the remaining students attending vocational schools. These percentages reflect the variety of subjects available at the 14 schools.

2.2 Instrument

The research utilized a classroom test developed in the second semester of 2023. This test was divided into three sections: tasks related to various elements of propositional logic applied to everyday scenarios, four mathematical tasks, and a rating system using a 5-point Likert scale. The survey identified independent variables connected to the respondents' social backgrounds, including gender, age, and the highest level of education attained by their parents. The dependent variables consisted of the outcomes from tasks involving logical reasoning, fundamental logical operations, and core mathematical knowledge. The test, designed by Wijaya et al. (2014) and Zeijlstra (2017), was divided into three categories of logical operations: Set A focused on understanding quantifiers like "at most" and "at least"; Set B addressed negating terms such as "at least," "there is," and "all"; and Set C involved reasoning with statements such as "if … then" and "therefore." Each set included similar types of problems presented in different contexts. The test assessed general logical reasoning skills and operations across various contexts, including everyday situations, statistics, algebra, geometry, and calculus. All tasks were true-false questions with a single correct answer. For everyday life tasks, which required completing a sentence or continuing reasoning with a brief response, each item was marked as either correct or incorrect, with 1 point given for a correct answer. Examples of three tasks from the different logical operation sets, presented in various contexts, are included in the Appendix.

3 Results

Out of a possible 15 correct answers, the average score on the test for 448 participants was 8.00 (SD = 1.775), with a median score of 8. Participants answered at least 2 tasks correctly, with up to 13 tasks answered correctly. Correct answers were given to 23% of questions from Set A, 0.2% of questions from Set B, and 10.9% of questions from Set C.

3.1 Overall results based on the type of the logical operations required in the tasks and their context

The findings reveal that the difficulty levels of various task types, and consequently the difficulty of basic logical operations, differ as illustrated in Table 1. Each set of tasks comprised 5 questions of the same kind, with a maximum score of 5 points. In Set A, 333 students correctly answered at least 3 tasks, earning 3 out of 5 points, and no participants failed to complete all five negation or reasoning tasks. In Set B, 90 students, or 20.1% of the participants, scored 0 points. Set C, which included tasks related to everyday life and mathematics, had the highest number of perfect scores; 49 students (10.9%) answered all 5 problems correctly.

Students achieved the highest proportion of correct answers on Set A tasks, which required understanding numerical quantifiers such as "at most/at least" (79.5%), followed by the interpretation of reasoning: "if … then", "therefore" (78.1%), and at least the negation of universal, existential and numerical quantifiers as "all", "there is", "at least" (21.2%). The Single-factor ANOVA reveals a significant difference in the success rates for solving various task sets ($F = 395.437$, $p \leq 0.000$), indicating that negating statements with quantifiers such as "every/everyone", "at least", and "there are" is particularly challenging for students, with the task of negating sentences involving "at least" being the most difficult.

When tasks are categorized by mathematical context, it is clear that the context significantly affects the interpretation of propositional logical operations. As shown in Table 1, students answered correctly 4.2% of the time in everyday life contexts, 20.8% in statistics, 2.9% in algebra, 21.7% in geometry, and 9.8% in calculus contexts. The highest percentage of correct answers was seen in statistics tasks (23.7%), followed by algebra and calculus (both 17.0%), and geometry (1.6%). The Single-factor ANOVA indicates a significant difference based on the task context ($F = 97.31$; $p \leq 0.001$).

Overall student performance was affected by both the type of logical operation and the task context. Multiple linear regression analysis, taking all factors into account, demonstrates that the task context has a significant impact on student performance, while the type of logical operation does not significantly influence the results (R-square value = 1, $p = 0.00$). This suggests that the context of the tasks plays a more crucial role in determining performance than the type of logical operation used.

3.2 Findings categorized by gender and age

The sample exhibits a gender imbalance, largely because of the high number of students in preschool and primary school teacher training programs (refer to Table 2). To assess differences in task performance between males and females, both *F*-tests and *T*-tests were conducted, but no significant differences were observed in test scores between genders or in any particular type of task or context.

Likewise, the sample shows age imbalances but still accurately represents the senior high school student population in Kendari City. To examine differences among age groups, both *F*-tests and *T*-tests were employed. As indicated in Table 2, the descriptive statistics for age group performance reveal significant variations in two types of tasks. For Set A tasks, performance differences were not statistically significant: younger students averaged 3.12 correct answers, while older students averaged 3.20 ($t = -0.957$, $p = 0.339$). For Set B tasks, performance was also not significantly different: younger students averaged 1.60 correct answers, compared to 1.53 for older students ($t = 0.628$, $p = 0.530$). Similarly, for Set C tasks, there was no significant difference: younger students averaged 3.30 correct answers, while older students averaged 3.25 ($t = -0.957$, $p = 0.339$).

Additionally, when tasks were categorized by context, there were no performance differences between the two groups: Everyday life ($t = 0.603$; $p = 0.547$); Statistics ($t = 0.521$; $p = 0.603$); Algebra ($t = -0.114$; $p = 0.909$); Geometry ($t = -0.318$; $p = 0.750$); Calculus ($t = 0.165$; $p = 0.869$). In all aspects of mathematical context students aged below 16, the average score was 8.040; students aged above 16 have got average score 7.968. there is no difference performance between the two groups of students ($t = 0.429$, $p = 0.668$).

3.3 Results presented by parents' highest education level

Table 3 informs that the level of parental education makes a tremendous contribution to reasoning abilities (Ramadhan and Ichsan, 2021), to students' cognitive abilities (Nurhayati and Husain, 2021), especially students' abilities in reasoning competence and

TABLE 1 Descriptive statistics for the task sets and contexts ($N = 448$).

Statistical facts	Type of tasks			Contexts of tasks				
	Set A (A1, A2, A3, A4, A5)	Set B (B1, B2, B3, B4, B5)	Set C (C1, C2, C3, C4, C5)	Everyday life (A4, B4, C4)	Statistics (A1, B1, C1)	Algebra (A3, B3, C3)	Geometry (A5, B5, C5)	Calculus (A2, B2, C2)
Mean	3.165	1.558	3.272	2.13	1.55	1.71	0.87	1.97
Median	3	2.000	3	1	1	2	1	2
Mode	3	1.000	3	2	1	2	0	2
Standard deviation	0.897	1.117	1.039	0.37	0.96	0.93	0.81	0.67
Minimum	1	0	0	1	0	0	0	0
Maximum	5	5	5	3	3	3	3	3
Success rate	79.5%	21.2%	78.1%	70.05%	56.86%	56.70%	27.04%	67.87%

TABLE 2 Mean test scores categorized by gender and age.

Statistical facts	Type of tasks			Context of tasks				
	Set A	Set B	Set C	Everyday life	Statistics	Algebra	Geometry	Calculus
Male (N = 134)	2.993	1.537	3.291	1.836	1.313	1.813	1.231	1.6349
Female (N = 314)	3.239	1.567	3.264	2.006	1.309	1.971	1.105	1.682
T	*2.679*	*0256*	*−0249*	*2.139*	*−0.048*	*2.246*	*−1.598*	*0.524*
P	*0.008*	*0.798*	*0804*	*0.033*	*0.961*	*0.025*	*0.111*	*0.60*
Under 16 year (N = 200)	3.120	1.595	3.300	1.980	1.335	1.920	1.130	1.675
Older than or 16 year (N = 224)	3.202	1.528	3.250	1.936	1.290	1.927	1.153	1.661
T	*−0.957*	*0.628*	*0.506*	*0.603*	*0.521*	*−0.114*	*−0.318*	*0.165*
P	*0.339*	*0.530*	*0.613*	*0.545*	*0.547*	*0.909*	*0.750*	*0.868*

skills in operating logical symbols in mathematics (Lanani, 2015). The higher the level of education of parents, the more competent their children are in reasoning and operational logic (Acoci et al., 2023).

The highest level of education achieved by parents was used as an explanatory variable. Notable non-parametric correlations were identified between parents' educational attainment and students' test scores on the three types of logical operation tasks analyzed (r = 0.277; Sig. (1-tailed) = 0.000). This suggests that the educational level of the parents has a significant impact on student performance on these tasks. As shown in Table 3, students whose parents have graduate degrees perform better across all contexts compared to students whose parents have lower levels of education. The most notable disparity is observed in tasks related to statistics and algebra. For instance, students whose parents have lower secondary education correctly answered less than 60.00% of the questions, whereas those with graduate-educated parents achieved correct responses in at least 57.80% of cases.

4 Discussion

The significance of this study lies in its approach to assessing skills. There is a scarcity of research on the fundamental logical operation skills of senior high school students, despite their crucial role in critical and scientific thinking across all educational levels. This conceptual replication study aimed to explore the relationship between logical operations and mathematical contexts, as well as the factors leading to the observed outcomes. With only minor exceptions, the findings support the conclusions of previous research by Fehér et al. (2023). Based on a new data sample from 14 high schools in Kendari, the study shows that both the types of logical operations and the mathematical contexts of tasks affect student performance. It also confirms a consistent order of difficulty among high school students in Kendari concerning different types of logical operations (reasoning, understanding quantifiers, negation of quantifiers) and mathematical contexts (everyday life, statistics, algebra, geometry, calculus). This suggests that the challenges related to logical operations and mathematical contexts are more influenced by intrinsic characteristics than by the educational systems.

Some researchers have found the comprehension of quantifiers, particularly the negation of quantifiers is among the most difficult aspects of logical operations (Hazem, 2021). This difficulty arises because certain quantifiers must be conveyed using a more formal style, which students typically face only in advanced education (Mesnil, 2017). Consequently, students are often unfamiliar with the formal expressions needed for reasoning tasks (Bronkhorst et al., 2022). The challenges students encounter with these logical processes and conceptual understanding may stem from the complexity of these concepts or the teaching methods used in the classroom (Mesnil, 2017). Additionally, students might not fully appreciate the significance of mathematical language in these tasks. Other research has shown that a common mistake is not distinguishing between everyday language and mathematical terminology, due to the overlap and confusion between technical terms in mathematics and their everyday counterparts.

A limitation of the research is its comparatively not big enough of sample size of secondary school learners from Kendari City, which indicates the findings may not be representative of the broader population across the province of Indonesia. This suggests the site selection was more a matter of practical constraints than ideal research design. When compared to students from other countries, such as Romania (Debrenti and Bordás, 2023); and other part of European countries and other countries (Fehér et al., 2023), the performance of Indonesian students aligns with the lower scores reported in PISA surveys, where Indonesia consistently falls less than the OECD average across every area (Teig, 2023). In contrast, Romania and Slovakia are significantly nearer to the OECD average.

Enhancing logical thinking is a key goal in mathematics education worldwide. Mathematics curricula are organized into various areas and topics, each designed to cultivate logical thinking skills. These areas differ across different countries; for example, Within the Slovak curriculum, logic, reasoning, and proof are treated as distinct subjects, while in Romania and Indonesia, these topics are not explicitly outlined but are integrated into other subjects. The achievement in learning mathematics and improving logical reasoning is influenced by teaching strategies, curriculum, and instructional approaches.

TABLE 3 Distribution of correct responses based on parents' educational levels and the percentage of correct answers out of the total possible responses.

Parents' educational level	Everyday life	Statistics	Algebra	Geometry	Calculus
Lower secondary education	26	7	26	7	21
Success rate ($N = 45$)	*57.80%*	*15.50%*	*57.80%*	15.50%	*46.60%*
Upper secondary education	155	93	166	67	122
Success rate ($N = 207$)	*74.90%*	*44.90%*	*80.02%*	*32.40%*	*59.00%*
Undergraduate education	142	71	139	66	107
Success rate ($N = 175$)	*81.01%*	*40.60%*	*79.50%*	*37.70%*	*61.10%*
Graduate education	18	20	20	14	17
Success rate ($N = 21$)	*85.00%*	*95.20%*	*95.20%*	*66.60%*	*81.00%*

Variations in teacher training systems among countries can be observed in terms of duration, the educational program, and the pedagogical, psychological, and methodological insights offered (Debrenti and Bordás, 2023). In Indonesia, there is a focus on both scientific disciplinary training and pedagogical-psychological subjects for teachers, which likely impacts students' performance on logical tests.

4.1 Comparison of reasoning abilities of high school students in Kendari vs. outside Kendari

The literacy/numeracy competency achievement of students in Southeast Sulawesi, including Kendari, has increased, according to official data from the Ministry of Education, Culture, Research, and Technology and the LTMPT (Indonesian Board of Entrance Test of Higher Education). Southeast Sulawesi high school students scored 64.62% in reading and 62.38% in numeracy on the 2024 National Assessment. This number is higher than the 58.81% national numeracy achievement in 2023 [The local government does not release AKM (Minimal Competency Assessment) data for Kendari City individually]. Southeast Sulawesi generally outperforms the national average in high school literacy and numeracy, demonstrating a rise in reasoning skills.

The lone Kendari school in the top 1,000 nationwide is MAN (Islamic Secondary School), according to the 2022 LTMPT UTBK ranking. This school is placed 190th nationwide (first in Southeast Sulawesi) with a UTBK score of 561.315. While several top schools outside of Kendari dominate the top national rankings, no other Kendari school made it past the Top 1,000 UTBK (Ramandani, 2025).

According to the results above, only one of Kendari's top schools can compete at the highest level of the country. Other Kendari kids and schools do not seem to be especially well-known across the country. Accordingly, UTBK data shows a competitive disparity between Kendari students and students outside of Kendari, despite Southeast Sulawesi (including Kendari) showing an increase in AKM.

Only one Kendari school does very well on the national UTBK, despite official data indicating that reasoning (AKM literacy-numeracy; incorporating logical reasoning and operational logic) achievement has improved in Southeast Sulawesi. This indicates that Kendari pupils (those who do not attend the top schools) still struggle to compete with students from other areas in the academic and reasoning domains.

At the provincial level, Kendari City senior high school students demonstrate strong reading and numeracy skills as well as logical reasoning and logical operation accomplishments in mathematics. However, city-specific data is unavailable due to a dearth of study on the subject. The distribution of pupils' reading, numeracy, and reasoning skills has improved in a number of Java Island districts. Students' reading and numeracy abilities still need to be improved in other districts, like North Sumatra and the Meranti Islands. Only a small number of Kendari and other district schools rank in the top 1,000 nationally on the UTBK (computer-based written test), suggesting a competitive deficit on a national scale.

Regarding with Hypothesis #1, one research shows that students' performance on logical reasoning tests is not considerably impacted by their gender. Psychologists have amassed strong evidence that there aren't many notable differences between the cognitive skills of boys and girls (Spelke, 2005). Although some studies have found differences in particular cognitive areas, such as males being better at certain spatial tasks and females being better at verbal tasks, these differences do not correspond to differences in general intelligence or logical reasoning (Hyde et al., 2008).

It is also crucial to recall that social and cultural influences, rather than innate cognitive ability, frequently impact the apparent inequalities in academic success. For example, parents' and students' views of gender roles can affect how well their children perform in math classes, with male students benefiting and female students suffering (Xie and Liu, 2023). The absence of significant gender differences in logical thinking tasks suggests that both males and females possess comparable capabilities in this area, with any observed variations likely stemming from external factors rather than innate differences.

In connection to Hypothesis #2, writers stated as follows. According to research, students' performance on logical thinking tests can be influenced by their age, with older students frequently exhibiting superior skills in comparison to their younger colleagues (Pellizzari and Billari, 2012; Navarro et al., 2015). This trend is attributed to cognitive development and increased educational exposure over time. For the case in this study, the age difference between the two groups is only a difference of days to months.

A study highlighted in Dwyer (2017) on the web Psychology Today found that mature students, averaging 42 years of age, showed significant improvement in critical thinking abilities over time compared to younger students, who averaged 19 years. Interestingly, the younger students initially outperformed the older ones before any critical thinking training was administered (Dwyer, 2017). The concept of the Relative Age Effect (RAE) further illustrates how older students within the same academic cohort often exhibit better academic performance. This phenomenon is particularly evident in younger students and is attributed to differences in experiences and maturation (Navarro et al., 2015).

However, findings are not entirely consistent across all studies. Some research indicates that neither age nor gender significantly affects performance on logical and lateral thinking tasks among secondary-level science students (Cassar and Musumeci, 2016). While older students may have advantages in logical thinking tasks due to cognitive maturation and accumulated educational experiences, the relationship between age and logical thinking performance is complex and can be influenced by various factors, including individual differences and specific educational contexts.

In connection to Hypothesis #3, writers stated as follows. Research indicates that the educational attainment of parents significantly influences their children's performance on logical thinking tasks and overall academic success. Higher parental education levels often correlate with enhanced cognitive development and critical thinking abilities in students. A study published in web of Psychology Today found that mature students, averaging 42 years of age, showed significant improvement in critical thinking abilities over time compared to younger students, who averaged 19 years. Interestingly, the younger students initially outperformed the older ones before any critical thinking training was administered (Dwyer, 2017).

Furthermore, the Columbia County Longitudinal Study demonstrated that parents' educational levels when their children were 8 years old significantly predicted the children's educational and occupational success 40 years later (Dubow et al., 2009). Additionally, a research has been published in 2022 by Tamayo Martinez suggests that higher parental education is associated with better cognitive outcomes in children, including enhanced logical reasoning skills (Tamayo Martinez et al., 2022). In summary, students with parents who have attained higher levels of education often exhibit superior performance on logical thinking tasks. This correlation underscores the importance of parental education in fostering cognitive development and academic achievement in children.

In connection to Hypothesis #4, writers stated as follows. Success in solving logical tasks is influenced by both the inherent characteristics of the tasks and the mathematical context in which they are presented. Students' ability to solve problems is greatly impacted by the intricacy of the language and numerical data in mathematical word problems. The success of primary school-aged children in completing mathematical word problems is linked to both language and numerical task characteristics, according to a comprehensive study and meta-analysis (Vessonen et al., 2024).

Logical reasoning can be affected by the way instructions are written. Children's performance in deductive and logical tasks can be improved by pragmatic alterations of task instructions, according to research, indicating the importance of context and clarity in instructions (Bagassi et al., 2020). Improved logical reasoning abilities are frequently linked to mathematical instruction. More mathematical training was linked to improved performance on tasks requiring logical and reasonable reasoning, according to a study that tested participants with different degrees of mathematical expertise on a variety of reasoning tasks (Cresswell and Speelman, 2020).

How mathematical problems are represented—whether through textual formats or graphs—has a significant impact on how people think through and resolve issues. Good representation can improve understanding and the effectiveness of problem-solving (Siefer et al., 2021). To conclude, performance outcomes are significantly influenced by the particular characteristics of logical tasks as well as the mathematical context in which they are encountered. Designing more effective teaching resources and tests that meet the needs of a wide range of learners can be made easier with an understanding of these variables. Both the tasks' intrinsic qualities and the setting in which they are given have an impact on how well logical problems are solved.

External factors, including the learning environment and cultural context, can affect reasoning performance. For instance, the presence of distractions or the cultural relevance of the task content can either impede or enhance logical reasoning abilities. In conclusion, both the specific attributes of logical tasks and the contexts in which they are encountered play pivotal roles in determining performance outcomes. Understanding these factors can aid in designing more effective educational tools and assessments that cater to diverse learning needs.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

Kodirun: Conceptualization, Data curation, Formal analysis, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. Kadir: Conceptualization, Funding acquisition, Methodology, Project administration, Writing – review & editing, Data curation, Formal analysis. Busnawir: Conceptualization, Formal analysis, Funding acquisition, Methodology, Validation, Writing – review & editing, Data curation. WI: Data curation, Investigation, Project administration, Validation, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Acknowledgments

The writers would acknowledge the contributions of teachers of senior and vocational school that aided the efforts of the authors.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1493737/full#supplementary-material

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