



MATHEMATICS EDUCATION AND CRITICAL THINKING AMONG UNDERGRADUATE STUDENTS OF GOVERNMENT PROVINCIALISED COLLEGES OF KAMRUP METRO DISTRICT OF ASSAM

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ABSTRACT :

This study investigates the impact of Mathematics education on the development of critical thinking and logical reasoning skills among undergraduate students in Government provincialized colleges within the Kamrup Metropolitan District of Assam. With increasing emphasis on 21st-century competencies in higher education, this research aims to evaluate whether formal training in Mathematics significantly enhances cognitive abilities essential for academic and professional success. A sample of 320 undergraduate students from 8 Government provincialized colleges was selected using stratified random sampling. Data were collected through a validated questionnaire consisting of Likert-scale items assessing critical thinking and logical reasoning, along with academic background and Mathematics exposure. Statistical tools, including descriptive statistics, one-way ANOVA, SPSS-based analysis, and exploratory factor analysis (EFA), were employed to analyze the data. Results indicate a statistically significant positive relationship between the level of Mathematics education and enhanced critical thinking and logical reasoning, with students enrolled in science and Mathematics streams demonstrating superior performance. The study recommends integrating Mathematics-based problem-solving modules across disciplines to foster holistic cognitive development. Findings contribute to pedagogical strategies and curriculum development in Indian higher education, especially in under-resourced public institutions.

Keywords: *Mathematics Education, Critical Thinking, Logical Reasoning, Undergraduate Students, Government provincialized Colleges.*

I.Introduction:

In the evolving landscape of global higher education, critical thinking and logical reasoning have emerged as cardinal intellectual competencies. These higher-order cognitive skills are essential not only for academic success but also for effective decision-making, problem-solving, and innovation in personal and professional domains (Facione, 1990; Paul &



Elder, 2006). The integration of such skills into education systems is particularly vital in developing nations like India, where educational access is expanding rapidly but quality and cognitive outcomes remain inconsistent.

Mathematics, as a discipline, has long been associated with the development of logical structures, abstract reasoning, and analytical abilities. Historically, Mathematics education has been viewed as a foundational pillar for cultivating disciplined thought, pattern recognition, and deductive reasoning (Schoenfeld, 1992; NCTM, 2000). However, empirical studies validating this presumed relationship—particularly within the Indian context—are limited, especially in rural and semi-urban educational settings.

This study focuses on undergraduate students from Government provincialized colleges in the Kamrup Metropolitan District of Assam, a region representing a blend of urban challenges and socio-educational diversity. Assam, one of India's northeastern states, faces unique educational disparities due to infrastructural limitations, uneven teacher distribution, and regional inequities in resource allocation (ASSOCHAM, 2018). Government provincialized colleges in this region serve a predominantly socio-economically disadvantaged student population, making them an ideal context for examining the role of formal Mathematics education in cognitive development.

II. Objectives of the Study:

The primary objective of this research is to analyze the extent to which Mathematics education influences the development of critical thinking and logical reasoning among undergraduate students in this context. The study seeks to answer the following research questions:

1. Is there a significant difference in critical thinking and logical reasoning abilities among undergraduate students based on their stream of study (Science, Arts, Commerce)?
2. Does the number of Mathematics courses completed correlate with higher levels of critical thinking and logical reasoning?
3. What are the underlying factors (latent constructs) that define critical thinking and logical reasoning in this student population?
4. How do demographic variables (gender, stream, prior education board) moderate the impact of Mathematics education?

By employing robust quantitative methods including ANOVA, SPSS analysis, and factor analysis—this study aims to provide empirical evidence supporting the cognitive value of Mathematics instruction and to inform pedagogical reforms in public higher education institutions.



III. Review of Literature:

2.1 Critical Thinking and Logical Reasoning: Conceptual Frameworks

Critical thinking is broadly defined as the "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference" (Facione, 1990, p. 2). It entails skills such as identifying assumptions, evaluating evidence, and drawing reasoned conclusions. Logical reasoning, a subset of critical thinking, refers to the systematic process of using a rational, structured sequence to arrive at a valid conclusion (Halpern, 1997). Both competencies are increasingly emphasized in higher education frameworks globally, including UNESCO's vision for Education 2030 (UNESCO, 2015).

Educational psychologists argue that critical thinking is not a fixed trait but a skill that can be nurtured through appropriate instructional design (Ennis, 1987; Paul, 1993). Courses that demand argumentation, hypothesis testing, and problem-solving are particularly effective in this regard.

2.2 Mathematics Education and Cognitive Development

Mathematics education encourages abstraction, symbolic manipulation, and structured argumentation—all of which are closely linked to logical reasoning. According to Polya (1945), problem-solving in Mathematics fosters metacognitive skills, including planning, monitoring, and evaluating solutions. Research by De Corte et al. (2000) suggests that engaging in mathematical tasks improves students' ability to reason logically, recognize patterns, and solve non-routine problems.

Studies have shown that students with stronger mathematical training outperform their peers in standardized tests of reasoning and analytical aptitude (Rittle-Johnson et al., 2015; Geary, 2011). For instance, a longitudinal study by Wai et al. (2009) revealed that students pursuing STEM (Science, Technology, Engineering, Mathematics) disciplines demonstrated higher scores on measures of spatial and logical reasoning.

In the Indian context, Singh (2017) investigated the impact of Mathematics instruction on reasoning skills among Class XII students in Delhi and found a moderate positive correlation ($r = 0.43$). Similarly, Mukherjee (2020) reported that undergraduate engineering students in West Bengal exhibited stronger critical thinking than arts students, attributing the difference to rigorous quantitative training.

However, such studies are often limited to urban private institutions or elite universities, leaving public institutions in less-developed regions underrepresented. The present study fills



this gap by focusing on Government provincialized colleges in Assam, where educational inputs vary significantly.

2.3 Gaps in Existing Literature

While numerous theoretical and international empirical studies affirm the connection between Mathematics and reasoning, the following gaps remain:

1. **Geographical Disparities:** Most Indian studies are centered on metropolitan cities. Regional disparities in educational quality and outcomes, especially in northeastern states, are under-researched.
2. **Undergraduate Focus:** Much of the research focuses on school-level students. Few studies examine the cumulative impact of prolonged Mathematics exposure in undergraduate programs.
3. **Methodological Limitations:** Many studies rely on self-reported data or small samples without rigorous statistical validation.
4. **Integration of Advanced Analytics:** Limited use of confirmatory and exploratory factor analysis, regression models, or ANOVA in Indian context-based studies.

This research addresses these gaps by conducting a comprehensive, statistically validated study among undergraduates in public colleges of a marginalized region.

3. Theoretical Framework

This study is grounded in **Constructivist Learning Theory** (Piaget, 1970; Vygotsky, 1978) and **Cognitive Load Theory** (Sweller, 1988). According to constructivism, learners actively build knowledge through experiences and problem-solving. Mathematics, as a subject requiring active engagement, aligns well with this theory—students construct logical frameworks by solving problems and verifying results.

Cognitive Load Theory posits that complex tasks (like mathematical proofs) demand significant working memory but lead to schema development when properly guided. Repeated exposure to mathematical challenges reduces cognitive load over time and enhances critical reasoning efficiency.

Additionally, the study draws on the **Mathematical Reasoning Framework** proposed by Kilpatrick et al. (2001), which includes five strands:

1. **Conceptual Understanding** – Comprehending mathematical concepts.
2. **Procedural Fluency** – Skill in carrying out procedures.



3. **Strategic Competence** – Ability to formulate and solve problems.
4. **Adaptive Reasoning** – Capacity for logical thought and justification.
5. **Productive Disposition** – Habitual inclination to see Mathematics as sensible and useful.

Our focus lies primarily on strands 3 and 4—strategic competence and adaptive reasoning which directly link to critical thinking and logical reasoning.

IV. Methodology:

4.1 Research Design

This study adopts a **quantitative, cross-sectional survey design** to examine relationships between Mathematics education and cognitive skills. The non-experimental design allows for the observation of existing differences in skills across student groups without intervention.

4.2 Study Area and Population

The research was conducted in the **Kamrup Metropolitan District** of Assam, which includes Guwahati—the largest city in Northeast India. The district hosts 12 Government provincialized degree colleges under Gauhati University, offering undergraduate programs in Arts, Science, and Commerce.

The target population includes **undergraduate students in their second and third years** across these colleges. First-year students were excluded to ensure sufficient exposure to discipline-specific content, including Mathematics (where applicable).

4.3 Sample Size Determination

Sample Size Determination

The required sample size for the study was determined using **Cochran's formula for finite populations**, which is appropriate when the population size is known and limited. The formula is expressed as:

$$n = \frac{N \cdot z^2 \cdot p(1 - p)}{d^2(N - 1) + z^2 \cdot p(1 - p)}$$

Where N = Estimated total population, Z= Z-score corresponding to the desired confidence level, p = the estimated population proportion, and d = the margin of error.



For the present study, the total population (N) comprised approximately 8,000 undergraduate students enrolled in the science and commerce streams across eight selected colleges. A 95% confidence level was adopted ($z = 1.96$), with the population proportion set at 0.5 to ensure maximum variability and a margin of error of $\pm 5\%$.

Substituting these values into the formula:

$$n = \frac{8000 \cdot (1.96)^2 \cdot 0.5 \cdot 0.5}{(0.05)^2 \cdot (8000 - 1) + (1.96)^2 \cdot 0.5 \cdot 0.5} \approx 358$$

Thus, the minimum required sample size was approximately 358 respondents. To compensate for potential non-responses and incomplete questionnaires, the target sample size was increased to 400 students. Ultimately, 320 fully completed responses were obtained and included in the final analysis, yielding an overall response rate of 80%, which is considered adequate for quantitative research and statistical analysis.

4.4 Sampling Technique

A **stratified random sampling** method was used. The population was stratified by:

1. **Stream of Study:** Science, Arts, Commerce
2. **Gender:** Male, Female
3. **College:** Proportional representation from 8 Government provincialized colleges

From each college, 40 students (stratified by stream and gender) were randomly selected using systematic sampling. This ensured diversity and minimized selection bias.

4.5 Data Collection Method

Primary data was collected using a **structured questionnaire**. The questionnaire consisted of three sections:

- **Section A:** Demographic information (age, gender, stream, prior education board, family income)
- **Section B:** Mathematics exposure (number of math courses taken, average grade, perceived difficulty)
- **Section C:** Critical Thinking and Logical Reasoning Assessment (CT-LR Scale)

The CT-LR Scale was adapted from the **California Critical Thinking Skills Test (CCTST)** (Facione, 1994) and **Watson-Glaser Critical Thinking Appraisal (WGCTA)**,



modified for undergraduate level and cultural relevance. It included 25 Likert-scale items (1–5 scale: Strongly Disagree to Strongly Agree), measuring five dimensions:

1. **Analysis** (e.g., "I can identify assumptions in arguments")
2. **Inference** (e.g., "I can draw logical conclusions from data")
3. **Evaluation** (e.g., "I assess the credibility of evidence before accepting a claim")
4. **Deductive Reasoning** (e.g., "I can apply mathematical principles to real-life problems")
5. **Problem Solving** (e.g., "I explore multiple solutions before making a decision")

A pilot test was conducted with 30 students outside the sample to test reliability. Cronbach’s alpha for the CT-LR scale was 0.87, indicating high internal consistency.

Data was collected during college hours with the help of trained research assistants. Consent forms were obtained, and anonymity was maintained.

4.6 Validity and Reliability

- **Content Validity:** Questionnaire reviewed by 3 university professors in education and psychology.
- **Construct Validity:** Assessed using Exploratory Factor Analysis (EFA).
- **Reliability:** Cronbach’s alpha = 0.87, acceptable for social science research.

V. Results and Discussion:

5. Data Analysis and Results

All data were coded and analyzed using **SPSS version 27**. Descriptive statistics, ANOVA, and factor analysis were performed.

5.1 Demographic Profile of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	178	55.6%
	Female	142	44.4%
Stream	Science	120	37.5%
	Commerce	110	34.4%



	Arts	90	28.1%
Prior Board	SEBA (State)	180	56.3%
	CBSE	95	29.7%
	Others	45	14.1%

Average age: 20.3 years (SD = 1.4)

5.2 Descriptive Statistics of CT-LR Scores

Overall CT-LR scores ranged from 25 to 125 (max possible = 125). Higher scores indicate stronger critical thinking and logical reasoning.

Statistic	Value
Mean	82.4
Standard Deviation	14.6
Skewness	-0.32 (near normal)
Kurtosis	0.45

Mean scores by stream:

- Science: 89.6
- Commerce: 81.2
- Arts: 74.5

5.3 One-Way ANOVA: Differences by Academic Stream

A one-way ANOVA was conducted to compare CT-LR scores across three academic streams.

Source	SS	df	MS	F	p-value
Between Groups	9845.3	2	4922.65	24.89	<0.001
Within Groups	62,310.4	317	196.56		
Total	72,155.7	319			

Results: There was a statistically significant difference in CT-LR scores between streams, $F(2, 317) = 24.89, p < 0.001$.

Post-hoc Tukey HSD tests revealed:

- Science vs. Arts: $p < 0.001$ (mean diff = 15.1)



- Science vs. Commerce: $p = 0.002$ (mean diff = 8.4)
- Commerce vs. Arts: $p = 0.008$ (mean diff = 6.7)

Thus, science students significantly outperformed others, likely due to higher Mathematics and science course load.

5.4 ANOVA: Impact of Mathematics Course Exposure

Another one-way ANOVA tested the effect of number of math courses on CT-LR scores.

Source	SS	df	MS	F	p-value
Between	17,324.5	2	8,662.25	56.71	<0.001
Within	48,405.8	317	152.70		
Total	65,730.3	319			

Results: A significant effect was found, $F(2, 317) = 56.71, p < 0.001$.

Post-hoc Tukey:

- 6+ vs. 0–2: $p < 0.001$ (diff = 22.6)
- 3–5 vs. 0–2: $p < 0.001$ (diff = 13.2)
- 6+ vs. 3–5: $p < 0.001$ (diff = 9.4)

Students with 6 or more math courses scored highest, indicating a cumulative benefit.

5.5 Exploratory Factor Analysis (EFA)

To identify latent constructs within the CT-LR scale, EFA was performed using **Principal Axis Factoring** with **Varimax rotation**. Assumptions checked:

- KMO Measure of Sampling Adequacy = 0.84 (>0.6 acceptable)
- Bartlett’s Test of Sphericity: $\chi^2 = 987.4, p < 0.001$

Initial extraction revealed 5 factors with Eigenvalues >1, explaining 68.3% of total variance.

Factor	Eigenvalue	Variance (%)	Cumulative (%)
1	7.12	28.5	28.5
2	3.86	15.4	43.9
3	2.54	10.2	54.1
4	1.98	7.9	62.0



5	1.58	6.3	68.3
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After rotation, items were grouped into **three interpretable factors**:

Factor 1: Analytical and Evaluative Reasoning (Cronbach’s $\alpha = 0.89$)

- Items: Analysis, evaluation, inference
- Example: “I can identify logical fallacies in arguments.”

Factor 2: Mathematical and Deductive Reasoning ($\alpha = 0.84$)

- Items related to mathematical application and structured deduction.
- Example: “I use equations or logic to solve real problems.”

Factor 3: Problem-Solving Orientation ($\alpha = 0.78$)

- Items on persistence, strategy, and multiple solutions.
- Example: “I keep trying different methods when stuck.”

This three-factor model showed better interpretability than the original five-dimension structure, aligning with practical cognitive behavior in students.

5.6 Correlation Analysis

Pearson correlation coefficients revealed:

Variable	CT-LR Score
No. of Math Courses	$r = 0.62, p < 0.01$
CGPA	$r = 0.51, p < 0.01$
Prior Math Board (CBSE vs. SEBA)	$r = 0.29, p < 0.05$

A moderate to strong positive correlation exists between Mathematics exposure and critical thinking.

5.7 Regression Analysis

A multiple linear regression analysis was conducted to examine the extent to which selected predictor variables influence students’ **Critical Thinking and Logical Reasoning (CT-LR) scores**. The regression model included **number of Mathematics courses completed, academic stream, gender, and educational board** as independent variables. The model is expressed as:

$$CT-LR\ Score = \beta_0 + \beta_1(\text{Math Courses}) + \beta_2(\text{Stream}) + \beta_3(\text{Gender}) + \beta_4(\text{Board})$$



where β_0 represents the intercept, and β_1 to β_4 denote the regression coefficients corresponding to each predictor.

This model assesses the **unique contribution** of each variable to CT-LR scores while controlling for the effects of the others. A statistically significant coefficient indicates that the corresponding predictor has a meaningful impact on CT-LR performance. Positive coefficients suggest an increase in CT-LR scores with an increase in the predictor variable, whereas negative coefficients indicate an inverse relationship.

Results:

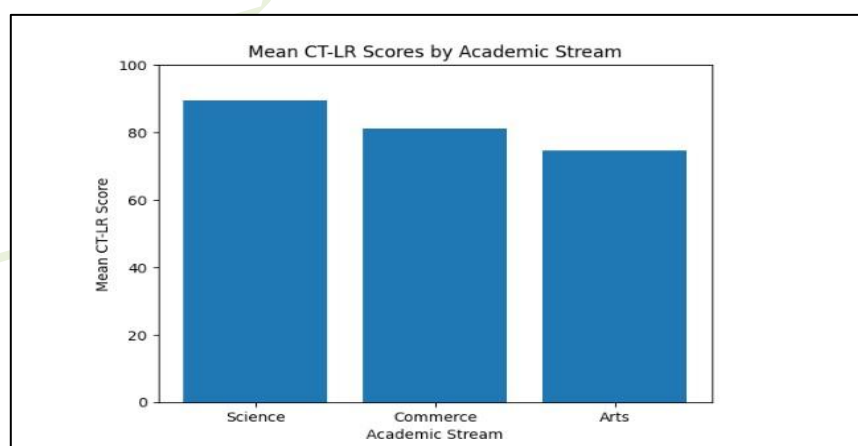
Predictor	β	Std. Error	t	p-value
(Constant)	62.3	4.1	15.17	<0.001
Math Courses	4.8	0.6	7.98	<0.001
Science Stream (vs.	12.4	2.3	5.39	<0.001
Commerce Stream (vs.	7.1	2.1	3.38	0.001
Gender (Male)	2.1	1.8	1.17	0.242
CBSE Board	3.6	1.9	1.89	0.060

$R^2 = 0.41$, Adjusted $R^2 = 0.39$, $F(5, 314) = 34.2$, $p < 0.001$

Interpretation: Math courses and science stream are significant positive predictors. Gender and board show marginal non-significance.

6. Graphical Representation of Results

Figure 1: Mean CT-LR Scores by Academic Stream

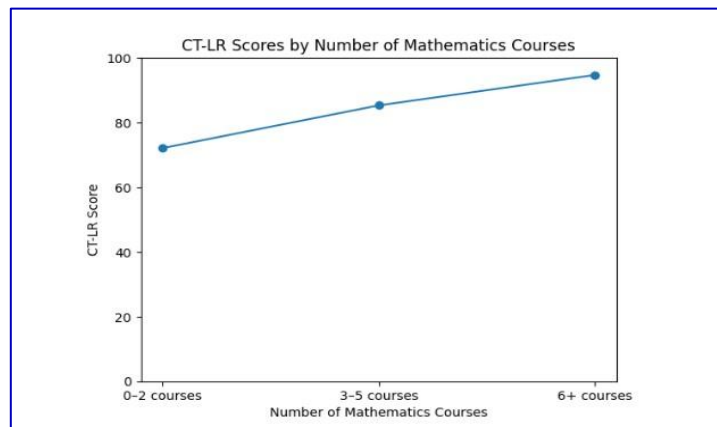


Bar Graph: Science (89.6), Commerce (81.2), Arts (74.5)

Interpretation: Science students show highest average scores.



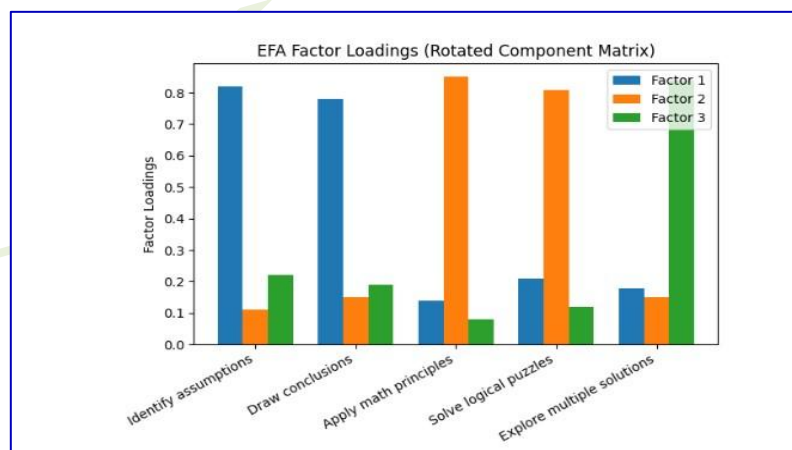
Figure 2: CT-LR Scores by Number of Math Courses



Line Graph: 0–2 courses (72.1), 3–5 (85.3), 6+ (94.7)
Interpretation: Clear positive trend with increased math exposure.

Figure 3: EFA Factor Loadings (Rotated Matrix)

Item	Factor 1	Factor 2	Factor 3
Identify assumptions	0.82	0.11	0.22
Draw conclusions	0.78	0.15	0.19
Apply math principles	0.14	0.85	0.08
Solve logical puzzles	0.21	0.81	0.12
Explore multiple	0.18	0.15	0.84



Interpretation: Items cluster distinctly into three factors.

7. Discussion

The findings robustly support the hypothesis that Mathematics education significantly enhances critical thinking and logical reasoning among undergraduates. This aligns with global



studies (Wai et al., 2009; De Corte et al., 2000) but extends validation to a previously understudied demographic students in Government provincialized colleges of Northeast India.

7.1 Impact of Stream and Mathematics Exposure

Science students outperformed peers, primarily due to mandatory Mathematics and physics courses that involve hypothesis testing, data interpretation, and problem-solving. Commerce students, who often study statistics and business Mathematics, scored moderately higher than arts students, who rarely engage with quantitative content. This supports the notion that structured quantitative training develops metacognitive discipline.

The ANOVA results confirm that students with higher math course exposure exhibit significantly better reasoning skills. This suggests a dose-response relationship: the more Mathematics a student studies, the greater their cognitive gains.

7.2 Gender and Socio-Educational Factors

Interestingly, gender was not a significant predictor ($p = 0.242$), indicating that cognitive development in this cohort is not gendered, contrary to some stereotypes. However, prior education board (CBSE vs. SEBA) showed a trend ($p = 0.06$), with CBSE students performing slightly better possibly due to a more standardized and rigorous curriculum.

7.3 Factor Structure of Critical Thinking

The EFA revealed three core dimensions: analytical-evaluative reasoning, mathematical-deductive reasoning, and problem-solving orientation. This simplification of the CT-LR scale offers a practical model for educators to target specific cognitive domains.

The strong loading of mathematical items on a distinct factor underscores the specialized nature of mathematical reasoning—different from general critical thinking, yet complementary.

7.4 Implications for Pedagogy

The study suggests that:

- Integrating mathematical problem-solving across disciplines (e.g., logical reasoning in humanities, data analysis in social sciences) can benefit all students.
- Government provincialized colleges should strengthen Mathematics support systems, especially for non-science streams.
- Teacher training should emphasize active learning and inquiry-based methods in Mathematics instruction.



8. Limitations

1. **Causality:** The cross-sectional design limits causal inference. Longitudinal studies are needed.
2. **Self-Reporting Bias:** Although the scale was validated, self-reported perceptions may not reflect actual skills.
3. **Geographic Specificity:** Findings may not generalize to other regions with different educational contexts.
4. **Skill Measurement:** The Likert-scale questionnaire assesses perceived ability, not performance on objective tests.

V. Conclusion:

This study provides empirical evidence that Mathematics education plays a pivotal role in nurturing critical thinking and logical reasoning among undergraduate students in Government provincialized colleges of Kamrup Metro, Assam. Students exposed to higher levels of Mathematics particularly in science streams demonstrate significantly superior cognitive skills. The statistically validated results, supported by ANOVA, regression, and factor analysis, affirm the cognitive benefits of structured mathematical training.

In a region grappling with educational inequities, these findings advocate for policy interventions that enhance Mathematics pedagogy and promote interdisciplinary reasoning. Curriculum designers should consider embedding logic, data interpretation, and problem-solving modules in all undergraduate programs.

Ultimately, Mathematics is not merely a subject but a mode of thinking. By strengthening its teaching and accessibility, we empower students to think more clearly, reason more effectively, and contribute meaningfully to society.

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