

Mathematical Reasoning and Critical Thinking using Data-Science-Infused Assessment of Grade 10 Students

Noriel M. Britania

Carlos Hilado Memorial State University

Talisay City, Negros Occidental, Philippines

DOI: <https://doi.org/10.47772/IJRISS.2026.100800931>

Received: 4 September 2026; Accepted: 9 September; Published: 21 September 2026

ABSTRACT

Mathematical reasoning and critical thinking are fundamental skills in authentic mathematical contexts. This descriptive- correlational study determined the mathematical reasoning and critical thinking of 395 out of 1,050 randomly selected Grade 10 students using G*power from a selected public secondary school in the northern part of Negros Occidental during the School Year 2025–2026. A 40-item researcher-developed, validated, and reliability-tested instrument was used to gather data. Descriptive statistics, One-way Analysis of Variance (ANOVA), Tukey's HSD, Spearman's rank-order correlation, and simple linear regression were employed. Findings revealed low proficient levels of mathematical reasoning and critical thinking. However, students with low socio-economic status, moderate access to digital resources, and average and below-average academic performance obtained not proficient levels of critical thinking. Significant differences were found in mathematical reasoning according to socio-economic status between high and low groups and academic performance between high and average groups. Significant strong positive relationship existed between mathematical reasoning and critical thinking in which mathematical reasoning significantly predicted students' critical thinking. The findings support existing literature on persistent challenges in higher-order thinking and emphasize the value of data-science-infused assessments. Accordingly, Project MRiCT was developed as an instructional intervention to strengthen students' mathematical reasoning and critical thinking.

INTRODUCTION

Background of the Study

Mathematical reasoning and critical thinking are fundamental competencies that enable students to solve problems, analyze information, justify decisions, and apply mathematics in authentic situations. International frameworks such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) emphasize these higher-order thinking skills as essential for students to interpret, evaluate, and apply mathematical knowledge beyond routine computation (Mullis et al., 2020; OECD, 2023).

Recognizing these priorities, the Philippine Department of Education strengthened classroom assessment through the MATATAG Curriculum. Department of Education Order No. 15, s. 2026 – Revised Guidelines on Classroom Assessment, Grading System, and Awards and Recognition for the K to 12 Basic Education Program promotes authentic assessment that develops mathematical reasoning, critical thinking, problem-solving, communication, and data literacy by engaging students in interpreting information, evaluating evidence, and justifying conclusions.

Despite these reforms, Filipino students continue to perform poorly in mathematics. In PISA 2022, the Philippines obtained an average mathematics score of 355, substantially below the OECD average of 472, while TIMSS findings likewise reveal persistent difficulties in reasoning, analyzing mathematical relationships, and solving non-routine problems (Mullis et al., 2020; OECD, 2023). These results strongly indicate that traditional assessments, which primarily emphasize procedural knowledge and routine computation, may not adequately measure higher-

order thinking skills.

Thus, one promising approach is data-science-infused assessment, which integrates authentic datasets, data visualization, interpretation, and evidence-based decision-making into mathematics assessment tasks (Engel et al., 2020). By requiring students to analyze real-world data, recognize patterns, and justify conclusions using evidence, these assessments foster mathematical reasoning, critical thinking, and data literacy.

Although previous studies have highlighted the benefits of contextualized and inquiry-based assessments, few have simultaneously examined mathematical reasoning and critical thinking through data-science-infused assessment in the Philippine context. Hence, this study investigates the level, differences and relationship of the mathematical reasoning and critical thinking of Grade 10 students using data-science-infused assessments to provide evidence that can support innovative assessment practices, strengthen the implementation of the MATATAG Curriculum, and guide instructional interventions that enhance higher-order thinking skills.

Statement of the Problem

This study aimed to determine the relationship between mathematical reasoning and critical thinking using data-science-infused assessments of Grade 10 students in one of the public high schools in the northern part of Negros Occidental during the School Year 2025–2026.

Specifically, this study sought to answer the following questions:

1. What is the level of mathematical reasoning using data-science-infused assessments when taken as a whole and when grouped according to:
 - a. socio-economic status;
 - b. access to digital resources; and
 - c. academic performance?
2. What is the level of critical thinking using data-science-infused assessments when taken as a whole and when grouped according to the aforementioned variables?
3. Is there a significant difference in the level of mathematical reasoning using data-science-infused assessments when grouped according to:
 - a. socio-economic status;
 - b. access to digital resources; and
 - c. academic performance?
4. Is there a significant difference in the level of critical thinking using data-science-infused assessments when grouped according to the aforementioned variables?
5. Is there a significant relationship between mathematical reasoning and critical thinking using data-science-infused assessments?
6. Does mathematical reasoning significantly predict critical thinking using data-science-infused assessment of Grade 10 students?
7. Based on the findings of the study, what instructional intervention plan may be proposed to enhance the

mathematical reasoning and the critical thinking of the students?

Hypotheses

The following hypotheses were tested in this study.

1. There is no significant difference in the level of mathematical reasoning using data-science-infused assessments when grouped according to:
 - a. socio-economic status,
 - b. access to digital resources, and
 - c. academic performance.
2. There is no significant difference in the level of critical thinking using data-science-infused assessments when grouped according to aforementioned variables.
3. There is no significant relationship between mathematical reasoning and critical thinking using data-science-infused assessments.
4. Mathematical reasoning does not predict the critical thinking using data-science-infused assessments of Grade 10 students.

Theoretical Framework

This study was anchored on Cognitive Constructivist Theory (Piaget, 1970; Schunk, 2020) and is further supported by Evidence-Centered Design (ECD) (Mislevy et al., 2003; Mislevy, 2018) and the OECD Data Literacy Framework (OECD, 2019, 2023). Collectively, these frameworks provided a comprehensive foundation for understanding how data-science-infused assessment offers authentic opportunities for students to demonstrate mathematical reasoning and critical thinking.

Cognitive Constructivist Theory posits that students actively construct knowledge through meaningful interactions with their environment. According to Piaget (1970), as discussed by Schunk (2020), learning occurred as individuals assimilate new information into existing cognitive structures and accommodate these structures when confronted with new experiences. Within the context of this study, data-science-infused assessment provided authentic mathematical situations that require students to interpret real-world data, analyze quantitative relationships, and construct evidence-based conclusions, thereby creating meaningful opportunities for students to demonstrate mathematical reasoning and critical thinking.

Complementing this learning perspective is ECD, which explains how assessments should be intentionally designed to generate observable evidence of students' knowledge, reasoning, and cognitive processes and emphasized assessment tasks that require students to analyze information, interpret evidence, justify decisions, and communicate logical arguments (Mislevy et al., 2003; Mislevy, 2018). ECD provided the theoretical basis for assessing mathematical reasoning and critical thinking through evidence-based performance, as data-science-infused assessment tasks require students to solve authentic mathematical problems using real-world datasets. The OECD Data Literacy Framework further strengthened the theoretical foundation by identifying the competencies students need to function effectively in a data-driven society. These competencies included collecting, interpreting, analyzing, evaluating, and communicating data responsibly to support informed decision-making (OECD, 2019, 2023). Data-science-infused assessment aligned with these competencies by engaging students in authentic investigations that require interpretation of quantitative information, recognition of patterns, evaluation of evidence, and formulation of reasoned conclusions. These processes corresponded closely to the mathematical

reasoning and critical thinking competencies examined in the present study.

Collectively, these frameworks established a coherent theoretical foundation for the study. Cognitive Constructivist Theory explains how students actively construct mathematical understanding through authentic experiences, Evidence-Centered Design provided the assessment framework for eliciting observable evidence of higher-order thinking, the OECD Data Literacy Framework defined the competencies required for interpreting and using quantitative information. Together, these frameworks supported the use of data-science-infused assessment as an authentic context for examining Grade 10 students' mathematical reasoning and critical thinking.

Conceptual Framework

The conceptual framework of this study illustrated the sequence through which the variables were examined within the context of a data-science-infused assessment. In this study, the data-science-infused assessment served as the assessment context through which Grade 10 students' mathematical reasoning and critical thinking were measured. The assessment consisted of authentic, data-based mathematical tasks requiring students to interpret datasets, analyze quantitative relationships, evaluate evidence, and justify conclusions using mathematical reasoning, thereby providing authentic opportunities for students to demonstrate higher-order thinking competencies.

The study determined the levels of mathematical reasoning and critical thinking among Grade 10 students and then examined whether significant differences existed when students were grouped according to socio-economic status, access to digital resources, and academic performance. These grouping variables were selected because previous literature and educational policies consistently identify them as learner-related factors associated with students' opportunities to learn, access educational resources, and mathematics achievement, making them relevant variables for examining variations in higher-order thinking skills.

The statistical relationship between mathematical reasoning and critical thinking was examined using correlation analysis. Subsequently, simple linear regression was employed to determine whether mathematical reasoning significantly predicted critical thinking. This direction of analysis was anchored in the theoretical perspective that mathematical reasoning provides the cognitive foundation for higher-order thinking by enabling learners to analyze information, construct logical arguments, justify conclusions, and evaluate evidence, core processes that support the development of critical thinking.

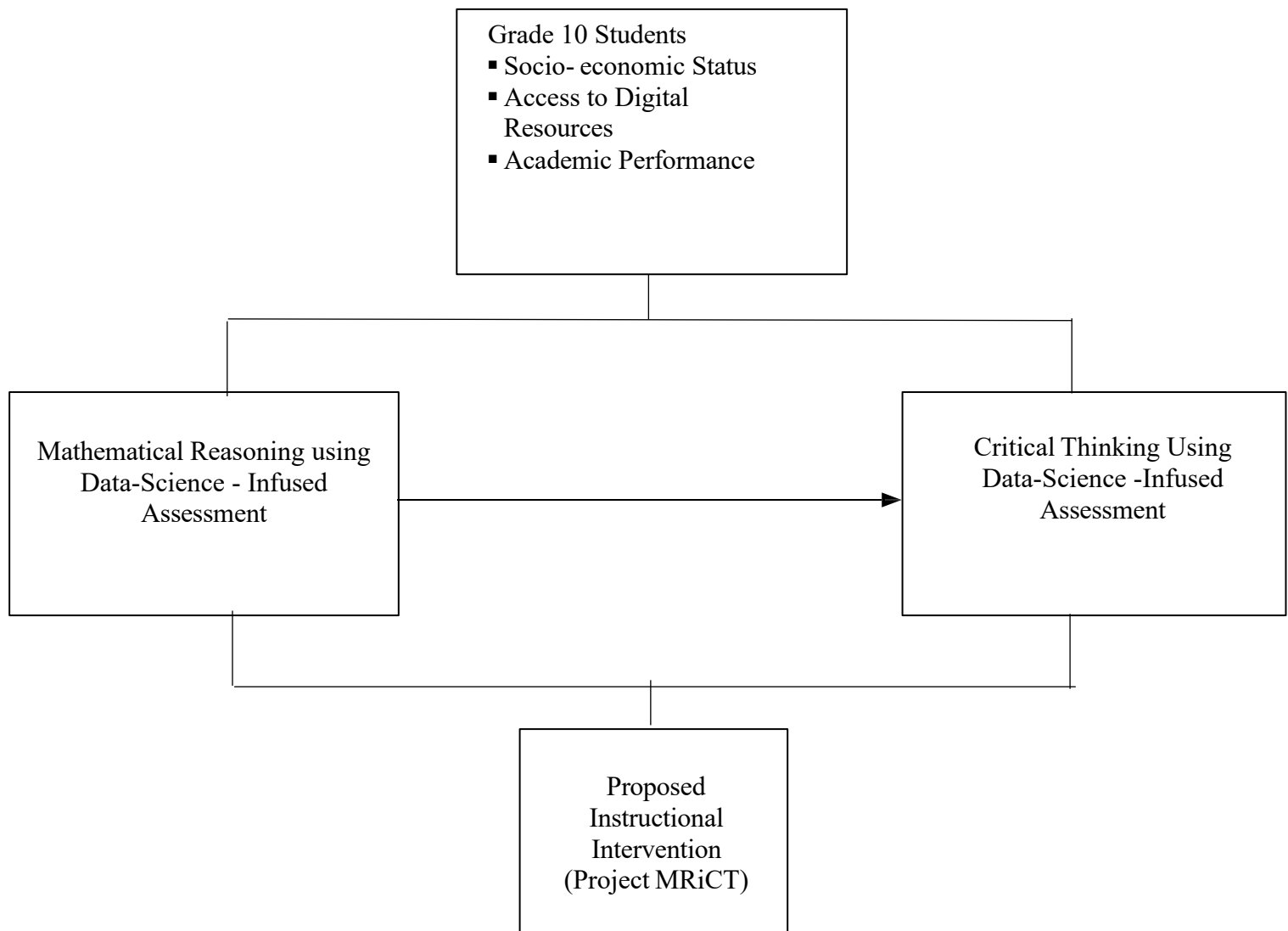
Consequently, mathematical reasoning was hypothesized to predict students' critical thinking.

Finally, the findings served as the basis for developing Project MRiCT (Mathematical Reasoning through Infused Data-Science Assessment for Critical Thinking), a proposed nine-week, inquiry-based instructional intervention that employs authentic data-science-infused assessment, Claim–Evidence–Reasoning (CER) activities, collaborative mathematical investigations, reflective learning, and differentiated instructional support to enhance students' mathematical reasoning and critical thinking.

Overall, the conceptual framework reflected the logical sequence of the study: Grade 10 students were assessed through data-science-infused assessment; the levels of mathematical reasoning and critical thinking were determined; differences across selected student characteristics were examined; the relationship between the two constructs was analyzed; mathematical reasoning was tested as a statistical predictor of critical thinking; and the findings became the basis for the proposed instructional intervention

Figure 1

Schematic Diagram Illustrating the Mathematical Reasoning and Critical Thinking using Data-Science-Infused Assessments of Grade 10 Students



Significance of the Study

This study provided empirical evidence on the mathematical reasoning and critical thinking of Grade 10 students as assessed through a data-science-infused assessment. Specifically, the study may benefit the following:

Students

The findings of this study may benefit students by providing evidence to support the integration of data-science-infused assessments into mathematics instruction. By engaging in authentic, data-based mathematical tasks that require interpreting datasets, analyzing quantitative relationships, evaluating evidence, and justifying conclusions, students are expected to strengthen their mathematical reasoning and critical thinking skills. These learning experiences promote evidence-based decision-making, problem-solving, and reflective thinking while enhancing students' ability to apply mathematics in real-world contexts. Consequently, students may become better prepared for future academic pursuits, workplace demands, and responsible participation as data-literate citizens in an increasingly data-driven society.

Mathematics Teachers

This study may offer empirical insights into the design and implementation of data-science-infused assessment tools aligned with the Grade 10 MATATAG Curriculum competencies. The results may serve as a practical guide in developing innovative, authentic, and meaningful assessments that effectively measure students' mathematical reasoning and critical thinking. Moreover, the study may support teachers in shifting from traditional assessment practices toward more inquiry-based, evidence-centered, and analytical approaches, thereby strengthening their instructional decision-making and assessment literacy. The findings may likewise inform the planning of differentiated instruction by enabling teachers to use assessment evidence to identify students' varying levels of mathematical reasoning and critical thinking, design targeted interventions, and provide appropriate instructional support that addresses diverse learning needs.

Parents

The study may help parents better understand the importance of supporting students' higher-order thinking skills beyond academic grades. By recognizing that mathematical reasoning and critical thinking are essential competencies in mathematics learning, parents may provide opportunities for students to engage in meaningful discussions, problem-solving activities, and home learning experiences that encourage reasoning, analysis, and evidence-based thinking. For example, parents may encourage their children to interpret graphs and charts from news reports, discuss household budgeting and spending decisions using numerical information, compare alternative solutions to everyday problems, or explain the reasoning behind their answers during homework and daily activities. Such experiences can reinforce classroom learning and cultivate students' ability to think critically and apply mathematical reasoning in authentic, real-life situations.

School Principal

The outcomes of this study may serve as a basis for school administrators in strengthening mathematics instruction and classroom assessment practices. The findings may guide decisions related to Learning Action Cell (LAC) sessions, in-service training (INSET), instructional supervision, and school-based intervention programs that emphasize authentic assessment, mathematical reasoning, and critical thinking. They may likewise inform resource allocation for instructional materials, assessment tools, teacher professional development, and data-science-infused learning resources that support the development of higher-order thinking skills. Furthermore, the results may assist school leaders in monitoring and evaluating the effectiveness of mathematics instructional initiatives and assessment practices, providing evidence for continuous school improvement. The findings may also serve as valuable inputs in the formulation, implementation, and evaluation of the School Improvement Plan (SIP) and other school-based programs aimed at improving mathematics achievement and promoting higher-order thinking among students.

Curriculum Implementation Division (CID) Chief

The Curriculum Implementation Division (CID) Chief may utilize the findings in planning professional development programs, curriculum support initiatives, and technical assistance that strengthen authentic assessment practices in mathematics. The results may inform the development of contextualized instructional materials, assessment exemplars, and teacher capability-building activities aligned with the goals of the MATATAG Curriculum and the provisions of DepEd Order No. 15, s. 2026, particularly in promoting competency-based classroom assessment, higher-order thinking skills, and evidence-based learning. Furthermore, the findings may support the implementation, monitoring, and continuous enhancement of division-wide mathematics programs that are responsive to national education reforms and aligned with international mathematics assessment frameworks such as PISA and TIMSS, thereby contributing to improved teaching quality and learner outcomes.

Researcher

The study may enhance the researcher's professional growth by strengthening knowledge and competencies in mathematics education, authentic classroom assessment, educational measurement, quantitative research, and evidence-based instructional planning. It also provides valuable experience in developing and validating data-science-infused assessment instruments, conducting statistical analyses, interpreting research findings, and designing instructional interventions that address identified learning needs. Furthermore, the study may deepen the researcher's competencies in assessment design, data analysis, research ethics, reflective practice, and the application of educational research to improve mathematics teaching, learning, and classroom assessment.

Future Researchers

This study may serve as a valuable reference for future investigations involving data-science-infused assessment, mathematical reasoning, and critical thinking. They may investigate additional student, instructional, and contextual variables that may account for the remaining unexplained variance. Replication studies across different grade levels, educational settings, subject areas, and geographical locations are likewise encouraged to determine the generalizability of the findings. Experimental, quasi-experimental, and mixed-methods studies may also be conducted to examine the effectiveness of interventions in providing authentic opportunities for students to demonstrate mathematical reasoning and critical thinking.

Delimitation of the Study

This study was delimited to 395 out of 1,050 Grade 10 students enrolled in a selected public secondary school in the northern part of Negros Occidental during the School Year 2025–2026. The school was selected because its large student population and diverse learner characteristics provided a suitable setting for examining mathematical reasoning and critical thinking across varied socio-economic backgrounds, levels of access to digital resources, and academic performance. Grade 10 students were chosen as the participants because they had already acquired the foundational mathematical knowledge and cognitive skills necessary to engage in data-science-infused assessment tasks. The study employed a quantitative descriptive-correlational research design and was specifically limited to determining the levels of mathematical reasoning and critical thinking, examining differences across selected grouping variables using descriptive statistics and one-way analysis of variance (ANOVA), investigating the relationship between the two constructs using Spearman's rank-order correlation, and determining whether mathematical reasoning significantly predicts critical thinking through simple linear regression analysis.

The scope of the study was confined to selected learner variables, namely socioeconomic status, access to digital resources, and academic performance, because these variables have been identified in the literature as relevant factors associated with students' opportunities to learn and mathematics achievement. Other potential influencing factors, such as students' motivation, learning styles, teacher competence, instructional strategies, classroom climate, and overall school technological infrastructure, were not included in the investigation. The study was likewise limited to the use of a researcher-developed 40-

item Data-Science-Infused Assessment Instrument consisting of multiple-choice and constructed-response items, which served solely as the assessment context for measuring students' mathematical reasoning and critical thinking through authentic, data-based mathematical tasks. The study did not compare data-science-infused assessment with other assessment approaches nor evaluate the instructional effectiveness of the assessment itself. Finally, the findings of the study are limited to the participants, research locale, research instrument, statistical procedures, and variables included in the investigation; therefore, the results should be interpreted within these specified boundaries.

Definition of Terms

For clarity and consistency, the following terms were defined conceptually and operationally as they were used in this study:

Academic Performance

The level of students' achievement in school as reflected in their academic grades (DepEd 2015).

For the purpose of this study, academic performance refers to the participants' third-quarter Mathematics grade obtained from school records and classified according to the researcher-defined categories adapted from grade intervals prescribed in DepEd Order No. 8, s. 2015.

Above Average Academic Performance. The students with grades 85%–89% and described as very satisfactory. Meets learning competencies and can apply skills with minimal guidance (DepEd 2015).

Within the context of this study, it refers to students exhibiting very good understanding of mathematical concepts, can solve problems with minimal guidance, and generally apply reasoning skills effectively.

Average Academic Performance. In its conceptual sense, it refers to students with grades 80%–84% and described as satisfactory. Meets basic learning competencies with some assistance; shows developing understanding (DepEd 2015).

In the present study, it refers to students show satisfactory comprehension of mathematical concepts, meet basic competencies, and apply reasoning skills with some guidance.

Below Average Academic Performance. This term pertains to students with grades 75%–79% and described as fairly satisfactory. Partially meets learning competencies and requires additional guidance and practice (DepEd 2015).

For this research, it refers to students demonstrate partial understanding of mathematical concepts, require additional support to meet learning competencies, and show developing reasoning skills.

High Academic Performance. The term denotes to students with grades 90%–100% and described as outstanding. Demonstrates mastery of learning competencies and can apply knowledge and skills independently (DepEd 2015).

In this study, the term refers to the performance of the students who demonstrate outstanding mastery of mathematical concepts, solve problems independently, and apply reasoning skills consistently in various tasks.

Access to Digital Resources

Within the literature, this refers to the extent to which students have access to digital devices, internet connectivity, and technology-based learning resources that support academic activities, including online learning, information retrieval, and data analysis (OECD, 2023; UNESCO, 2023).

For this study, it refers to the participants' access to digital devices, internet connectivity, and utilization of digital learning tools as determined through the demographic questionnaire. The participants were classified into three categories:

High Access. Conceptually, it refers to students who own or have regular access to multiple digital devices (computer, tablet, or smartphone), have reliable internet connectivity at home or school, and frequently use digital learning tools to support learning and complete data-related tasks (OECD, 2023; UNESCO, 2023)

For this investigation, this refers to students who have multiple functional digital devices at home, stable broadband/fiber internet, and use of digital tools daily (5-7 days/week) for learning.

Low Access. The term represents to students who have little or no access to digital devices, lack stable internet

connectivity, and rarely or never use digital learning tools, making it difficult to complete data-related or online learning tasks independently (OECD, 2023; UNESCO, 2023).

Operationally, this refers to students who have limited or no digital devices at home and no stable connection, using digital tools (1-2 days/week or less) for learning.

Moderate Access. The students who have access to at least one digital device, have intermittent or limited internet connectivity, and occasionally use digital learning tools to support learning and complete tasks involving data (OECD, 2023; UNESCO, 2023)

Within the context of this study, this refers to students who have at least one functional device and intermittent internet connectivity (mobile data or shared broadband) and use digital tools (4-3 days/week) for learning.

Critical Thinking

From a conceptual perspective, it refers to the process of purposeful and reflective judgment that enables individuals to analyze information, evaluate evidence, interpret ideas, make logical inferences, and formulate reasoned judgments Facione et al. (2020),

As applied in this study, it is measured through students' performance in tasks requiring data evaluation, comparison of solutions, decision-making, and interpretation, scored using predefined criteria.

Data-Science-Infused Assessments

The concept refers to the assessments that integrate principles of data science, including data collection, interpretation, visualization, analysis, and evidence-based decision-making within authentic learning contexts (Engel et al., 2020).

For the purpose of this study, it refers to the researcher-developed assessment instrument used in this study, consisting of authentic, contextualized mathematical tasks based on real-world datasets. The instrument served as the assessment context for measuring students' mathematical reasoning and critical thinking and comprised 40 items, including multiple-choice and constructed-response questions

Mathematical Reasoning

Based on existing literature, it refers to the ability to analyze mathematical situations, identify patterns and relationships, formulate logical arguments, justify solutions, and apply mathematical concepts to authentic contexts (Goos et al., 2019).

In this study, it is measured through students' performance in tasks required to analyze mathematical situations, identify patterns and relationships, formulate logical arguments, and justify solutions scored using predefined criteria.

Socio-Economic Status (SES)

The construct is generally understood as the economic and social position of a family, commonly determined by household income, parents' educational attainment, and occupational status (APA, 2023).

Within the context of this study, it refers to the participants' classification based on their parents' or guardians' educational attainment, occupation, and estimated monthly household income as reported in the demographic questionnaire. Following the thresholds adapted by the researcher from Philippine income classifications (PSA, 2023; Albert et al., 2024), participants were grouped into:

High Socio-Economic Status. It characterizes families with a monthly household income above ₱166,000.00, whose parents or guardians possess college or professional degrees and are employed in professional, managerial, or business-related occupations.

Students from this group generally have ample access to educational support and learning resources at home (PSA, 2023; Albert et al., 2024).

In this investigation, the term refers to students whose parents or guardians have attained at least a college degree, are employed in professional, managerial, or business-related occupations, and belong to households with an estimated monthly income of

₱166,000.00 and above as indicated in the participants' demographic profile questionnaire.

Low Socio-Economic Status. From a conceptual standpoint, low socio-economic status pertains to families with a monthly household income below ₱28,000.00, whose parents or guardians have elementary or some high school education and are employed in unskilled occupations or are unemployed. Students from this group may have limited access to educational support and learning resources at home (PSA, 2023; Albert et al., 2024).

As utilized in this study, participants were classified as having low socioeconomic status if their parents or guardians had attained elementary or junior high school education, were engaged in unskilled labor or were unemployed, and belonged to households with an estimated monthly income below ₱28,000.00, based on the information provided in the participants' demographic profile.

Middle Socio-Economic Status. In the context of socio-economic classification, middle socio-economic status describes families with a monthly household income ranging from ₱28,000.00 to ₱166,000.00, whose parents or guardians have completed secondary or vocational education and are engaged in skilled or semi-skilled occupations. Students from this group typically have moderate access to educational support at home (PSA, 2023; Albert et al., 2024).

As operationalized in this investigation, participants were categorized under middle socio-economic status if their parents or guardians had completed high school to some college education, were employed in skilled or semi-skilled occupations, and

belonged to households with an estimated monthly income ranging from ₱28,000.00 to

₱166,000.00, as reported in the participants' demographic profile questionnaire.

REVIEW OF RELATED LITERATURE

This chapter reviews literature and related studies relevant to data-science-infused assessments, mathematical reasoning, and critical thinking. The discussion examines how authentic and data-based assessment practices influence higher-order thinking skills and how these constructs relate within mathematics learning contexts. The review focuses on three major areas: (1) mathematical reasoning using data-science-infused assessments, (2) critical thinking using data-science-infused assessments, and (3) the relationship between mathematical reasoning and critical thinking. The chapter concludes with a synthesis of the reviewed literature, emphasizing converging findings, research gaps, and the relevance of the present investigation.

Mathematical Reasoning Using Data-Science-Infused Assessments of Students

Mathematical reasoning is widely recognized as one of the most essential competencies in mathematics education because it enables students to analyze situations, establish logical relationships, justify conclusions, and apply mathematical concepts to unfamiliar and authentic contexts. Rather than simply performing computational

procedures, mathematically proficient students are expected to formulate arguments, interpret quantitative evidence, evaluate alternative solution strategies, and communicate their thinking using logical justification. Contemporary mathematics education therefore views reasoning not merely as a mathematical process skill but as the foundation of conceptual understanding, problem solving, and informed decision-making (National

Council of Teachers of Mathematics [NCTM], 2018). This perspective reflects a global shift from traditional assessment practices that primarily measure procedural fluency toward assessment approaches that provide evidence of students' higher-order thinking and reasoning processes.

International assessment frameworks consistently reinforce the centrality of mathematical reasoning in developing mathematical literacy. The Programme for International Student Assessment (PISA) 2022 Mathematics Framework defines mathematical literacy as an individual's capacity to formulate, employ, and interpret mathematics across diverse real-world contexts while making sound judgments based on quantitative evidence (OECD, 2023). This framework emphasizes that successful mathematical performance extends beyond obtaining correct answers; students must demonstrate the ability to interpret information, analyze data, evaluate assumptions, and justify conclusions through coherent reasoning. Likewise, the Trends in International Mathematics and Science Study (TIMSS) 2019 Assessment Framework identifies reasoning as one of the highest cognitive domains in mathematics, requiring students to analyze relationships, generalize patterns, synthesize information, and solve non-routine problems (Mullis et al., 2020). Together, these international frameworks suggest that reasoning is most effectively assessed when students engage with authentic mathematical situations that require interpretation, explanation, and evidence-based decision-making rather than isolated computational exercises.

These international expectations closely align with recent educational reforms in the Philippines. Through Department of Education Order No. 15, s. 2026, classroom assessment under the MATATAG Curriculum is positioned as an integral component of teaching and learning that provides meaningful evidence of students' progress toward achieving curriculum standards. The policy emphasizes that assessment should measure students' ability to analyze, reason, solve problems, and apply knowledge in authentic contexts rather than merely demonstrate factual recall or procedural accuracy (DepEd, 2026). Specifically, the policy highlights that assessment for students in Key Stage 3 (Grades 7–10) should progressively cultivate analytical thinking, mathematical reasoning, problem solving, and critical evaluation through contextualized assessment tasks.

Consequently, classroom assessment is no longer viewed solely as a mechanism for assigning grades but as an opportunity to generate evidence of students' conceptual understanding and higher-order thinking.

Despite these policy directions, national evidence indicates that Philippine classrooms continue to experience significant challenges in translating curriculum expectations into classroom practice. The Second Congressional Commission on Education (EDCOM II) reported that although curriculum reforms emphasize conceptual understanding and higher-order thinking, classroom instruction and assessment frequently remain dominated by procedural exercises, factual recall, and examination-oriented practices that provide limited opportunities for students to develop analytical reasoning (EDCOM II, 2024). The commission further observed that many teachers continue to experience difficulties in designing authentic assessment tasks capable of measuring

reasoning, application, and problem solving, partly because of insufficient professional preparation, limited assessment resources, and persistent reliance on traditional testing approaches (EDCOM II, 2025). These findings suggest that strengthening students' mathematical reasoning requires not only curriculum reform but also innovations in classroom assessment capable of capturing evidence of complex cognitive processes.

One promising response to these challenges is the growing integration of data-science-infused assessments within mathematics education. Data-science-infused assessments incorporate authentic datasets, graphical representations, statistical information, and contextualized quantitative problems that require students to collect, organize, interpret, analyze, and communicate information using mathematical reasoning (Engel et al., 2020). Unlike conventional

assessments that emphasize procedural computation, these assessments present students with complex situations where multiple solution pathways may be possible, thereby requiring interpretation, justification, and evidence-based explanation. As students analyze real-world data, they engage in reasoning processes that mirror authentic mathematical practice, enabling assessment to capture deeper conceptual understanding rather than isolated procedural knowledge.

The educational value of data-science-infused assessment is supported by emerging literature on data literacy and evidence-centered assessment. Engel et al. (2020) described students' engagement with authentic datasets as involving a series of interconnected "data moves," including collecting, organizing, visualizing, interpreting, and evaluating quantitative information. These cognitive activities require students to

construct explanations, recognize patterns, and justify conclusions, thereby naturally eliciting mathematical reasoning. Similarly, Kong et al. (2022) argued that contemporary mathematics assessment should increasingly reflect the analytical demands of modern society by requiring students to interpret complex information, evaluate relationships among variables, and communicate evidence-based conclusions. Rather than treating reasoning as an isolated cognitive skill, these studies position reasoning as an outcome emerging from students' sustained interaction with authentic quantitative information.

An equally important perspective comes from Evidence-Centered Design (ECD), which provides a theoretical foundation for designing assessments capable of measuring complex competencies such as mathematical reasoning. Effective assessment begins by clearly identifying the knowledge, skills, and reasoning processes that students are expected to demonstrate before designing tasks capable of eliciting observable evidence of those competencies (Mislevy et al., 2003; Mislevy, 2018). Within this framework, assessment validity depends not simply on the correctness of students' answers but on the quality of evidence supporting inferences about their reasoning processes. Open-ended, contextualized, and inquiry-oriented assessment tasks therefore provide stronger evidence of mathematical reasoning than traditional selected-response items because they require students to explain, justify, and defend their solutions. This perspective aligns closely with current international assessment reforms, which increasingly emphasize authenticity, cognitive complexity, and meaningful evidence of learning.

Beyond providing authentic contexts for mathematical inquiry, data-science-infused assessments also align with contemporary recommendations for statistics and data science education. The Guidelines for Assessment and Instruction in Statistics Education II (GAISE II) advocate for learning experiences that require students to formulate statistical questions, collect and organize data, analyze patterns, interpret results, and communicate conclusions using evidence (Franklin et al., 2020). Rather than treating data analysis as an isolated topic within mathematics, GAISE II recognizes data reasoning as a fundamental competency that supports mathematical understanding across grade levels. When students engage with authentic datasets, they simultaneously apply numerical reasoning, proportional reasoning, graphical interpretation, and logical argumentation. Consequently, data-science-infused assessments provide opportunities to evaluate multiple dimensions of mathematical proficiency within a single authentic assessment task, making them particularly appropriate for assessing higher-order thinking skills expected under contemporary mathematics curricula.

Research examining data-rich learning environments consistently demonstrates that mathematical reasoning becomes more evident when students actively construct meaning from quantitative information rather than memorize computational procedures. Franklin and Bargagliotti (2020) found that students who regularly interpreted authentic datasets developed stronger statistical reasoning because they were required to explain variability, evaluate evidence, and justify conclusions using mathematical arguments.

Similarly, Aridor and Ben-Zvi (2018) observed that students demonstrated deeper conceptual reasoning when classroom activities required them to identify relationships

among variables, explain emerging patterns, and reconcile conflicting evidence obtained from real-world data.

Although these investigations focused primarily on statistics education, their findings collectively suggest that reasoning develops through sustained engagement with authentic mathematical inquiry rather than repetitive practice of routine algorithms.

A similar conclusion emerges from studies involving technology-enhanced learning environments. Santos-Trigo and Reyes-Martínez (2019) reported that interactive visualization tools enabled students to manipulate variables, examine relationships dynamically, and formulate hypotheses based on observed patterns. Rather than simply calculating numerical answers, students engaged in iterative reasoning as they interpreted changing graphical representations and evaluated the implications of different mathematical scenarios. Likewise, Darling-Hammond et al. (2020) argued that authentic performance assessments supported deeper mathematical understanding because they required students to integrate conceptual knowledge, procedural skills, and analytical reasoning within meaningful contexts. Collectively, these studies demonstrate that authentic assessment environments do not merely measure reasoning; they actively encourage students to engage in reasoning throughout the assessment process.

Viewed collectively, the international literature reveals a consistent pattern.

Although the studies differ in instructional settings, technologies employed, and assessment formats, they converge on the conclusion that mathematical reasoning is strengthened when assessment tasks require students to interpret evidence, evaluate

relationships, communicate explanations, and justify conclusions using authentic quantitative information. Rather than identifying isolated instructional strategies as universally effective, the literature suggests that the cognitive demands embedded within assessment tasks largely determine whether reasoning processes are elicited.

Consequently, the educational value of data-science-infused assessments lies not simply in the inclusion of data but in their capacity to generate observable evidence of students' analytical thinking and mathematical reasoning.

The Philippine literature likewise supports the movement toward contextualized and reasoning-oriented mathematics assessment, although implementation remains inconsistent. Studies have shown that contextualized mathematical problems encourage students to connect mathematical concepts with authentic experiences, thereby improving conceptual understanding and reasoning. Verzosa (2019) emphasized that mathematics instruction becomes more meaningful when students are required to explain mathematical ideas and justify their solutions rather than merely perform computations. Likewise, observed that instructional approaches emphasizing inquiry and problem solving contributed to improvements in students' analytical thinking and mathematical understanding. These findings are consistent with international evidence suggesting that reasoning flourishes when students are actively engaged in interpreting and explaining mathematical relationships.

However, the Philippine literature also reveals persistent barriers to implementing authentic assessment practices. EDCOM II (2025) noted that classroom assessments in

many secondary schools continue to emphasize procedural fluency, factual recall, and teacher-generated paper-and-pencil examinations, providing relatively few opportunities for students to demonstrate mathematical reasoning. Similar observations have been reported in studies examining classroom assessment practices, where teachers acknowledged difficulties in designing open-ended tasks, evaluating students' reasoning processes, and managing the additional time required for authentic assessment Herbert et al. (2022) These challenges indicate that although teachers generally recognize the importance of reasoning-oriented assessment, practical constraints often limit its consistent classroom implementation.

The concerns identified in empirical studies are further reinforced by national policy reviews. The EDCOM II-Year Two Report (2025) emphasized that despite substantial curriculum reforms, many Filipino students continue to exhibit weak conceptual understanding because classroom assessment practices remain heavily examination-driven and insufficiently focused on reasoning, application, and higher-order thinking. The report further noted that

improving student achievement requires strengthening teachers' assessment literacy, particularly in designing classroom assessments capable of measuring analytical thinking, problem solving, and conceptual understanding rather than isolated factual knowledge (EDCOM II, 2025). These observations support earlier findings indicating that assessment reform represents a critical component of broader educational improvement efforts.

Evidence from international large-scale assessments further illustrates the urgency of strengthening mathematical reasoning among Filipino students. In PISA 2022, the Philippines remained among the lowest-performing participating education systems in mathematics with many students' demonstrating difficulty interpreting quantitative information, solving non-routine problems, and applying mathematical knowledge in unfamiliar contexts (OECD, 2023). Similarly, TIMSS has consistently reported that students from lower-performing education systems experience greater difficulty with reasoning-domain items requiring analysis, generalization, and justification than with routine computational questions (Mullis et al., 2020). These findings suggest that strengthening mathematical reasoning is not simply a curricular objective, but a national educational priority closely associated with improving students' mathematical literacy and global competitiveness.

Despite growing international and national recognition of authentic assessment, important gaps remain within the existing body of research. Many of the international literature has examined reasoning within statistics education, inquiry-based learning, or technology-enhanced instruction, while relatively fewer studies have investigated reasoning specifically through data-science-infused assessment in secondary mathematics classrooms. Likewise, many Philippine investigations have focused broadly on contextualized instruction, problem solving, or inquiry learning without explicitly examining how authentic data-based assessment tasks measure mathematical reasoning. Moreover, only a limited number of local studies have explored the assessment validity of data-science-infused tasks or examined how such assessments generate evidence of students' reasoning processes within public secondary schools.

These gaps are particularly significant considering the assessment reforms advocated by DepEd Order No. 15, s. 2026, which call for classroom assessments that provide meaningful evidence of students' reasoning, problem-solving, and analytical thinking. Although current policies strongly encourage authentic assessment, empirical evidence regarding the effectiveness of data-science-infused assessments in measuring mathematical reasoning among Grade 10 students remains limited in the Philippine context. Addressing this gap is therefore important not only for extending current scholarship but also for providing local evidence that may guide the implementation of classroom assessment reforms under the MATATAG Curriculum. Accordingly, the present study seeks to examine the level of mathematical reasoning demonstrated by Grade 10 students using data-science-infused assessments and to contribute empirical evidence regarding the role of authentic assessment in evaluating higher-order mathematical competencies

Critical Thinking Using Data-Science-Infused Assessments of Students

Critical thinking has become one of the most essential competencies in twenty-first-century education because it enables students to analyze information, evaluate evidence, formulate sound judgments, and make informed decisions in increasingly complex and data-rich environments. Within mathematics education, critical thinking extends beyond solving computational problems; it involves interpreting quantitative

information, questioning assumptions, evaluating the validity of arguments, and justifying conclusions using logical and mathematical evidence. Consequently, contemporary educational systems increasingly recognize that mathematics instruction and assessment should cultivate students who can reason critically about real-world situations rather than merely recalling formulas or executing memorized procedures. This paradigm reflects a significant shift from traditional assessment models toward authentic assessment practices that capture students' higher-order cognitive processes and their capacity to apply mathematical knowledge meaningfully (Brookhart, 2018; OECD, 2023).

The theoretical foundation of critical thinking has been extensively articulated in educational research. Ennis (2018) described critical thinking as reflective and reasonable thinking directed toward deciding what to believe or do, emphasizing students' ability to examine evidence, evaluate alternative perspectives, and justify conclusions logically.

Although these definitions originate from different theoretical traditions, they converge in emphasizing that critical thinking requires students to engage in disciplined reasoning rather than passive acquisition of information. Within mathematics, these competencies become particularly important because students must continuously interpret quantitative evidence, assess mathematical relationships, evaluate solution strategies, and defend conclusions using logical arguments.

The growing emphasis on critical thinking reflects broader educational reforms that prioritize higher-order thinking over rote memorization. Brookhart (2018) argued

that higher-order thinking encompasses analysis, evaluation, and creation, requiring students to organize information, synthesize multiple sources of evidence, and generate reasoned solutions to unfamiliar problems. From this perspective, classroom assessment should move beyond measuring factual recall and instead provide opportunities for students to demonstrate complex cognitive processes through authentic performance tasks. Consequently, assessment is increasingly viewed not merely as a means of assigning grades but as a mechanism for generating meaningful evidence about students' conceptual understanding and critical thinking abilities.

These theoretical perspectives strongly align with international assessment frameworks that define mathematical proficiency in terms of reasoning, interpretation, and evidence-based decision-making. The Programme for International Student Assessment (PISA) 2022 Mathematics Framework emphasizes that mathematically literate individuals must formulate, employ, and interpret mathematics while making informed judgments based on quantitative evidence in real-world contexts (OECD, 2023). Rather than focusing exclusively on procedural accuracy, PISA assesses students' capacity to analyze situations, interpret graphical and statistical information, evaluate assumptions, and communicate evidence-based conclusions. Similarly, the TIMSS 2019 Assessment Framework identifies reasoning as the highest cognitive domain, requiring students to synthesize information, evaluate mathematical arguments, generalize patterns, and solve non-routine problems (Mullis et al., 2020). Together, these international frameworks underscore that critical thinking and mathematical reasoning are inseparable competencies that should be cultivated through authentic assessment experiences.

One instructional approach that effectively supports these competencies is data-science-infused assessment, which integrates authentic datasets, statistical representations, graphical information, and contextualized quantitative problems into classroom assessment. Unlike traditional paper-and-pencil tests that primarily evaluate procedural computation, data-science-infused assessments require students to interpret evidence, analyze patterns, question assumptions, and justify decisions using mathematical reasoning. As students engage with authentic data, they simultaneously evaluate the quality of information, compare alternative explanations, and communicate evidence-based conclusions. These cognitive processes naturally activate higher-order thinking, making data-science-infused assessment particularly suitable for measuring critical thinking in mathematics classrooms.

The educational value of data-science-infused assessment is supported by research on data literacy, which has emerged as a fundamental competency in modern education. Data literacy extends beyond the ability to read graphs or perform statistical calculations; it encompasses students' capacity to collect, organize, interpret, evaluate, and communicate data responsibly within authentic contexts (Franklin et al., 2020). Engel et al. (2020) similarly explained that students engaged in authentic data investigations perform interconnected "data moves," including collecting, visualizing, interpreting, evaluating, and communicating evidence. These activities require students not only to manipulate numerical information but also to question the reliability of evidence, recognize uncertainty, identify patterns, and justify interpretations. Consequently, data

literacy provides an authentic context through which critical thinking can be observed and assessed.

The GAISE II further reinforce this perspective by advocating classroom learning experiences that require students to formulate statistical questions, investigate authentic datasets, evaluate evidence, and communicate conclusions using appropriate quantitative reasoning (Franklin et al., 2020). Rather than viewing statistics as an isolated mathematical topic, GAISE II positions data investigation as a context for developing analytical reasoning, evidence appraisal, and informed decision-making. From this standpoint, authentic assessment tasks involving data analysis naturally elicit critical thinking because students must interpret complex information, evaluate competing explanations, and defend conclusions using empirical evidence.

Another important framework supporting authentic assessment is Evidence-Centered Design (ECD). (Mislevy et al., 2003; Mislevy, 2018) argued that effective assessments should be intentionally designed to generate observable evidence of complex competencies, including critical thinking. According to ECD, assessment validity depends on the extent to which assessment tasks successfully elicit behaviours that reflect the underlying cognitive processes being measured. Traditional selected-response tests often provide limited evidence regarding students' analytical thinking because they focus primarily on identifying correct answers. In contrast, open-ended, inquiry-oriented, and contextualized assessment tasks allow students to demonstrate interpretation, evaluation, justification, and reflective thinking, thereby producing richer evidence of critical

thinking. This perspective is particularly relevant to data-science-infused assessments because authentic data analysis requires students to explain their reasoning, evaluate evidence quality, and justify conclusions using logical arguments rather than relying solely on computational accuracy.

The movement toward authentic assessment has also been reflected in recent educational reforms within the Philippines. Department of Education Order No. 15, s. 2026, which institutionalizes classroom assessment under the MATATAG Curriculum, emphasizes that assessment should generate meaningful evidence of students' conceptual understanding, analytical thinking, problem-solving ability, and critical evaluation rather than merely measure factual recall or procedural proficiency (Department of Education [DepEd], 2026). The policy specifically highlights that classroom assessment for Key Stage 3 (Grades 7–10) should progressively cultivate higher-order thinking by engaging students in contextualized, performance-based, and inquiry-oriented tasks. Consequently, classroom assessment is envisioned not only as an evaluative tool but also as a learning process that supports the development of reasoning, critical thinking, and informed decision-making.

National educational evidence further reinforces the urgency of strengthening critical thinking in Philippine classrooms. The Second Congressional Commission on Education (EDCOM II) reported that many Filipino students continue to struggle with higher-order cognitive skills because classroom instruction and assessment remain largely focused on procedural knowledge, factual recall, and examination-oriented practices

(EDCOM II, 2024). The commission emphasized that while curriculum reforms advocate analytical thinking and authentic learning experiences, classroom implementation often falls short because teachers face challenges in designing assessment tasks capable of measuring critical thinking and conceptual understanding. The EDCOM II-Year Two Report (2025) further identified assessment literacy as a critical area for professional development, noting that meaningful improvements in student achievement require classroom assessments that evaluate reasoning, evidence-based decision-making, and analytical thinking rather than isolated factual knowledge.

These international frameworks, theoretical perspectives, and national policy reforms collectively indicate that critical thinking develops most effectively when students engage in authentic assessment tasks requiring interpretation, evaluation, and evidence-based reasoning. Rather than treating critical thinking as an abstract cognitive ability, contemporary literature increasingly views it as a competency that emerges through sustained engagement with meaningful, contextualized, and data-rich learning experiences. Consequently, data-science-infused assessments provide a promising approach for cultivating and measuring critical thinking because they

require students to integrate mathematical understanding, analytical reasoning, and evidence-based judgment within authentic real-world contexts

Although existing international and Philippine literature consistently supports the educational value of authentic and inquiry-oriented assessment, important empirical gaps remain. Much of the international literature has examined critical thinking within

problem-based learning, inquiry learning, or technology-enhanced instruction, while relatively fewer studies have investigated critical thinking specifically through data-science-infused assessments in mathematics education. Similarly, Philippine research has generally focused on contextualized instruction, inquiry learning, or problem-solving approaches without explicitly examining authentic data-based assessment as a mechanism for measuring critical thinking. Furthermore, only limited local investigations have evaluated the validity of data-science-infused assessments as instruments for generating evidence of higher-order cognitive competencies among secondary students.

These gaps become particularly important considering the renewed emphasis on authentic classroom assessment under DepEd Order No. 15, s. 2026 and the educational reforms recommended by EDCOM II. Although national policy strongly encourages assessment practices that cultivate critical thinking, empirical evidence regarding the effectiveness of data-science-infused assessments in measuring critical thinking among Grade 10 students in Philippine public secondary schools remains limited. Accordingly, the present study seeks to contribute local evidence by examining the level of critical thinking demonstrated by Grade 10 students through data-science-infused assessments. In doing so, the study aims to extend existing literature while providing evidence that may inform the continuing implementation of classroom assessment reforms under the MATATAG Curriculum and strengthen the assessment of higher-order thinking in Philippine mathematics education.

Mathematical Reasoning and Critical Thinking using Data-Science- Infused Assessment of Students

The relationship between mathematical reasoning and critical thinking has become a significant area of inquiry in mathematics education because both competencies represent essential dimensions of higher-order thinking required for meaningful problem solving and evidence-based decision-making. Although mathematical reasoning and critical thinking are conceptually distinct, contemporary educational research increasingly recognizes that they function as mutually reinforcing cognitive processes during mathematical inquiry. In authentic mathematical contexts, however, these cognitive processes rarely operate independently. Instead, students continuously reason mathematically while simultaneously evaluating evidence, critiquing assumptions, and defending conclusions. Consequently, recent scholarship increasingly views mathematical reasoning not only as a related competency but also as a foundational cognitive process that contributes to the development of critical thinking (Goos et al., 2019; OECD, 2023).

Facione et al. (2020) further reinforced this relationship by explaining that human reasoning and critical thinking are closely interconnected cognitive processes. Drawing on empirical evidence, they argued that critical thinking involves interpretation, analysis, evaluation, inference, and evidence-based judgment, all of which depend on sound reasoning. Their findings also suggest that reasoning abilities can be strengthened through purposeful instruction and meaningful learning experiences rather than being

viewed as fixed abilities. Within mathematics education, this implies that students who develop stronger mathematical reasoning are more likely to demonstrate higher levels of critical thinking because both competencies rely on similar cognitive processes used in analyzing information, evaluating evidence, and making justified conclusions.

This perspective is reflected in the framework of Critical Mathematical Thinking (CMT), which conceptualizes mathematics learning as a reflective process requiring students to interpret information, analyze mathematical

situations, critique arguments, justify conclusions, and evaluate CMT positions students as active constructors of knowledge who continuously examine evidence, question assumptions, and defend mathematical claims through logical reasoning (Goos et al., 2019). Within this framework, mathematical reasoning provides the cognitive foundation upon which critical thinking develops because students must first establish logical relationships before evaluating the validity, reliability, or implications of mathematical conclusions.

Consequently, reasoning and critical evaluation are viewed as complementary processes that collectively support deeper conceptual understanding and mathematical literacy.

The close relationship between these competencies is likewise reflected in international assessment frameworks. The Programme for International Student Assessment (PISA) 2022 Mathematics Framework. The framework does not separate reasoning from critical thinking; instead, both are integrated throughout the mathematical modelling cycle as students interpret information, evaluate assumptions, justify conclusions, and communicate evidence-based decisions. Similarly, the TIMSS 2019

Assessment Framework identifies reasoning as the highest cognitive domain within mathematics, requiring students to analyze relationships, synthesize information, generalize patterns, evaluate solution strategies, and solve unfamiliar problems (Mullis et al., 2020). These international frameworks therefore suggest that mathematical reasoning naturally supports critical thinking because both competencies are required simultaneously during authentic mathematical inquiry.

The emergence of data science education further strengthens this relationship by situating mathematical reasoning and critical thinking within authentic contexts involving data interpretation, uncertainty, and evidence-based decision-making. The GAISE II Report emphasizes that students should not merely perform statistical procedures but should formulate meaningful questions, analyze authentic datasets, evaluate the quality of evidence, interpret variability, and communicate conclusions supported by quantitative information (Franklin et al., 2020). Likewise, the National Academies of Sciences, Engineering, and Medicine (2018) argued that modern mathematics education should prepare students to interpret increasingly complex data environments by integrating statistical reasoning, computational thinking, and critical evaluation. These recommendations suggest that contemporary mathematics learning requires students to reason mathematically while simultaneously exercising critical judgment regarding the reliability, interpretation, and implications of quantitative evidence. Consequently, authentic data-based assessment environments provide a natural context in which mathematical reasoning and critical thinking become highly interconnected.

Empirical investigations consistently support this theoretical relationship. Across diverse educational contexts, studies have demonstrated that students who exhibit stronger mathematical reasoning also demonstrate greater capacity to evaluate evidence, justify conclusions, and solve unfamiliar problems. Ben-Zvi et al. (2018), found that students engaged in authentic data investigations demonstrated simultaneous improvements in statistical reasoning and evaluative judgment because interpreting complex datasets required them to construct explanations, critique interpretations, and defend conclusions using evidence. Similarly, Franklin et al. (2020) observed that students who developed stronger reasoning during statistical investigations also demonstrated greater critical evaluation when assessing data quality, interpreting variability, and communicating evidence-based conclusions. Although these studies focused primarily on statistical reasoning, they collectively indicate that reasoning and critical thinking develop concurrently through sustained engagement with authentic mathematical inquiry.

Research on mathematical argumentation provides additional support for this relationship. Stylianides and Stylianides (2017) argued that mathematical argumentation requires students to construct logical explanations, evaluate competing claims, critique mathematical reasoning, and justify conclusions using evidence. These cognitive activities extend beyond procedural problem solving because students must continuously evaluate the validity of arguments while defending their own reasoning. Consequently, mathematical argumentation serves as a bridge between reasoning and critical thinking by integrating logical analysis with evaluative judgment. Similarly,

distinguished intuitive reasoning from reflective analytical thinking argue that deliberate evaluation of evidence promotes more accurate decision-making than reliance on immediate intuitive responses (Evans & Stanovich, 2013; Evans, 2019). Within mathematics education, this distinction highlights how mathematical reasoning facilitates critical thinking by encouraging students to move beyond instinctive answers toward evidence-based analysis.

An emerging body of predictive research further strengthens this relationship.

Facione et al. (2020) explained that empirical evidence consistently shows that reasoning serves as the cognitive foundation of critical thinking because individuals who demonstrate stronger analytical reasoning are better able to interpret information, evaluate evidence, and make sound judgments. Likewise, research grounded in cognitive psychology suggests that reasoning functions as an underlying cognitive mechanism supporting analytical thinking because students must first identify relationships and construct logical arguments before evaluating evidence critically (Evans, 2019).

Consequently, regression-based studies increasingly identify reasoning as a statistically significant predictor of complex cognitive outcomes, including mathematical literacy, analytical thinking, and critical judgment. These findings suggest that the relationship between mathematical reasoning and critical thinking extends beyond simple association, supporting the hypothesis that mathematical reasoning contributes meaningfully to the development of critical thinking.

From the perspective of educational measurement, these findings underscore the importance of designing assessments capable of capturing both reasoning and critical thinking simultaneously. According to the American Educational Research Association, American Psychological Association, and National Council on Measurement in Education (2014) assessment validity depends upon the extent to which evidence and theory support the intended interpretations of assessment scores. Consequently, assessments intended to measure higher-order thinking should require students to demonstrate observable reasoning processes rather than merely select correct answers. This principle is further reinforced by Evidence-Centered Design (ECD), which emphasizes that assessment tasks should be intentionally constructed to elicit evidence of the cognitive processes underlying student performance (Mislevy et al., 2003; Mislevy, 2018). Within ECD, authentic and open-ended assessment tasks provide stronger evidence of reasoning and critical thinking because they require students to explain, justify, evaluate, and communicate their thinking. Accordingly, data-science-infused assessments possess strong theoretical potential for measuring both mathematical reasoning and critical thinking simultaneously, since authentic data interpretation inherently requires students to integrate logical reasoning with evaluative judgment.

While international literature consistently supports the close relationship between mathematical reasoning and critical thinking, empirical evidence from the Philippine context likewise demonstrates that these higher-order cognitive competencies are interdependent and mutually reinforcing. However, unlike many international investigations that increasingly examine predictive relationships among cognitive variables, local studies have largely concentrated on describing students' reasoning or critical thinking independently or examining their association through correlational

analyses. Consequently, there remains limited empirical evidence explaining the extent to which mathematical reasoning predicts critical thinking among Filipino secondary students, particularly within authentic assessment environments involving data interpretation and quantitative reasoning. This gap is especially significant considering the continuing reforms in Philippine mathematics education, which emphasize the development of higher-order thinking through contextualized and evidence-based classroom assessment.

Existing Philippine studies generally indicate that students who demonstrate stronger mathematical reasoning also exhibit higher levels of analytical thinking, reflective judgment, and problem-solving performance. Verzosa (2020) argued that mathematical reasoning serves as a central component of conceptual understanding because students who can construct logical explanations and justifying mathematical procedures are likewise better able to evaluate

evidence and make informed decisions. Similarly, Verzosa and Vistro-Yu (2019) observed that instructional approaches emphasizing reasoning, explanation, and inquiry contributed to improvements in students' reflective thinking, suggesting that reasoning facilitates deeper cognitive engagement than procedural instruction alone. Rather than functioning as isolated competencies, these studies collectively suggest that mathematical reasoning provides an important cognitive foundation upon which critical thinking develops.

Comparable conclusions have emerged from investigations of contextualized mathematics instruction. Andrade et al. (2020) reported that students engaged in authentic

mathematical tasks requiring explanation and interpretation demonstrated stronger analytical judgment than those exposed primarily to routine computational exercises. Likewise, De Las Peñas et al. (2021) found that inquiry-oriented learning environments encouraged students to justify conclusions, evaluate alternative solution strategies, and communicate evidence-based explanations, thereby simultaneously strengthening reasoning and critical thinking. Although these studies primarily examined instructional interventions rather than predictive relationships, they consistently indicate that learning experiences emphasizing mathematical reasoning also cultivate critical evaluation and reflective judgment. This convergence supports the theoretical proposition that mathematical reasoning functions as an important antecedent to higher-order thinking.

Although international and Philippine literature consistently demonstrates a positive relationship between mathematical reasoning and critical thinking, the methodological characteristics of previous investigations reveal several important limitations. Many studies have employed descriptive or correlational designs that establish the existence of relationships without examining the predictive contribution of mathematical reasoning to critical thinking. Correlation coefficients indicate the strength and direction of association between variables but do not estimate the extent to which one variable explains variation in another. Because the present study seeks to determine whether mathematical reasoning significantly predicts critical thinking, predictive statistical evidence becomes particularly relevant.

Moreover, much of the existing literature has examined reasoning and critical thinking within inquiry-based learning, contextualized instruction, or problem-solving interventions rather than within data-science-infused assessment. Consequently, relatively little empirical evidence exists regarding how authentic data-based assessment tasks simultaneously measure these competencies among secondary mathematics students.

Given the increasing importance of data literacy, evidence-based reasoning, and authentic assessment in contemporary mathematics education, this represents an important gap in the literature.

In addition, relatively few Philippine studies have grounded the measurement of mathematical reasoning and critical thinking within established frameworks of assessment validity. According to AERA, APA, and NCME (2014), valid assessment requires evidence supporting the interpretation of assessment scores in relation to the intended construct. Likewise, Evidence-Centered Design emphasizes that assessment tasks should intentionally elicit observable evidence of students' reasoning processes and higher-order thinking (Mislevy et al., 2003; Mislevy, 2018). Data-science-infused assessments satisfy these principles because authentic datasets require students to interpret information, evaluate evidence, justify conclusions, and communicate explanations, thereby providing richer cognitive evidence than conventional selected-response assessments. Furthermore, recommendations from the GAISE II Report (Franklin et al., 2020) and the NASEM (2018) similarly advocate assessment environments in which students demonstrate reasoning and critical judgment through authentic analysis of real-world data.

Collectively, the reviewed literature provides strong theoretical and empirical support for the proposition that mathematical reasoning and critical thinking are closely interconnected higher-order cognitive competencies. International frameworks, educational theories, and empirical investigations consistently suggest that students who reason effectively are better able to evaluate evidence, justify conclusions, and make informed decisions within authentic mathematical contexts. Nevertheless, important gaps remain in the Philippine literature. Few studies have

examined these constructs simultaneously using data-science-infused assessments, and even fewer have investigated whether mathematical reasoning significantly predicts critical thinking through simple linear regression among Grade 10 students in Philippine public secondary schools.

Addressing this gap is significant because it extends existing literature beyond merely describing or correlating these constructs by providing empirical evidence regarding the predictive role of mathematical reasoning within an authentic assessment context. Such evidence may contribute to the implementation of DepEd Order No. 15, s. 2026, respond to the assessment reforms advocated by EDCOM II (2024, 2025), and provide local evidence supporting classroom assessment practices that cultivate higher-order thinking aligned with international standards such as PISA 2022 and TIMSS.

Synthesis

Organisation for Economic Co-operation and Development (OECD, 2023), Mullis et al. (2020), National Council of Teachers of Mathematics (NCTM, 2018), Facione et al.

(2020), Franklin et al. (2020), Engel et al. (2020), Goos et al. (2019), Ben-Zvi et al. (2018), Santos-Trigo and Reyes-Martínez (2019), and Darling-Hammond et al. (2020). consistently emphasized that authentic assessment tasks requiring students to interpret quantitative information, analyze relationships, justify conclusions, evaluate evidence, and solve real-world problems effectively promote mathematical reasoning and critical thinking. Likewise, Mislevy et al. (2003), Mislevy (2018), and the American Educational Research Association, American Psychological Association, and National Council on Measurement in Education (2014) agreed that authentic and evidence-centered assessments provide richer evidence of students' higher-order thinking than traditional selected-response tests.

Comparable findings were reported in Philippine studies. Verzosa (2020), Verzosa and Vistro-Yu (2019), Andrade et al. (2020), and De Las Peñas et al. (2021) similarly found that contextualized, inquiry-based, and explanation-oriented mathematics instruction enhances students' conceptual understanding, analytical reasoning, and reflective thinking. These findings support international evidence that meaningful mathematical learning occurs when students actively explain, justify, and apply mathematical concepts in authentic situations.

However, contrasting findings emerged between educational frameworks and actual classroom practice. While OECD (2023), Mullis et al. (2020), Franklin et al. (2020), DepEd (2026), and Mislevy (2018) advocate authentic assessments emphasizing reasoning and evidence-based judgment, EDCOM II (2024, 2025) and Herbert et al.

(2022) reported that classroom assessment in many schools remains dominated by procedural exercises, factual recall, and traditional paper-and-pencil examinations. Similarly, although international studies demonstrated that authentic data-based tasks improve higher-order thinking, PISA 2022 (OECD, 2023) and TIMSS 2019 (Mullis et al., 2020) revealed that many students, particularly in the Philippines, continue to perform poorly on reasoning and problem-solving tasks, indicating a gap between assessment policy and classroom implementation.

The literature also reveals important research gaps. Most previous studies examined mathematical reasoning and critical thinking separately or within inquiry-based and technology-enhanced instruction rather than through data-science-infused assessments. Moreover, many investigations employed descriptive or correlational designs, with few examining the predictive influence of mathematical reasoning on critical thinking using simple linear regression. In the Philippine context, limited studies have simultaneously assessed these constructs using authentic data-science-infused assessments among Grade 10 students while considering socio-economic status, access to digital resources, and academic performance. The present study addresses these gaps by examining the levels, differences, relationship, and predictive association between mathematical reasoning and critical thinking using data-science-infused assessments, thereby providing local empirical evidence to support the implementation of authentic classroom assessment under the MATATAG Curriculum.

METHODOLOGY

This chapter presents the methodology used in examining the mathematical reasoning and critical thinking of Grade 10 students through data-science-infused assessment in a public high school in the northern part of Negros Occidental during the School Year 2025–2026. It describes the research design, participants of the study, research instruments, data-gathering procedure, data analysis procedure, and ethical considerations.

Research Design

This study employed a quantitative descriptive-correlational research design to determine the levels of mathematical reasoning and critical thinking and to examine the relationship between these variables among Grade 10 students using a data-science-infused assessment. The descriptive-correlational research design combines descriptive and correlational approaches within a quantitative framework. The descriptive component systematically describes the characteristics and levels of the variables under investigation, while the correlational component determines the degree and direction of the relationship between two or more variables without manipulating them (Creswell & Creswell, 2018). This design enables researchers to collect numerical data, summarize observed phenomena using appropriate statistical measures, and examine whether variables are significantly associated under naturally occurring conditions (Fraenkel et al., 2019).

This research design was appropriate for the present study because it aligned with its objectives of determining the levels of mathematical reasoning and critical thinking and examining the relationship between these variables among Grade 10 students.

Participants of the Study

The participants of this study consisted of 395 out of 1050 Grade 10 students enrolled in one selected public secondary school in the northern part of Negros Occidental during School Year 2025–2026 determined using G*Power with a small effect size ($f^2 = 0.02$), a 0.05 level of significance, and a statistical power of 0.80. This was considered sufficient to detect statistically significant relationships and predictive associations among the study variables while ensuring adequate statistical power (Faul et al., 2009; Field, 2018). A proportionate stratified random sampling technique was employed to ensure adequate representation of students from the different academic programs then the required number of participants from each stratum was determined proportionately. Participants within each stratum were then selected through simple random sampling. (See Appendix D)

Table 1 Distribution of the Participants

Grouping Variables	<i>f</i>	%
A. As a Whole	395	100
B. Socio-Economic Status		
High	36	9.1
Middle	257	65.1
Low	102	25.8
C. Access to Digital Resources		
High	119	30.1
Moderate	240	60.8
Low	36	9.1
D. Academic Performance		

High	149	37.7
Above Average	142	35.9
Average	78	19.8
Below Average	26	6.6

Table 1 presents the distribution of the 395 Grade 10 student participants according to socio-economic status, access to digital resources, and academic performance. As to socio-economic status, students with middle socio-economic status ($n = 257$) comprised the largest proportion of the participants while students with high socio-economic status ($n = 36$) had the smallest representation. Regarding access to digital resources, the moderate access category accounted for the highest proportion with 60.8%, whereas only 9.1% reported low access to digital resources. In terms of academic performance, the high academic performance group recorded the largest number of participants with 149 students while the below-average academic performance group had the fewest with 26 students.

Research Instrument

This study utilized a researcher-developed Data-Science-Infused Assessment Instrument designed to measure the mathematical reasoning and critical thinking of Grade 10 students within authentic, data-based mathematical contexts. The instrument was developed through a systematic process involving the review of relevant literature, the PISA Mathematics Framework (OECD, 2023), the Grade 10 MATATAG Mathematics Curriculum, and the learning competencies prescribed by the Department of Education. A Table of Specifications (TOS) was prepared to ensure adequate representation of the targeted competencies and higher-order thinking skills before the construction of the assessment items. (See Appendix F)

The instrument consisted of two portions. Part I was a Demographic Profile Questionnaire, which gathered information on the participants' socio-economic status, access to digital resources, and academic performance. Socio-economic status was determined using parents' or guardians' educational attainment, occupation, and estimated monthly household income. Access to digital resources was determined based on the availability of digital devices, internet connectivity, and frequency of using digital learning tools for educational purposes. Academic performance was obtained from the participants' official third-quarter mathematics grade.

Part II was the Data-Science-Infused Assessment, which comprised of researcher-developed mathematical reasoning and critical thinking test. Each construct contained 20 items, composed of 10 multiple-choice items and 10 constructed-response items, for a total of 40 assessment items. The assessment tasks were contextualized using authentic datasets and real-life situations relevant to Grade 10 students, requiring participants to interpret data, analyze quantitative relationships, evaluate evidence, formulate logical arguments, and justify conclusions. These tasks were designed to measure higher-order thinking skills consistent with the objectives of the study and the principles of mathematical literacy emphasized by the PISA Mathematics Framework.

The multiple-choice items were scored dichotomously, with one point awarded for each correct response and zero points for incorrect responses, resulting in a maximum score of 10 points for each test. The constructed-response items were evaluated using researcher-developed analytic scoring rubrics, with each response rated on a five-point scale (0–4) based on the quality of reasoning, accuracy of interpretation, use of evidence, logical justification, and coherence of explanation. The ten constructed-response items yielded a maximum score of 40 points. Consequently, each assessment had a maximum possible score of 50 points. The obtained scores for the Mathematical Reasoning Test and the Critical Thinking Test were interpreted using proficiency classifications adapted from the Bureau of Education Assessment (BEA) Mean Percentage Score (MPS) proficiency levels (DepEd, 2022). The interpretation of students' performance was aligned with the criterion-referenced classroom assessment principles prescribed in DepEd Order No. 15,

s. 2026 (DepEd, 2026). The official MPS proficiency ranges were converted into equivalent mean score ranges for the 50-item assessment used in this study.

Mean Score Range	Interpretation
45.00 - 50.00	Highly Proficient
37.50 - 44.99	Proficient
25.00 - 37.49	Nearly Proficient
12.50 - 24.99	Low Proficient
0.00 - 12.49	Not Proficient

The instrument underwent expert validation to establish its content validity. Three experts specializing in Mathematics Education, Educational Assessment, and Research Methodology evaluated the instrument with respect to its alignment with the objectives of the study, consistency with the Grade 10 Mathematics competencies, appropriateness of the contextualized datasets, relevance of the assessment tasks to mathematical reasoning and critical thinking, clarity of instructions, language suitability, and adequacy of the scoring rubrics. The comments and recommendations of the validators were incorporated to improve the quality, organization, and appropriateness of the instrument before pilot testing. The evaluation yielded an average weighted mean score of 2.90 for the Mathematical Reasoning Test and 2.98 for the Critical Thinking Test. Based on the

validation rubric, an average weighted mean ranging from 2.50 to 3.00 indicates that the instrument is highly valid. (See Appendix G).

This indicated that both instruments were highly valid and appropriate for measuring the intended constructs. Following expert validation, a pilot test was conducted among 20 Grade 10 students from the same school who were not included in the actual participants of the study. The internal consistency of the multiple-choice items was determined using the Kuder–Richardson Formula 20 (KR-20), which is appropriate for dichotomously scored cognitive assessments. The KR-20 coefficients were 0.73 for the Mathematical Reasoning Test and 0.75 for the Critical Thinking Test, indicating acceptable internal consistency. The constructed-response items were independently scored by three trained Mathematics teachers who possessed postgraduate degrees and were teaching Grade 10 Mathematics. Before the scoring process, the raters participated in rubric orientation and scoring calibration to ensure consistent application of the scoring criteria. Fleiss' Kappa was computed to determine the degree of inter-rater agreement.

The Mathematical Reasoning Test and the Critical Thinking Test each obtained a Fleiss' Kappa coefficient of 0.65, indicating substantial agreement among the raters. (See Appendix H)

The systematic procedures undertaken in the development of the instrument including the preparation of the Table of Specifications, expert validation, pilot testing, reliability analysis, and inter-rater agreement assessment provided sufficient evidence that the researcher-developed Data-Science-Infused Assessment Instrument is both valid and reliable for measuring the mathematical reasoning and critical thinking of Grade 10 students through authentic, data-based mathematical assessment tasks.

Data Gathering Procedure

The data gathering procedure was conducted systematically and ethically to ensure the accuracy, consistency, and integrity of the data collected. Prior to the conduct of the study, formal approval was obtained from the principal of the selected public secondary school and the Officer-in-Charge of the Mathematics Department.

Coordination with the Grade 10 mathematics teachers was likewise undertaken to determine the schedule for the administration of the assessment and to minimize disruption to regular classroom instruction. A pilot testing was

completed before the actual data collection. Following the approval to conduct the study, written parental consent forms and student assent forms were distributed to the prospective participants through their respective Grade 10 mathematics teachers. The consent and assent forms explained the purpose of the study, the procedures involved, the voluntary nature of participation, the confidentiality of the information to be collected, and the participants' right to withdraw from the study at any stage without penalty. Only students who returned duly signed parental consent and student assent forms were included in the study.

Before the administration of the researcher-developed Data-Science-Infused Assessment Instrument, which measured students' mathematical reasoning and critical thinking, the purpose of the study, testing procedures, and ethical safeguards were

explained to the participants. The assessment was administered during the participants' regular mathematics class under standardized testing conditions and was completed within 60 minutes, equivalent to one standard class period. Uniform instructions, testing time, and administration procedures were observed to ensure consistency throughout the assessment process. The demographic profile questionnaire was administered first to gather information on the participants' socio-economic status, access to digital resources, and academic performance. After completing the demographic questionnaire, the participants answered the Data-Science-Infused Assessment, which consisted of multiple-choice and constructed-response items designed to measure mathematical reasoning and critical thinking through authentic, data-based mathematical tasks. Throughout the assessment, the researcher monitored the testing process to ensure that standardized procedures were consistently followed and that the participants completed the assessment independently.

After the administration of the assessment, all completed instruments were collected and checked for completeness. The responses to the constructed-response items were independently scored by three Grade 10 mathematics teachers with postgraduate degrees using the validated analytic scoring rubric developed for the study. The scores assigned by the three raters were consolidated and verified before data encoding. Finally, the collected data were encoded, verified for completeness and accuracy, and organized in preparation for statistical analysis. Throughout the entire data gathering process, the researcher strictly adhered to approved research protocols, ethical principles, and the provisions of the Data Privacy Act of 2012 (Republic Act No. 10173) to protect the

rights, privacy, and welfare of the participants and to preserve the credibility and integrity of the study.

Data Analysis Procedure

The collected data were screened, encoded, and analyzed using appropriate descriptive and inferential statistical techniques aligned with each research problem. Prior to conducting inferential analyses, the assumptions specific to each statistical procedure were examined to ensure that the selected analyses were appropriate. The assumptions evaluated varied depending on the statistical technique employed. (See Appendix I)

For statement of the problem numbers 1 and 2, which aimed to determine the level of mathematical reasoning and critical thinking, mean and standard deviation were computed to describe the central tendency and variability of mathematical reasoning and critical thinking scores for the entire sample and when grouped according to socio-economic status, access to digital resources and academic performance.

For statement of the problem numbers 3 and 4, which aimed to determine whether significant differences existed in the levels of mathematical reasoning and critical thinking when participants were grouped according to socio-economic status, access to digital resources, and academic performance, One-way Analysis of Variance (ANOVA) was employed. Tukey's (HSD) post hoc test was performed if the omnibus ANOVA yielded a statistically significant result to determine which specific group pairs differed significantly. The assumptions of normality of the dependent variable within groups and

homogeneity of variances were examined using the Shapiro–Wilk test and Levene's test, respectively

For statement of the problem number 5, which investigated the significant relationship between mathematical reasoning and critical thinking, Spearman's Rank-Order Correlation Coefficient (ρ) was employed because it is appropriate for analyzing the strength and direction of the relationship between two variables when the data are not normally distributed. The assumption of a monotonic relationship between the variables was verified through visual inspection of the scatterplot.

For statement of the problem number 6, which examined whether mathematical reasoning significantly predicts critical thinking, simple linear regression analysis was conducted. The assumptions of linearity, independence of errors, homoscedasticity, normality of residuals, and absence of influential outliers were examined. The diagnostic results, including a Durbin–Watson value of 1.79, acceptable residual plots, standardized residuals within ± 3.00 , and no influential cases were detected by Cook's Distance, indicated that the assumptions were reasonably satisfied; thus, regression analysis was considered appropriate

Ethical Considerations

This study adhered to the ethical principles governing educational research to protect the rights, dignity, safety, and welfare of the participants throughout the conduct of the investigation. Prior to data collection, permission to conduct the study was obtained from the appropriate university authorities, the school principal, and other

concerned school officials. The study likewise complied with the ethical standards for research involving human participants and observed the provisions of the Data Privacy Act of 2012 (Republic Act No. 10173) in the collection, processing, storage, and disposal of research data.

Social Value

The study upheld social value by contributing to the improvement of mathematics education through the generation of empirical evidence on the mathematical reasoning and critical thinking of Grade 10 students using a data-science-infused assessment. The findings provided valuable information for strengthening classroom assessment practices, promoting higher-order thinking skills, and supporting the implementation of the MATATAG Curriculum, particularly the integration of authentic assessment and data literacy in mathematics instruction. To maximize the educational benefits of the study, the findings will be disseminated to relevant stakeholders through the submission of the research report, research presentations, Learning Action Cell (LAC) sessions, and other appropriate academic or school-based dissemination activities. The dissemination of the findings is intended to support evidence-based decision-making, instructional improvement, and the development of school and division initiatives that enhance mathematics teaching, learning, and assessment.

Informed Consent and Assent

Participation in the study was entirely voluntary. Since the participants were Grade 10 students and therefore minors, written informed consent was secured from their

parents or legal guardians, while written assent was obtained from the student participants prior to their participation. The purpose of the study, research procedures, expected duration of participation, potential risks and benefits, confidentiality measures, and participants' rights were clearly explained using language appropriate to both parents and students. The parental consent and student assent forms were distributed through the participants' respective Grade 10 mathematics teachers and were collected before the administration of the assessment. Only students who returned duly signed parental consent and student assent forms were included in the study. Participants were informed that they could decline participation or withdraw from the study at any stage without penalty, coercion, or any effect on their academic standing, grades, or school privileges.

Protection of Vulnerable Participants

Considering that the participants were minors, appropriate safeguards were implemented throughout the study. The administration of the assessment was conducted during scheduled class hours with the knowledge and supervision of the school administration and mathematics teachers. Participation did not interfere with regular classroom instruction, and no respondent was subjected to pressure, discrimination, or undue influence. The researcher ensured that all participants were treated with respect, fairness, and dignity throughout the research process.

Risks and Benefits

The study involved minimal risk, as the assessment activities were comparable to regular classroom assessment tasks routinely administered in mathematics classes. No

physical, psychological, social, or legal harm was anticipated. Participation or non-participation had no bearing on the participants' academic grades or standing. Although participants did not receive direct material incentives, they benefited from engaging in authentic, data-based mathematical tasks that promoted mathematical reasoning and critical thinking. More importantly, the findings of the study assisted teachers, school administrators, and curriculum implementers in improving mathematics instruction and assessment practices.

Privacy, Confidentiality, and Data Privacy

The privacy and confidentiality of all participants were strictly protected. Personal identifiers such as names, student numbers, or other identifying information were excluded from the assessment instruments and research database. Instead, numerical codes were assigned to each respondent to ensure anonymity during data processing and analysis. All collected data were used exclusively for academic and research purposes and were reported only in aggregate form to prevent the identification of individual participants. All research records were retained and disposed of in accordance with institutional policies and the provisions of the Data Privacy Act of 2012.

Justice and Fair Participant Selection

The principle of justice was observed by ensuring equitable participant selection through proportionate stratified random sampling. Every eligible Grade 10 student within the identified academic programs had an equal opportunity to be selected as a respondent regardless of socio-economic status, access to digital resources, academic performance,

sex, or other personal characteristics. No respondent received preferential treatment, and all participants completed the assessment under the same standardized testing conditions.

Transparency

The researcher maintains honesty, transparency, and integrity throughout the conduct of the investigation. The objectives, procedures, and intended use of the gathered data were clearly communicated to school authorities, parents, and participants prior to data collection. Data were analyzed and reported objectively without fabrication, falsification, selective reporting, or misrepresentation of findings. Both statistically significant and non-significant results were presented and interpreted faithfully based on the evidence obtained from the study. Any limitations encountered during the conduct of the investigation were likewise acknowledged in the manuscript. Furthermore, the researcher declared that no conflict of interest existed that could have influenced the conduct, analysis, interpretation, or reporting of the study.

Qualifications of the Researcher

The researcher possesses adequate academic preparation and training in educational research, assessment, and data

analysis necessary to conduct the study responsibly. The researcher likewise sought guidance from qualified research advisers and subject-matter experts to ensure methodological rigor and ethical compliance throughout the research process.

Adequacy of Facilities

The study was conducted in a safe, organized, and appropriate school environment conducive to data collection and assessment administration. Available classrooms and school facilities were utilized to ensure that participants completed the assessment tasks comfortably and without unnecessary distractions. Standardized testing conditions, including consistent instructions, adequate seating arrangements, and sufficient time allocation, were observed throughout the administration of the assessment instrument.

Community Involvement

The study recognized the importance of collaboration and coordination with the school community throughout the conduct of the research. Prior to data collection, coordination was undertaken with school administrators, Grade 10 mathematics teachers, parents or guardians, and other relevant stakeholders to ensure that the study aligned with the educational context and institutional policies of the school. Upon completion of the research, the findings and the proposed enhancement program were shared with the school community to support collaborative efforts aimed at improving mathematics assessment practices, mathematical reasoning, and critical thinking among students.

Presentation and Analysis of Results

This chapter presents the data gathered, the results of the statistical analysis done and interpretation of findings. These are presented in tables following the sequence of the specific research problem regarding the Mathematical Reasoning and Critical Thinking of Grade 10 Students.

Level of Mathematical Reasoning of Grade 10 Students

The results of the level of mathematical reasoning of grade 10 students when taken as a whole and grouped according to socio-economic status, access to digital resources and academic performance are shown in Table 2.

Table 2 shows that the level of mathematical reasoning of the Grade 10 students is Low Proficient ($M = 18.9$, $SD = 11.5$). When grouped according to socio-economic status, access to digital resources, and academic performance, all groups demonstrated a Low Proficient of mathematical reasoning, with mean scores ranging from 15.2 to 22.6. The standard deviations, ranging from 10.0 to 11.7, indicate moderate variability in students' mathematical reasoning scores within each subgroup.

The findings imply that students have not yet attained the expected level of mathematical reasoning required for higher-order mathematical thinking.

Table 2 Level of Mathematical Reasoning of Grade 10 Students When Taken as a Whole and Grouped According to Socio-Economic Status, Access to Digital Resources and Academic Performance

Grouping Variable	<i>M</i>	VI	<i>SD</i>
A. As a Whole	18.9	LP	11.5
B. Socio-Economic Status			
High	22.6	LP	11.1
Middle	19.1	LP	11.6

Low	17.0	LP	11.1
C. Access to Digital Resources			
High	20.6	LP	11.5
Moderate	17.9	LP	11.7
Low	19.6	LP	10.3
D. Academic Performance			
High	21.1	LP	11.6
Above Average	18.5	LP	11.4
Average	16.5	LP	11.4
Below Average	15.2	LP	10.0

Note. 0.00–12.49– Not Proficient (NOP); 12.50-24.99 –Low Proficient (LP); 25.00-37.49- Nearly Proficient (NP); 37.50–44.99– Proficient (P); 45.00–50.00– High Proficient (HP)

The findings are strongly supported by OECD (2023), which emphasized that many students continue to struggle with mathematical reasoning because they find it difficult to formulate, employ, and interpret mathematics in real-world situations.

Similarly, Mullis et al. (2020) reported in the TIMSS 2019 International Results in Mathematics and Science that the reasoning cognitive domain remains the most challenging area for students across participating countries. Many students perform better on routine computational tasks than on items requiring analysis, justification, and higher-order reasoning. Furthermore, the findings are consistent with EDCOM II (2024) and

EDCOM II (2025), which identified weaknesses in Filipino students' higher-order thinking skills. These reports noted that classroom instruction and assessment often emphasize factual recall and procedural knowledge, limiting students' opportunities to develop mathematical reasoning and critical thinking. The consistently Low Proficient performance across all learner groups in the present study reflects these national concerns and highlights the need for more authentic and reasoning-focused mathematics instruction

Level of Critical Thinking of Grade 10 Students

The results of the level of critical thinking of grade 10 students when taken as a whole and grouped according to socio-economic status, access to digital resources and academic performance are shown in Table 3.

Table 3 shows that the overall level of critical thinking of the Grade 10 students is Low Proficient ($M = 13.2$, $SD = 9.1$). When grouped according to socio-economic status, the level of students in low socio-economic status ($M = 12.0$, $SD = 8.9$) is Not Proficient while the other groups are Low Proficient with means ranging from 13.4 to 13.6.

Regarding the access to digital resources, students belong to the moderate access to digital resources ($M = 12.3$, $SD = 9.0$) obtained a Not Proficient level, in contrast, Low Proficient level were obtained by other groups with means ranging from 14.3 to 15.1. In terms of academic performance, both high and above average academic performance groups demonstrated a Low Proficient level of critical thinking, with mean scores ranging from 13.5 to 14.1. Whereas both the average and below average academic performance

groups attained a Low Proficient level of critical thinking, with mean scores ranging from

10.7 to 11.5. The standard deviations, ranging from 7.1 to 9.4, indicate moderate variability in students'

mathematical reasoning scores within each subgroup.

Table 3 Level of Critical Thinking of Grade 10 Students When Taken as a Whole and Grouped According to Socio-Economic tatus, Access to Digital Resources and Academic Performance

Grouping Variable	<i>M</i>	VI	<i>SD</i>
A. As a Whole	13.2	LP	9.1
B. Socio-Economic Status			
High	13.4	LP	7.1
Middle	13.6	LP	9.4
Low	12.0	NOP	8.9
C. Access to Digital Resources			
High	14.3	LP	9.0
Moderate	12.3	NOP	9.0
Low	15.1	LP	9.1
D. Academic Performance			
High	14.1	LP	9.0
Above Average	13.5	LP	9.1
Average	11.5	NOP	8.8
Below Average	10.7	NOP	9.1

Note. 0.00–12.49– Not Proficient (NOP); 12.50-24.99 –Low Proficient (LP); 25.00-37.49- Nearly Proficient (NP); 37.50–44.99– Proficient (P); 45.00–50.00– High Proficient (HP)

These findings indicate that students demonstrated limited ability analyzing information, evaluating evidence, drawing logical conclusions, and making reasoned decisions when presented with authentic mathematical situations. Therefore, mathematics

instruction needs to foster classroom learning experiences that provide more opportunities to develop critical thinking through higher-order and data-based tasks.

The findings are consistent with OECD (2023), which emphasized that students are expected to analyze information, evaluate evidence, and make sound judgments when solving real-world mathematical problems. However, many students continue to struggle with these higher-order thinking processes, as reflected in international assessment results. Similarly, EDCOM II (2024, 2025) highlighted persistent weaknesses in Filipino learners' higher-order thinking skills and recommended strengthening classroom instruction and assessment beyond factual recall and routine procedures to better develop reasoning, critical thinking, and problem-solving competencies. These reports recommend strengthening classroom assessment through authentic and inquiry-based learning experiences. The results also support Facione et al. (2020) described critical thinking as the ability to interpret information, analyze arguments, evaluate evidence, make logical inferences, and formulate reasoned judgments. The generally Low Proficient performance in this study suggests that many students have not yet fully developed these essential critical thinking skills. Furthermore, the findings align with DepEd Order No. 15, s. 2026, which emphasizes that classroom assessment under the MATATAG Curriculum should promote higher-order thinking by engaging students in authentic tasks that require reasoning, analysis, evaluation, and evidence-based decision-making rather than simple recall of knowledge.

Difference in the Level of Mathematical Reasoning

The results of the difference in the level of mathematical reasoning when grouped according to socio-economic status are shown in Table 4.

Table 4 One-Way ANOVA Results Comparing Mathematical Reasoning Scores by Socio-Economic Status

Variable	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Socio-Economic Status	861.51	2	430.76	3.28*	.039
Residuals (Error)	51430.59	392	131.20		

Note. *SS* = Sum of Squares; *df* = degree of freedom; *MS* = Mean Square. Type III Sum of Squares used. Levene's test for equality of variances was non-significant, $F(2, 392) = 0.58, p = .568$. ** $p < .01$

Table 4 presents the results of the one-way between-subjects analysis of variance (ANOVA) conducted to determine whether mathematical reasoning scores differed according to socio-economic status. Prior to the analysis, the assumption of homogeneity of variances was examined using Levene's test, which yielded a non-significant result, $F(2, 392) = 0.58, p = .568$, indicating that the assumption of equal variances was satisfied.

The ANOVA revealed a statistically significant effect of socio-economic status on mathematical reasoning scores, $F(2, 392) = 3.28, p = .039$. This finding indicates that

mathematical reasoning differed significantly across at least one pair of socio-economic status groups. Consequently, Tukey's Honestly Significant Difference (HSD) post hoc test was performed to determine which specific groups means differed significantly. It is appropriate for conducting all pairwise comparisons among group means (Field, 2018).

he results are shown in Table 5.

Table 5 Tukey HSD Post Hoc Comparisons of Mathematical Reasoning by Socio-Economic Status

(I)Socio-Economic Status	(J) Socio-Economic Status	Mean Difference (I-J)	Std. Error	df	t	p
High	Low	5.58	2.22	392	2.51*	.033
	Middle	3.52	2.04	392	1.73	.196
Low	Middle	-2.06	1.34	392	-1.54	.275

Note. $N = 395$. *SE* = standard error. *p*-values adjusted for a family of 4 estimates using Tukey's *HSD* correction. * $p < .05$.

The primary objective of this analysis was to investigate whether differences in mathematical reasoning exist across various levels of socio-economic status. The post hoc comparisons, evaluated using Tukey's HSD test, revealed a nuanced pattern of results. Specifically, a statistically significant difference in mathematical reasoning scores was observed exclusively between the High Socio-Economic Status group and the Low Socio-Economic Status group (Mean Difference = 5.58, $t(392) = 2.51, p = .033$). This result indicated that students at the highest socio-economic level demonstrated significantly stronger mathematical reasoning than those at the lowest level.

Interestingly, no other pairwise comparisons reached statistical significance at the conventional $\alpha = .05$ level. The mathematical reasoning scores of the Low group didnot significantly differ from those of the Middle ($p = .275$). Similarly, the difference between the High and Middle groups was not significant ($p = .196$).

The findings are strongly supported by OECD (2023), which reported that socioeconomic status is one of the strongest predictors of students' mathematics performance. Students from more advantaged socio-economic

backgrounds generally achieve higher mathematics scores because they have greater access to educational resources, learning materials, supportive home environments, and opportunities that promote higher-order thinking. Similarly, EDCOM II (2025) emphasized that disparities in family economic conditions contribute to differences in learning outcomes among Filipino students.

Students from disadvantaged households often have fewer educational resources and learning opportunities, which can hinder the development of higher-order thinking skills such as mathematical reasoning. The results also agree with Mullis et al. (2020), who reported in the TIMSS 2019 study that students with greater educational support and more favorable home learning environments generally perform better in mathematics, particularly on tasks requiring reasoning and problem solving rather than routine computation. Overall, these studies support the present finding that students from higher socio-economic backgrounds tend to demonstrate stronger mathematical reasoning than those from lower socio-economic backgrounds because of differences in educational support and learning opportunities.

The results of the difference in the level of mathematical reasoning when grouped according to access to digital resources are shown in Table 6.

Table 6 presents the results of the one-way between-subjects analysis of variance (ANOVA) conducted to determine whether mathematical reasoning scores differed according to students' level of access to digital resources. Prior to the analysis, the assumption of homogeneity of variances was examined using Levene's test, which yielded a non-significant result, $F(2, 392) = 0.55, p = .580$, indicating that the assumption of equal variances was satisfied. The ANOVA revealed no statistically significant effect of access to digital resources on mathematical reasoning scores, $F(2, 392) = 2.15$,

$p = .118$.

Table 6 One-Way ANOVA Results Comparing Mathematical Reasoning Scores by Access to Digital Resources

Variable	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Access to Digital Resources	566.67	2	283.34	2.147	.118
Residuals (Error)	51725.42	392	131.95		

Note. *SS* = Sum of Squares; *df* = degree of freedom; *MS* = Mean Square. Type III Sum of Squares used. Levene's test for equality of variances was non-significant, $F(2, 392) = 0.55, p = 0.580$. ** $p < .01$.

The findings indicate that access to digital resources does not significantly influence the mathematical reasoning of Grade 10 students. This suggests that simply having greater access to digital devices or internet connectivity does not necessarily improve students' ability to analyze, justify, and solve mathematical problems.

The findings are consistent with OECD (2023), which reported that access to digital technology alone does not guarantee improved mathematics performance. The PISA 2022 Mathematics Framework emphasizes that learning outcomes depend more on how technology is meaningfully integrated into teaching and learning than on students' mere access to digital devices or the internet. Similarly, Franklin et al. (2020), in the GAISE II Report, emphasized that digital tools contribute to students' mathematical reasoning only when they are used to engage students in authentic data exploration, analysis, interpretation, and problem solving. Simply providing access to technology is insufficient to develop higher-order thinking skills. The findings also support DepEd Order No. 15, s. 2026, which underscores that the development of mathematical reasoning depends on the use of authentic, learner-centered, and higher-order assessment tasks rather than the availability of digital resources alone. The policy emphasizes that instructional strategies and meaningful assessment practices are more critical in promoting reasoning and problem-solving skills than access to technology itself. Overall, these studies suggest that the educational use of technology, rather than its availability alone, is what contributes to the development of mathematical reasoning.

The results of the difference in the level of mathematical reasoning when grouped according to academic performance are shown in Table 7.

Table 7 shows the results of a one-way between-subjects omnibus analysis of variance (ANOVA) which was conducted to evaluate the effect of academic performance level on mathematical reasoning scores. Prior to analysis, the assumption of homogeneity

of variance was tested and satisfied via Levene's test, $F(3, 391) = 0.91, p = .438$, indicating that the group variances were sufficiently equal.

Table 7 One-Way ANOVA Results Comparing Mathematical Reasoning Scores by Academic Performance

Variable	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Academic Performance	1603.98	3	534.66	4.12**	.007
Residuals (Error)	50688.12	391	129.64		

Note. *SS* = Sum of Squares; *df* = degree of freedom; *MS* = Mean Square. Type III Sum of Squares used. Levene's test for equality of variances was non-significant, $F(3, 391) = 0.91, p = .438$. ** $p < .01$.

The omnibus ANOVA revealed a statistically significant main effect of academic performance tier on mathematical reasoning capabilities, $F(3, 391) = 4.12, p = .007$. This significant *F*-statistic indicates that mathematical reasoning scores differed across at least two of the academic performance groups. Because the omnibus test was significant, post hoc comparisons were evaluated using Tukey's HSD test to isolate specific pairwise differences. It is appropriate for conducting all pairwise comparisons among group means (Field, 2018). The results are shown in Table 8.

The primary objective of this analysis was to investigate whether differences in mathematical reasoning exist across various levels of academic performance. The post hoc comparisons, evaluated using Tukey's HSD test, revealed a nuanced pattern of results. Specifically, a statistically significant difference in mathematical reasoning scores

was observed exclusively between the Average Academic Performance group and the High Academic Performance group (Mean Difference = -4.70, $t(391) = -2.95, p = .017$).

Table 8 Tukey HSD Post Hoc Comparisons of Mathematical Reasoning by Academic Performance

(I)Academic Performance	(J)Academic Performance	Mean Difference (I-J)	Std. Error	<i>df</i>	<i>t</i>	<i>p</i>
Above Average	Below Average	3.26	2.43	391	1.34	.538
	Average	2.01	1.61	391	1.25	.593
	High	-2.69	1.34	391	-2.01	.185
Average	Below Average	1.24	2.58	391	0.48	.963
	High	-4.70	1.59	391	-2.95*	.017
Below Average	High	-5.94	2.42	391	-2.46	.069

Note. $N = 395$. *SE* = standard error. *p*-values adjusted for a family of 6 estimates using Tukey's *HSD* correction. * $p < .05$.

This finding indicates that individuals classified within the highest tier of academic performance demonstrated significantly superior mathematical reasoning capabilities compared to their peers in the average tier.

Interestingly, no other pairwise comparisons reached statistical significance at the conventional $\alpha = .05$ level.

The mathematical reasoning scores of the Above Average group did not significantly differ from those of the Average ($p = .593$), Below Average ($p = .538$), or High ($p = .185$) performance groups. Similarly, the difference between the Average and Below Average groups was negligible ($p = .963$).

The findings are supported by OECD (2023), which emphasized that students with stronger academic achievement generally perform better in mathematical reasoning because they are better able to apply mathematical knowledge, analyze information, and solve real-world problems. The PISA 2022 Mathematics Framework highlights that successful students demonstrate not only content knowledge but also the ability to reason and justify mathematical decisions. Similarly, Mullis et al. (2020) reported in the TIMSS 2019 International Results in Mathematics and Science that students with higher levels of mathematics achievement consistently perform better on reasoning tasks than those with lower achievement levels. High-achieving students are more capable of analyzing mathematical situations, making logical connections, and solving non-routine problems. The findings also align with NCTM (2018), which emphasized that mathematical reasoning is a fundamental component of mathematical proficiency and is strengthened through continuous engagement with challenging mathematical tasks. Students who achieve higher academic performance are more likely to have developed these reasoning skills through meaningful learning experiences. Overall, these studies support the present finding that students with higher academic performance tend to demonstrate stronger mathematical reasoning.

Difference in the Level of Critical Thinking of Grade 10 Students

The results of the difference in the level of critical thinking when grouped according to socio-economic status are shown in Table 9.

Table 9 shows the results of a one-way between-subjects omnibus analysis of variance (ANOVA) which was conducted to evaluate the effect of socio-economic status on critical thinking scores. Prior to analysis, the assumption of homogeneity of variance was tested and satisfied via Levene's test, $F(2, 392) = 2.67$, $p = .071$, indicating that the group variances were sufficiently equal. The omnibus ANOVA revealed no statistically significant difference in critical thinking scores according to socio-economic status, $F(2, 392) = 1.12$, $p = .328$.

Table 9 One-Way ANOVA Results Comparing Critical Thinking Scores by Socio-Economic Status

Variable	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Socio-Economic Status	184.01	2	92.01	1.12	.328
Residuals (Error)	32235.01	392	82.23		

Note. *SS* = Sum of Squares; *df* = degree of freedom; *MS* = Mean Square. Type III Sum of Squares used. Levene's test for equality of variances was non-significant, $F(2, 392) = 2.67$, $p = .071$. $**p < .01$

This suggests that students from different socio-economic backgrounds demonstrated comparable levels of critical thinking. The findings are supported by Facione et al. (2020) explained that critical thinking is a set of cognitive skills involving interpretation, analysis, evaluation, inference, and reasoned judgment that can be developed through appropriate instruction and practice. This suggests that students' critical thinking is not determined solely by their socio-economic background. Similarly, OECD (2023) emphasized that higher-order thinking skills, including critical thinking,

are developed through meaningful learning experiences that require students to analyze information, evaluate evidence, and solve authentic problems. The framework highlights the importance of learning opportunities and classroom practices rather than socioeconomic status alone.

The findings also align with DepEd Order No. 15, s. 2026, which emphasizes that classroom assessment should promote higher-order thinking by engaging students in authentic, inquiry-based, and performance-oriented tasks.

This policy suggests that well-designed instruction and assessment can help develop critical thinking among students regardless of their socio-economic background. Overall, these studies support the present finding that critical thinking does not significantly differ according to socio-economic status, indicating that the development of critical thinking depends more on the quality of teaching, assessment, and learning experiences than on students' economic circumstances alone.

The results of the difference in the level of critical thinking when grouped according to access to digital resources are shown in Table 10.

Table 10 presents the results of the one-way between-subjects analysis of variance (ANOVA) conducted to determine whether critical thinking scores differed according to students' level of access to digital resources. Prior to the analysis, Levene's test yielded a non-significant result, $F(2, 392) = .01$, $p = .995$, indicating that the assumption of homogeneity of variances was satisfied. The ANOVA revealed no statistically significant difference in access to digital resources on critical thinking scores, $F(2, 392) = 2.83$,

$p = .060$. This suggests that simply having access to digital devices or the internet does not necessarily improve students' ability to analyze information, evaluate evidence, and make reasoned judgments. The development of critical thinking likely depends more on how digital resources are used during instruction than on their availability alone.

Table 10 One-Way ANOVA Results Comparing Critical Thinking Scores by Access to Digital Resources

Variable	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Access to Digital Resources	460.68	2	230.34	2.83	.060
Residuals (Error)	31958.33	392	81.526		

Note. *SS* = Sum of Squares; *df* = degree of freedom; *MS* = Mean Square. Type III Sum of Squares used. Levene's test for equality of variances was non-significant, $F(2, 392) = .01$, $p = .995$. ** $p < .01$

The findings are supported by OECD (2023), which emphasized that access to digital technology alone does not automatically improve higher-order thinking skills. Rather, learning outcomes depend on how technology is meaningfully integrated into teaching and learning activities that promote analysis, reasoning, and problem solving. Similarly, Franklin et al. (2020), in the GAISE II Report, explained that digital technologies enhance critical thinking only when students actively engage in authentic data investigations, interpretation, and evidence-based decision-making. Merely providing access to digital devices is insufficient to develop higher-order cognitive skills. The findings also align with DepEd Order No. 15, s. 2026, which emphasizes that

classroom assessment should provide authentic, inquiry-based, and performance-oriented tasks that develop critical thinking. The policy highlights that effective instructional strategies and meaningful learning experiences, rather than access to technology alone, are essential for fostering higher-order thinking. Overall, these studies support the present finding that critical thinking does not significantly differ according to students' access to digital resources, suggesting that the effective use of technology in instruction is more important than its availability alone in developing critical thinking skills.

The results of the difference in the level of critical thinking when grouped according to academic performance are shown in Table 11.

Table 11 One-Way ANOVA Results Comparing Critical Thinking Scores by Academic Performance

Variable	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Academic Performance	523.91	3	174.64	2.14	.095
Residuals (Error)	31895.11	391	81.57		

Note. SS = Sum of Squares; df = degree of freedom; MS = Mean Square. Type III Sum of Squares used. Levene's test for equality of variances was non-significant, $F(3, 391) = .16, p = .923$. $**p < .01$

Table 11 presents the results of the one-way between-subjects analysis of variance (ANOVA) conducted to determine whether critical thinking scores differed according to students' academic performance. Prior to the analysis, Levene's test yielded a non-significant result, $F(3, 391) = 0.16, p = .923$, indicating that the assumption of homogeneity of variances was satisfied. The ANOVA revealed no statistically significant

effect of academic performance on critical thinking scores, $F(3, 391) = 2.14, p = .095$. The findings indicate that academic performance does not significantly influence the critical thinking of Grade 10 students. This suggests that students with varying levels of academic achievement demonstrated comparable critical thinking abilities.

The findings are supported by Facione et al. (2020) emphasized that critical thinking is a learned cognitive skill developed through deliberate instruction, reflective thinking, and continuous practice in analysis, evaluation, and reasoning. This suggests that students' academic grades alone do not necessarily reflect their level of critical thinking. Similarly, OECD (2023) emphasized that higher-order thinking skills, including critical thinking, are developed through learning experiences that require students to interpret information, evaluate evidence, and solve authentic problems. The framework highlights that these competencies are fostered through meaningful classroom tasks rather than by academic achievement alone. The findings also align with DepEd Order No. 15,

s. 2026, which emphasizes that classroom assessment should develop higher-order thinking through authentic, performance-based, and inquiry-oriented activities. The policy recognizes that critical thinking is best cultivated through appropriate instructional and assessment practices rather than measured solely by students' academic grades. Overall, these studies support the present finding that critical thinking does not significantly differ according to academic performance, indicating that strong academic achievement does not automatically translate into stronger critical thinking skills. Instead, the development of critical thinking depends largely on the quality of learning experiences and opportunities for higher-order thinking in the classroom.

Difference in the Relationships Between Mathematical Reasoning and Critical Thinking

The results of the difference in the relationships between mathematical reasoning and critical thinking are shown in Table 12.

Table 12 Spearman's Rank-Order Correlation Between Mathematical Reasoning and Critical Thinking

Variable	1	2
1. Mathematical Reasoning	—	
2. Critical Thinking	.62**	—

Note. $N = 395$; $**p < .01$.

Table 12 shows the relationship between mathematical reasoning and critical thinking skills. Spearman's rank-order correlation was used because the data did not satisfy the assumptions required for Pearson's correlation, particularly the assumption of normality, making it appropriate for examining the strength and direction of the monotonic relationship between the two variables. The results indicated a statistically significant, strong positive relationship between the two constructs, $r_s(393) = .62$,

$p < .001$. This finding suggests that individuals who exhibit higher proficiencies in mathematical reasoning also tend to demonstrate stronger critical thinking capabilities.

These results align closely with cognitive load and dual-process theories, which suggest that both mathematical problem-solving and higher-order critical thinking draw from shared executive functioning resources, such as

working memory and analytical processing. The robust correlation observed in this sample ($N = 395$) underscores the idea that mathematical reasoning is not merely an isolated algorithmic skill, but rather an intrinsic component of broad-scale logical evaluation.

The findings are strongly supported by OECD (2023), which emphasized that mathematical reasoning is central to mathematical literacy and requires students to analyze information, interpret data, justify conclusions, and make evidence-based decisions. These same cognitive processes are fundamental components of critical thinking, explaining the close relationship between the two constructs. Similarly, Facione et al. (2020) described critical thinking as involving interpretation, analysis, evaluation, inference, and reasoned judgment. These cognitive skills closely parallel the processes used in mathematical reasoning, such as examining evidence, recognizing patterns, drawing logical conclusions, and justifying solutions. Consequently, students who demonstrate stronger mathematical reasoning are also more likely to exhibit stronger critical thinking skills. The findings also agree with NCTM (2018), which emphasized that mathematical reasoning is an essential aspect of mathematical proficiency and should be developed through problem solving, justification, communication, and reflection.

These learning experiences simultaneously cultivate critical thinking because they require students to evaluate evidence, explain their reasoning, and defend their conclusions.

Furthermore, the results are consistent with Mullis et al. (2020), who reported in the

TIMSS 2019 International Results in Mathematics and Science that reasoning tasks require students to analyze situations, justify solutions, and apply higher-order thinking skills. These cognitive demands overlap substantially with the core components of critical thinking, supporting the strong positive relationship observed between the two variables in the present study.

Predictor of Critical Thinking Using Data-Science Infused Assessment

The results of the Predictor of Critical Thinking Using Data-Science Infused Assessment are shown in Table 13 and 14.

Table 13 Model Summary for the Regression Analysis of Mathematical Reasoning Predicting Critical Thinking

Model	R	R^2	Adjusted R^2	F	df	p
M ₁	.62	.38	.38	239.49**	(1,393)	<.001

Note. $N = 395$. Predictor: (Constant), Mathematical Reasoning. Dependent Variable: Critical Thinking. ** $p < .01$

The results of the regression revealed that mathematical reasoning explained a statistically significant and substantial proportion of variance in critical thinking scores, $R^2 = .38$, $F(1, 393) = 239.49$, $p < .001$. According to Cohen's (1988) guidelines, this represents a large effect size, indicating that approximately 38% of the variance in critical thinking is uniquely accounted for by mathematical reasoning capacity.

Table 14 Regression Coefficients for Mathematical Reasoning Predicting Critical Thinking

Predictor	B	SE	β	t	P
(Constant)	4.00	.69		5.77**	<.001
Mathematical Reasoning	.49	.03	.62	15.48**	<.001

Note. B = unstandardized regression coefficient; SE = standard error; β = standardized regression coefficient. $**p < .01$.

The specific regression equation used to predict critical thinking from mathematical reasoning was:

Critical Thinking = $4.00 + 0.49$ (Mathematical Reasoning) Mathematical reasoning was a significant positive predictor of critical thinking,

$B = 0.49$, $SE = .03$, $\beta = .62$, $t(393) = 15.48$, $p < .001$. The standardized coefficient indicates that for every standard deviation increase in mathematical reasoning, critical thinking scores increase by 0.62 standard deviations. Complete model summary and regression coefficients are presented in Table 13 and Table 14, respectively.

The primary objective of this analysis was to evaluate the predictive relationship between mathematical reasoning and critical thinking. The findings strongly support the hypothesized model, demonstrating that higher levels of mathematical reasoning are associated with superior critical thinking outcomes. This robust positive relationship aligns with existing cognitive psychology frameworks which suggest that the logical

frameworks utilized in structured mathematical problem-solving fundamentally underpin broader evaluative domains.

The findings are strongly supported by OECD (2023), which emphasized that mathematical reasoning is a core component of mathematical literacy because it requires students to analyze information, interpret evidence, justify conclusions, and solve real-world problems. These same cognitive processes are fundamental to critical thinking, making mathematical reasoning an important contributor to the development of higher-order thinking skills. Similarly, Facione et al. (2020) explained that critical thinking involves interpretation, analysis, evaluation, inference, and reasoned judgment. These cognitive skills closely align with the processes involved in mathematical reasoning, suggesting that students who reason effectively in mathematics are more likely to demonstrate stronger critical thinking. The findings also agree with NCTM (2018), which emphasized that mathematical reasoning should be at the center of mathematics instruction because it enables students to construct arguments, justify solutions, evaluate evidence, and make logical decisions. These practices simultaneously strengthen critical thinking by engaging students in higher-order cognitive processes. Furthermore, the results are consistent with Mullis et al. (2020), who reported in the TIMSS 2019 International Results in Mathematics and Science that reasoning tasks require students to analyze situations, draw logical conclusions, and justify their answers. Since these reasoning processes overlap with the essential components of critical thinking, stronger mathematical reasoning is expected to contribute to higher levels of critical thinking.

Overall, the present findings reinforce the view that mathematical reasoning is an

important predictor of critical thinking, highlighting the value of integrating reasoning-rich and authentic mathematical tasks into classroom instruction to enhance students' higher-order thinking skills.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the summary of the study, the conclusions drawn from the findings, and the recommendations based on the results.

Summary

This study employed a quantitative descriptive-correlational research design to examine the mathematical reasoning and critical thinking of 395 out of 1050 Grade 10 students using data-science-infused assessments in a selected public secondary school in the northern part of Negros Occidental during the School Year 2025–2026. Specifically, the study determined the levels of mathematical reasoning and critical thinking when participants were considered

as a whole and when grouped according to socio-economic status, access to digital resources, and academic performance. It likewise examined whether significant differences existed in mathematical reasoning and critical thinking across the identified grouping variables, determined the relationship between mathematical reasoning and critical thinking, investigated whether mathematical reasoning significantly predicts critical thinking, and used the findings as the basis for developing an instructional enhancement program for Grade 10 mathematics instruction.

Data were gathered using a 40-item researcher-developed, validated, and reliability-tested assessment instrument consisted of mathematical reasoning and critical thinking test. Mean and standard deviation, were used to determine the levels of mathematical reasoning and critical thinking. One-way Analysis of Variance (ANOVA)

was employed to determine significant differences among groups. Tukey's (HSD) post hoc test was performed if the omnibus ANOVA yielded a statistically significant result to determine which specific group pairs differed significantly. Spearman's rank-order correlation was used to determine the relationship between mathematical reasoning and critical thinking, while simple linear regression analysis was conducted to determine whether mathematical reasoning significantly predicts critical thinking. All statistical tests were evaluated at the 0.05 level of significance.

The following findings were obtained:

The overall level of mathematical reasoning of Grade 10 students was Low Proficient. When grouped according to socio-economic status, access to digital resources and academic performance the levels were Low Proficient.

The Grade 10 students' overall level of critical thinking was Low Proficient.

When grouped according to socio-economic status, students belong to low socioeconomic status was Not Proficient while those who belong to high and middle socio-economic status were Low Proficient level. Regarding access to digital resources, Not Proficient level was obtained by students in moderate access to digital resources while Low Proficient levels were attained by students in low and high access to digital resources. In terms of academic performance, students with high and above average academic performance demonstrated Low Proficient levels whereas, Not Proficient levels were observed in students with average and below average academic performance.

A statistically significant difference in mathematical reasoning was found when students were grouped according to socio-economic status. Post hoc analysis revealed that students with high socio-economic status obtained significantly higher mathematical reasoning scores than students with low socio-economic status, while no significant differences were observed among the remaining pairwise comparisons. On the other hand, no statistically significant difference existed in mathematical reasoning when students were grouped according to access to digital resources. Whereas, a statistically significant difference in mathematical reasoning was found when students were grouped according to academic performance. Post hoc analysis indicated significant difference occurred only between students with high academic performance and those with average academic performance, while no significant differences were observed among the remaining pairwise comparisons.

No statistically significant difference in critical thinking was found when students were grouped according to socio-economic status, access to digital resources and academic performance. A statistically significant positively strong relationship existed between mathematical reasoning and critical thinking of Grade 10 students.

Mathematical reasoning was found statistically significant positive predictor of critical thinking.

CONCLUSIONS

Based on the findings of the study, the following conclusions were drawn:

1. The Grade 10 students generally demonstrated a low proficient level of mathematical reasoning regardless of

socio-economic status, access to digital resources, and academic performance indicating that students demonstrated limited ability in analyzing mathematical situations, recognizing relationships, constructing logical arguments, and justifying solutions in authentic, data-science-infused assessment tasks.

2. The generally low proficient level of critical thinking of Grade 10 students, although variations in levels were observed across some groups, indicates that higher-order thinking skills remain insufficiently developed among the students.
3. The mathematical reasoning of students vary based on their socio-economic status, particularly between students from high and low socio-economic backgrounds. This suggests that differences in learning opportunities and educational support associated with socio-economic conditions may contribute to students' mathematical reasoning. This implies that the availability of digital devices or internet access is not sufficient to improve mathematical reasoning without meaningful instructional use. Whereas, the academic performance is associated with students' mathematical reasoning, as students with higher academic performance demonstrated stronger mathematical reasoning than those with average academic performance. This indicates that stronger academic achievement is accompanied by better reasoning ability.
4. The critical thinking did not significantly differ according to socio-economic status, indicating that students from different socio-economic backgrounds demonstrated comparable levels of critical thinking. Likewise, the students with varying levels of access to digital resources exhibited similar levels of critical thinking. Also, the critical thinking did not significantly differ according to academic performance, indicating that students with varying levels of academic achievement demonstrated comparable levels of critical thinking.
5. Mathematical reasoning and critical thinking were strongly and positively correlated, indicating that students with higher mathematical reasoning scores generally tended to demonstrate higher critical thinking scores.
6. Mathematical reasoning is an important predictor of critical thinking. This indicates that strengthening students' mathematical reasoning may contribute to the improvement of their critical thinking, although other factors not examined in the study may also influence critical thinking.

Recommendations

Considering the findings and conclusions of the study, the following recommendations are offered:

The Grade 10 students may be encouraged to actively strengthen their mathematical reasoning and critical thinking by engaging in learning activities that require them to analyze mathematical situations, interpret authentic data, evaluate evidence, explain their reasoning, and justify their solutions. They are likewise encouraged to participate in collaborative discussions, reflective learning activities, and inquiry-based mathematical tasks that provide opportunities to demonstrate higher-order thinking skills.

The mathematics teachers may provide regular opportunities for students to engage in authentic, data-science-infused assessment tasks that require interpretation of real-world data, analysis of quantitative evidence, evaluation of alternative solution strategies, and justification of mathematical conclusions. Teachers are likewise encouraged to implement differentiated instructional strategies that address the varying mathematical reasoning abilities of students, particularly those demonstrating lower reasoning performance, while providing enrichment activities that challenge higher-performing students.

The parents and guardians may be encouraged to provide a supportive home learning environment that promotes mathematical reasoning and critical thinking. They may encourage their children to engage in meaningful discussions, solve real-life mathematical problems, interpret data presented in everyday situations, and explain their reasoning when making decisions. Regardless of socio-economic background, parents can support their children's learning by showing interest in their academic progress, fostering positive study habits, and encouraging persistence

in solving challenging tasks. Such involvement may help strengthen students' higher-order thinking skills and complement classroom learning experiences.

The school principal may strengthen school-based instructional support by promoting classroom assessment practices that emphasize reasoning, critical thinking, and authentic problem solving consistent with the goals of the MATATAG Curriculum. Learning Action Cell (LAC) sessions, in-service training (INSET), workshops, and professional learning communities may be conducted to enhance teachers' competencies in designing authentic assessment tasks, facilitating mathematical discourse, integrating real-world data into mathematics instruction, and assessing higher-order thinking skills. Schools may likewise provide instructional resources that support the implementation of contextualized and evidence-based mathematics learning experiences.

The Curriculum Implementation Division personnel may utilize the findings of this study in strengthening the implementation of mathematics instruction and classroom assessment across schools. Division-level initiatives may focus on developing contextualized instructional materials, exemplar lesson plans, and authentic assessment exemplars that integrate mathematical reasoning, critical thinking, and data literacy consistent with the MATATAG Curriculum, DepEd Order No. 15, s. 2026, and international frameworks such as PISA and TIMSS. Capability-building programs may also be conducted to enhance teachers' knowledge and skills in designing and implementing data-science-infused assessment tasks that provide authentic opportunities for students to demonstrate higher-order thinking.

The researcher may disseminate the findings of the study to school administrators, mathematics teachers, curriculum specialists, and other educational stakeholders to support evidence-informed decision-making related to mathematics instruction and

assessment. The findings may likewise serve as a basis for developing, implementing, and evaluating school-based intervention programs that provide authentic opportunities for students to demonstrate mathematical reasoning and critical thinking through data-science-infused assessment.

The future researchers may investigate additional student, instructional, and contextual variables that may account for the remaining unexplained variance. These variables may include mathematical self-efficacy, mathematical anxiety, motivation, metacognitive awareness, self-regulated learning, classroom discourse, instructional quality, teacher pedagogical content knowledge, collaborative learning, parental involvement, and artificial intelligence-assisted mathematics instruction.

INSTRUCTIONAL INTERVENTION PLAN

Title: **PROJECT MRiCT (Mathematical Reasoning through Infused Data-Science Assessments for Critical Thinking):** An Instructional Intervention for Grade 10 Mathematics

Target Clientele: Grade 10 Students (Priority students demonstrating Low Mathematical Reasoning and Low Critical Thinking)

Program Duration: One Academic Quarter (9 Weeks)

Implementation Site: One Selected Public Secondary School, Northern Negros Occidental

Rationale

The findings of the present study revealed that Grade 10 students generally demonstrated low proficient levels of mathematical reasoning and critical thinking using data-science-infused assessment, indicating that many students continue to demonstrate limited ability in interpreting quantitative information, analyzing mathematical relationships, evaluating evidence, constructing logical arguments, and justifying mathematical conclusions in

authentic assessment tasks. The study further revealed that mathematical reasoning significantly differed according to socio-economic status and academic performance but did not differ according to access to digital resources. In contrast, critical thinking did not significantly differ according to socio-economic status, access to digital resources, or academic performance. These findings suggest that strengthening higher-order thinking skills should remain a priority for all students through equitable and meaningful learning experiences.

The study likewise established a strong positive relationship between mathematical reasoning and critical thinking. Moreover, mathematical reasoning was found to be a significant positive predictor of critical thinking, indicating that students with stronger mathematical reasoning also tend to demonstrate higher critical thinking. These findings underscore the importance of providing classroom learning experiences that intentionally develop mathematical reasoning through authentic problem-solving, evidence evaluation, and reasoning-based assessment tasks to support the development of higher-order thinking skills.

The proposed intervention is aligned with the goals of the MATATAG Curriculum and Department of Education Order No. 15, s. 2026, which emphasize classroom assessment as an integral component of teaching and learning that promotes reasoning, critical thinking, problem-solving, and evidence-based decision-making through authentic assessment practices. Likewise, the PISA 2022 Mathematics Framework (OECD, 2023) highlights mathematical literacy as students' ability to formulate, employ, and interpret mathematics in real-world contexts, while the TIMSS 2019 Assessment Framework (Mullis et al., 2020) identifies reasoning as the highest cognitive domain in mathematics. Furthermore, the EDCOM II (2024, 2025) reports emphasize the need to strengthen higher-order thinking skills among Filipino students by improving classroom instruction and assessment practices that extend beyond factual recall and routine procedures.

Project MRiCT is anchored on Cognitive Constructivist Theory, which explains that students construct knowledge through active engagement in meaningful learning

experiences, inquiry, reflection, and problem solving (Schunk, 2020). It is likewise grounded in Evidence-Centered Design (ECD), which emphasizes the development of assessment tasks that generate observable evidence of students' knowledge, reasoning, and higher-order thinking (Mislevy, 2018). These theoretical foundations support the integration of authentic datasets, contextualized mathematical investigations to develop students' mathematical reasoning and critical thinking.

In response to these findings, Project MRiCT (Mathematical Reasoning through Infused Data-Science Assessments for Critical Thinking) is proposed as a nine-week instructional intervention for Grade 10 Mathematics. The project integrates data-science-infused assessment to provide students with meaningful opportunities to analyze quantitative information, justify mathematical conclusions, evaluate evidence, and solve real-world problems. Ultimately, the intervention aims to strengthen students' mathematical reasoning and critical thinking while supporting the implementation of the MATATAG Curriculum and promoting more relevant and evidence-based mathematics learning.

General Objective

To improve the mathematical reasoning and critical thinking of Grade 10 students through authentic data-science-infused assessment activities.

Specific Objectives

At the end of the nine-week implementation of Project MRiCT (Mathematical Reasoning through Infused Data-Science Assessments for Critical Thinking), the participating Grade 10 students are expected to:

Demonstrate a statistically significant improvement in mathematical reasoning test, as evidenced by higher post-test scores compared with their pre-test scores using the Data-Science-Infused Assessment.

Demonstrate a statistically significant improvement in critical thinking, as evidenced by higher post-test scores compared with their pre-test scores using the Data-Science-Infused Critical Thinking Assessment.

Interpret and analyze authentic datasets by accurately identifying patterns, relationships, trends, and quantitative information in contextualized mathematical situations, with at least 80% proficiency based on teacher-developed analytic rubrics.

Construct and justify mathematical solutions by presenting logical arguments supported by appropriate mathematical evidence in authentic problem-solving tasks, with at least 80% of students achieving the Proficient level in the mathematical reasoning rubric.

Evaluate quantitative evidence and alternative solution strategies in contextualized mathematical investigations, with at least 80% of students demonstrating proficiency in evidence evaluation and decision-making based on established critical thinking rubrics.

Collaboratively complete an authentic community data investigation project by collecting, organizing, analyzing, interpreting, and presenting real-world data to support evidence-based mathematical conclusions, with 100% of student groups successfully completing and presenting their outputs. Demonstrate reflective thinking and metacognitive awareness by maintaining reflective mathematical journals that explain reasoning processes, justify conclusions, and identify alternative interpretations throughout the implementation of the intervention.

Produce a portfolio of authentic mathematical investigations containing completed data interpretation activities, reasoning tasks, reflective journals, performance assessments, and collaborative investigation outputs that demonstrate students' application of mathematical reasoning and critical thinking throughout the intervention period.

Implementation Matrix

Project MRiCT (Mathematical Reasoning through Infused Data-Science Assessments for Critical Thinking)

Phase	Activity/Strategy	Time Frame	Persons Involved	Resources Needed	Success Indicator
Pre-Implementation	Administer the Mathematical Reasoning and Critical Thinking Pre-Test; identify target students; orient mathematics teachers, school heads, parents, and students regarding the objectives, implementation procedures, and infused data-science assessment requirements of Project MRiCT.	Week 1 (1 session, 2 hours)	School Head, Mathematics Coordinator, Grade 10 Mathematics Teachers, Students, Parents	Research instrument, orientation materials, projector, student profiles, consent forms	100% of participating students complete the pre-test and orientation; baseline scores established for monitoring student progress.
Phase 1: Data Exploration	Data Detective Strategy – Students analyze authentic local and national datasets (e.g., weather,	Weeks 2–3 (2 sessions/week, 1 hour/session)	Mathematics Teachers	Local datasets, graphs, spreadsheets, worksheets, calculators,	At least 80% of students accurately interpret datasets and identify mathematical

	population, school attendance, waste generation, community health statistics) to identify trends, relationships, and mathematical patterns through guided inquiry activities.			printed modules	patterns based on analytic rubric scores.
Phase 2: Mathematical Reasoning	Claim–Evidence–Reasoning (CER) Strategy – Students solve contextualized mathematical problems by formulating mathematical claims, presenting supporting quantitative evidence, and providing logical mathematical justifications using structured reasoning templates.	Weeks 4–5 (2 sessions/week, 1 hour/session)	Mathematics Teachers	Data-science-infused activity sheets, CER templates, reasoning rubrics, contextualized datasets	At least 80% of students attain Proficient or higher ratings in mathematical reasoning based on the analytic rubric.
Phase 3: Critical Thinking and Decision-Making	Think–Analyze–Evaluate Framework – Students evaluate mathematical claims, identify misleading interpretations, compare multiple solution strategies, interpret graphical information, and defend evidence-based conclusions through collaborative classroom discussions.	Weeks 6–7 (2 sessions/week, 1 hour/session)	Mathematics Teachers	News articles, statistical reports, infographics, authentic datasets, evaluation worksheets	At least 80% of students demonstrate proficiency in evaluating evidence, comparing solution strategies, and defending mathematical conclusions using the critical thinking rubric.
Phase 4: Authentic Mathematical Investigation	Community Data Investigation Project – Student groups investigate authentic community issues using local datasets. They collect, organize, analyze, interpret, and present mathematical evidence to support recommendations addressing real-life situations.	Week 8 (2 sessions, 1.5 hours/session)	Mathematics Teachers, ICT Coordinator, School Head	Laptops (if available), printed datasets, presentation materials, scoring rubrics	100% of student groups complete and present a mathematical investigation project demonstrating appropriate use of data, reasoning, evidence, and communication.
Evaluation and	Administer	Week 9 (2	Mathematics	Post-tests,	Post-test results

Reflection	Mathematical Reasoning and Critical Thinking Post-Tests; evaluate student portfolios, performance tasks, reflective journals, and community investigation outputs; conduct student reflection and program evaluation.	sessions, 2 hours/session)	Teachers, Mathematics Coordinator, School Head	scoring rubrics, reflection journals, portfolio checklist, evaluation forms	indicate measurable improvement in students' mathematical reasoning and critical thinking compared with baseline performance. Student portfolios and performance tasks demonstrate evidence of higher-order thinking throughout the intervention.
-------------------	---	----------------------------	--	---	---

Implementation Notes

- All learning activities shall employ authentic and contextualized datasets derived from local community issues, government statistical reports, school records (when appropriate), and publicly available educational datasets.
- Activities shall emphasize reasoning, interpretation, evidence evaluation, justification, collaboration, and reflection rather than routine procedural computation.
- Instruction shall follow the principles of Cognitive Constructivist Theory, allowing students to actively construct understanding through inquiry, discussion, and authentic problem-solving experiences.
- Assessment tasks shall be designed following the principles of Evidence-Centered Design, ensuring that every activity provides observable evidence of students' mathematical reasoning and critical thinking.
- Differentiated instructional support shall be provided to students demonstrating lower mathematical reasoning, while enrichment tasks shall be offered to students requiring additional challenges.
- Teacher feedback shall be provided after every activity to guide students in improving their reasoning, evidence use, communication, and reflective thinking before the next learning task.
- Targeted Small-Group Remediation – Students scoring below the Proficient level during formative assessments participate in teacher-guided small-group reasoning sessions using scaffolded mathematical tasks and guided questioning.

Intervention Strategies

The instructional intervention adopts student-centered, inquiry-based, and authentic assessment approaches consistent with Cognitive Constructivist Theory and Evidence-Centered Design (ECD). Cognitive Constructivist Theory emphasizes that students actively construct understanding through meaningful engagement with authentic learning experiences, while Evidence-Centered Design ensures that assessment tasks intentionally elicit observable evidence of students' mathematical reasoning and critical thinking. Accordingly, the following instructional strategies provide structured opportunities for students to demonstrate reasoning, interpret quantitative evidence, justify conclusions, and communicate mathematical ideas within authentic contexts.

Data Detective Strategy

Students examine authentic datasets obtained from their school, community, government agencies, and publicly

available statistical reports. Working individually and collaboratively, they identify trends, recognize patterns, compare variables, formulate mathematical observations, and communicate evidence-based interpretations before solving contextualized mathematical problems.

Each activity requires students to explain how numerical evidence supports their conclusions rather than merely reporting answers. Teachers facilitate guided questioning to encourage students to interpret information critically and justify their observations using mathematical evidence.

Students demonstrating lower levels of mathematical reasoning shall receive scaffolded Data Detective activities beginning with highly guided datasets, structured questioning prompts, graphic organizers, and teacher modeling before progressing to increasingly independent data interpretation tasks.

Claim–Evidence–Reasoning Strategy

Students solve contextualized mathematical problems by organizing their responses into three interconnected components:

Claim – the mathematical conclusion or decision.

Evidence – numerical data, calculations, graphs, or statistical information supporting the claim.

Reasoning – the logical explanation connecting the evidence to the conclusion.

This structured approach encourages students to justify mathematical arguments using quantitative evidence rather than relying solely on computational procedures. To accommodate differences in students' reasoning abilities, tiered CER worksheets shall be provided. Basic worksheets shall include partially completed reasoning templates, intermediate worksheets shall require students to generate supporting evidence independently, while advanced worksheets shall require complete justification and evaluation of alternative mathematical arguments.

Sample Task

Claim: Barangay An experienced the greatest increase in dengue cases. **Evidence:** Reported cases increased from 15 to 37 during the monitoring period.

Reasoning: The increase represents approximately a 147% rise, indicating a substantially greater increase than the other barangays based on the available data.

Think–Analyze–Evaluate Framework

Students complete every mathematical investigation using a structured reasoning process consisting of three successive stages:

Think- Interpret the problem.

Identify relevant mathematical information. Determine what is being asked.

Analyze- Examine relationships, patterns, graphs, tables, and quantitative evidence.

Compare possible mathematical approaches.

Evaluate- Defend conclusions using mathematical evidence.

Assess the validity of alternative solutions.

Reflect on the strength and limitations of the available evidence.

Teacher questioning focuses on "Why?", "How do you know?", and "What evidence supports your conclusion?" to encourage deeper mathematical discourse.

Collaborative Mathematical Investigation

Students work in small groups to investigate authentic community issues using contextualized datasets. Possible investigation topics include:

- School attendance trends
- Household electricity consumption
- Rainfall and flooding patterns
- Community waste generation
- Population growth
- Public health statistics

Each group collects or organizes available data, performs mathematical analyses, interprets findings, and presents evidence-based recommendations to the class. Oral presentations are evaluated using analytic rubrics focusing on reasoning, evidence utilization, communication, collaboration, and justification.

Reflective Mathematical Journal

At the conclusion of each learning session, students complete a reflective journal documenting their mathematical thinking and reasoning processes. Reflection prompts include:

- What mathematical evidence supports my conclusion?
- How did I arrive at my solution?
- Which strategy was most effective and why?
- Could another interpretation also be valid?
- What additional information would strengthen my conclusion?
- What difficulties did I encounter while interpreting the data?

Teachers review journals regularly and provide formative feedback to guide students in refining their reasoning and reflective thinking.

Instructional Principles Across All Strategies

Throughout the implementation of Project MRICT, all instructional activities shall adhere to the following principles:

- a. Utilize authentic, contextualized datasets relevant to students' school and community experiences.

- b. Promote inquiry, reasoning, interpretation, justification, and evidence-based decision-making rather than routine procedural computation.
- c. Encourage collaborative mathematical discourse and reflective learning.
- d. Employ analytic rubrics that explicitly assess mathematical reasoning, critical thinking, communication, and evidence utilization.
- e. Provide continuous formative feedback to support students in refining their reasoning and problem-solving processes.
- f. Ensure equitable participation by providing differentiated instructional support for students demonstrating varying levels of mathematical reasoning and critical thinking.
- g. Align classroom assessment practices with the expectations of the MATATAG Curriculum, DepEd Order No. 15, s. 2026, and international mathematics assessment frameworks such as PISA 2022 and TIMSS 2019.
- h. Provide differentiated instructional support through flexible grouping, peer tutoring, scaffolded learning tasks, and targeted teacher guidance based on students' formative assessment results, particularly for learners demonstrating low mathematical reasoning and critical thinking

Monitoring and Evaluation

The implementation of Project MRICT (Data-Science Assessment for Reasoning and Thinking) shall employ a systematic monitoring and evaluation process to determine students' progress in mathematical reasoning and critical thinking throughout the nine-week intervention. Consistent with the principles of Evidence-Centered Design (ECD), assessment activities shall generate observable evidence of students' reasoning, interpretation, analysis, evaluation, justification, and communication during authentic mathematical tasks. Monitoring shall include diagnostic, formative, and summative assessments to document student performance and provide timely feedback for instructional improvement.

Diagnostic Assessment (Pre-Implementation)

During Week 1, all participating students shall complete a Mathematical Reasoning Pre-Test and a Critical Thinking Pre-Test using the validated Data-Science-Infused Assessment Instrument developed for the study. The pre-test shall establish baseline performance levels, identify students requiring additional instructional support, and guide teachers in planning differentiated learning activities throughout the intervention.

The results shall be analyzed using descriptive statistics (mean and standard deviation) to determine students' initial performance levels. These baseline results shall also serve as the reference for evaluating changes in students' mathematical reasoning and critical thinking after the intervention.

Formative Assessment

Formative assessment shall be conducted continuously throughout the implementation period to monitor student progress and provide immediate instructional feedback. Rather than emphasizing numerical scores alone, assessment activities shall focus on gathering evidence of students' higher-order thinking through authentic mathematical tasks. Weekly formative assessments shall include:

- Data Interpretation Exercises
- Mathematical Reasoning Tasks

- Claim–Evidence–Reasoning (CER) Activities
- Critical Thinking Exit Tickets
- Collaborative Mathematical Investigations
- Reflective Mathematical Journals
- Observation Checklists
- Performance-Based Tasks

Teachers shall provide descriptive written and oral feedback after every activity, emphasizing students' interpretation of data, logical reasoning, evidence utilization, justification of conclusions, and communication of mathematical ideas. Students demonstrating difficulty in mathematical reasoning shall receive additional scaffolding, guided practice, and differentiated instructional support before progressing to succeeding activities. Students who score below the Proficient level on weekly formative assessments shall participate in targeted remediation sessions involving guided mathematical reasoning, scaffolded Data Detective activities, and peer-assisted learning

before proceeding to subsequent instructional activities. Their progress shall be monitored through follow-up formative assessments to determine improvement.

Summative Assessment (Post-Implementation)

At the conclusion of the intervention (Week 9), students shall complete a comprehensive post-intervention assessment consisting of:

- Mathematical Reasoning Post-Test
- Critical Thinking Post-Test
- Community Data Investigation Project
- Portfolio Assessment
- Reflective Learning Journal
- Oral Presentation of Community Investigation

Post-test scores shall be compared with pre-test scores to determine changes in student performance following participation in Project MRICT. Student portfolios shall likewise be examined to determine growth in reasoning, evidence evaluation, communication, and reflective thinking throughout the intervention.

Analytic Assessment Rubrics

To ensure objective and consistent evaluation of student performance, analytic rubrics shall be used across all major performance tasks.

Table A. Mathematical Reasoning Rubric

Criterion	Beginning (1)	Developing (2)	Proficient (3)	Advanced (4)
Problem Interpretation	Misinterprets the mathematical problem	Identifies some relevant information	Correctly interprets the problem	Demonstrates comprehensive understanding and identifies all relevant information
Mathematical Reasoning	Limited logical reasoning	Reasoning partially supports the solution	Reasoning logically supports the conclusion	Reasoning is comprehensive, coherent, and consistently justified
Evidence Utilization	Uses little or no mathematical evidence	Uses limited supporting evidence	Uses appropriate mathematical evidence	Integrates multiple forms of mathematical evidence effectively
Justification	Provides minimal explanation	Explanation is partially logical	Provides clear mathematical justification	Presents well-developed and convincing
				mathematical arguments
Communication	Explanation lacks clarity	Ideas are partially organized	Ideas are clearly communicated	Mathematical communication is precise, coherent, and highly organized

Table B. Critical Thinking Rubric

Criterion	Beginning (1)	Developing (2)	Proficient (3)	Advanced (4)
Interpretation of Evidence	Misinterprets data	Interprets some information correctly	Correctly interprets evidence	Demonstrates insightful interpretation of evidence
Analysis	Limited analysis	Identifies basic relationships	Accurately analyzes relationships	Demonstrates comprehensive and insightful analysis
Evaluation	Accepts information	Evaluates evidence inconsistently	Critically evaluates evidence	Consistently evaluates evidence using sound judgment
	without evaluation			
Decision-Making	Decisions lack justification	Decisions are partially justified	Decisions are supported by evidence	Decisions are logical, evidence-based, and well defended
Reflection	Limited reflection	Basic reflection on learning	Reflects on reasoning process	Demonstrates deep metacognitive reflection and self-evaluation

Evaluation of Program Effectiveness

The effectiveness of Project MRiCT shall be evaluated using multiple sources of evidence to ensure a comprehensive assessment of student outcomes. The intervention shall be considered successfully implemented when the following indicators are achieved:

All participating students complete both the pre-test and post-test assessments.

Post-test mean scores in mathematical reasoning and critical thinking are higher than the corresponding pre-test means scores.

At least 80% of students attain Proficient or higher ratings in the mathematical reasoning and critical thinking analytic rubrics.

At least 80% of students successfully complete authentic mathematical investigation projects demonstrating appropriate interpretation of data, mathematical reasoning, evidence evaluation, and justification of conclusions.

Student portfolios demonstrate consistent improvement in reasoning, communication, reflection, and evidence-based problem solving across the intervention period.

Statistical analysis of the pre-test and post-test results indicates a significant improvement in students' mathematical reasoning and critical thinking at the 0.05 level of significance.

Findings from the monitoring and evaluation process shall be used to refine subsequent implementations of Project MRiCT and to inform school-based instructional planning, Learning Action Cell (LAC) sessions, and future mathematics intervention initiatives.

Success Indicators

The implementation of Project MRiCT (Data-Science Assessment for Reasoning and Thinking) shall be considered successful when the following indicators are achieved: **Student Performance Indicators**

- 100% of participating students complete the Mathematical Reasoning and Critical Thinking pre-test and post-test assessments.
- The post-test mean scores in Mathematical Reasoning and Critical Thinking are higher than the corresponding pre-test mean scores, indicating measurable improvement in student performance following the intervention.
- Statistical analysis of the pre-test and post-test results demonstrates a statistically significant improvement ($p < .05$) in students' mathematical reasoning and critical thinking.
- At least 80% of participating students attain Proficient or Advanced ratings in the Mathematical Reasoning Analytic Rubric during authentic performance tasks.
- At least 80% of participating students attain Proficient or Advanced ratings in the Critical Thinking Analytic Rubric during authentic mathematical investigations.

Performance Assessment Indicators

- At least 80% of students accurately interpret authentic datasets, identify mathematical relationships, and communicate evidence-based conclusions during Data Detective activities.
- At least 80% of students successfully formulate mathematical claims supported by appropriate quantitative evidence and logical justification using the Claim–Evidence–Reasoning (CER) framework.
- 100% of student groups complete and present a Community Data Investigation Project demonstrating appropriate data interpretation, mathematical reasoning, evidence utilization, collaboration, and communication.
- All participating students' complete reflective mathematical journals documenting their reasoning processes,

evaluation of evidence, and reflections on learning throughout the intervention.

Instructional Implementation Indicators

- Mathematics teachers implement all planned Project MRiCT learning activities according to the approved implementation schedule and instructional procedures.
- Teachers provide timely formative feedback after each learning activity using the established analytic rubrics and observation checklists.
- Learning Action Cell (LAC) discussions or post-implementation reflection meetings are conducted to evaluate the implementation of Project MRiCT and identify areas for continuous improvement.

Sustainability Plan

To ensure the continuity and long-term impact of Project MRiCT (Mathematical Reasoning through Infused Data-Science Assessments for Critical Thinking), the following sustainability measures shall be implemented:

1. **Integration into the Mathematics Improvement Program.** Project MRiCT shall be incorporated into the school's Mathematics Improvement Program as an intervention strategy for Grade 10 students who demonstrate low mathematical reasoning and critical thinking. Selected project activities may also be integrated into the school's remediation, enrichment, and intervention programs.
2. **Continuous Classroom Implementation.** The instructional strategies, authentic assessment tasks, and data-science-infused learning activities developed through Project MRiCT shall continue to be utilized in regular Grade 10 Mathematics instruction to strengthen students' mathematical reasoning, critical thinking, and problem-solving skills.
3. **Learning Action Cell (LAC) Integration.** The implementation experiences, instructional strategies, assessment practices, and best practices from Project MRiCT shall be shared during Learning Action Cell (LAC) sessions to enhance teachers' competencies in designing authentic, inquiry-based, and evidence-centered mathematics instruction aligned with the MATATAG Curriculum.
4. **Development of Instructional Resources.** A repository of localized data-science-infused assessment tasks, contextualized datasets, performance activities, scoring rubrics, and teacher guides shall be developed and maintained for continuous use and improvement by mathematics teachers.
5. **Teacher Collaboration and Adoption.** Mathematics teachers shall be encouraged to adopt, contextualize, and enhance Project MRiCT strategies across Grade 10 classes and, where appropriate, adapt selected activities for other grade levels to promote consistent development of higher-order thinking skills throughout the mathematics curriculum.
6. **Monitoring and Continuous Improvement.** The implementation of Project MRiCT shall be regularly monitored through classroom observations, assessment results, learner outputs, and teacher reflections. Feedback gathered from teachers, students, and school administrators shall be used to refine instructional activities and improve future implementations of the project.
7. **Stakeholder Support and Partnership.** The school shall strengthen collaboration with parents, the School Governing Council (SGC), the Parents-Teachers Association (PTA), and community partners in supporting authentic, contextualized mathematical investigations by providing relevant local data, learning resources, and opportunities for community-based learning experiences.

Expected Outputs

Upon completion of Project MRiCT, the following outputs are expected:

Student Outputs

- Completed Mathematical Reasoning and Critical Thinking pre-test and post-test assessment results.
- Individual student portfolios containing:
 - a. Data interpretation activities;
 - b. Claim–Evidence–Reasoning (CER) outputs;
 - c. Mathematical reasoning tasks;
 - d. Critical thinking activities;
 - e. Reflective mathematical journals; and
 - f. Performance assessment outputs.
- Community Data Investigation Project reports with accompanying oral presentations and analytic rubric ratings.
- Evidence of students' mathematical reasoning, critical thinking, communication, collaboration, and reflective thinking as documented through authentic assessment tasks.

Teacher Outputs

- Localized data-science-infused assessment activities aligned with the Grade 10 Mathematics curriculum.
- Contextualized lesson exemplars integrating authentic datasets and inquiry-based learning activities.
- Teacher-developed analytic rubrics for assessing mathematical reasoning and critical thinking.
- Classroom monitoring records, learner progress reports, and formative assessment documentation.
- Repository of authentic datasets, instructional materials, and assessment resources for future classroom implementation. Enhanced teacher capacity in designing assessment tasks that provide students with opportunities to demonstrate mathematical reasoning and critical thinking consistent with the MATATAG Curriculum and DepEd Order No. 15, s. 2026.

School Outputs

- Project MRiCT Implementation Report containing the project's objectives, implementation activities, accomplishments, challenges encountered, evaluation results, and recommendations for continuous improvement.
- A school-based repository of localized data-science-infused assessment materials, authentic datasets, and intervention resources for use by mathematics teachers.
- Documentation of Learning Action Cell (LAC) sessions, teacher reflections, and capability-building activities conducted during the implementation of the project.

- Integration of effective Project MRiCT strategies into the school's Mathematics Improvement Program, School Improvement Plan (SIP), Annual Implementation Plan (AIP), and other school-based intervention initiatives.
- A sustainable instructional intervention framework that may be adopted or replicated by other mathematics teachers to strengthen mathematical reasoning and critical thinking through authentic, data-science-infused assessment.

REFERENCES

1. Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, 18(3), 91–93. <https://doi.org/10.1016/j.tjem.2018.08.001>
2. Albert, J. R. G., Briones, R. M., & Rivera, J. P. R. (2024). Wealth creation for expanding the middle class in the Philippines (PIDS Discussion Paper No. 2024-10). Philippine Institute for Development Studies. <https://doi.org/10.62986/dp2024.10>
3. American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (2014). *Standards for educational and psychological testing*. American Educational Research Association.
4. American Psychological Association. (2023). Socioeconomic status. *APA Dictionary of Psychology*. <https://dictionary.apa.org/socioeconomic-status>
5. Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.
6. Andrade, R. R., Fortes, E. C., & Mabilangan, R. A. (2020). Problem solving heuristics and mathematical abilities of heterogeneous students. *Universal Journal of Educational Research*, 8(11), 5114–5126. <https://doi.org/10.13189/ujer.2020.081111>
7. Aridor, K., & Ben-Zvi, D. (2018). Statistical modeling to promote students' aggregate reasoning with sample and sampling. *ZDM—Mathematics Education*, 50(7), 1165–1181. <https://doi.org/10.1007/s11858-018-0994-5>
8. Armstrong, P. (2020). Bloom's taxonomy. Vanderbilt University Center for Teaching. <https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/>
9. Bargagliotti, A., Franklin, C., Arnold, P., Gould, R., Johnson, S., Perez, L., & Spangler, D. A. (2020). Pre-K–12 guidelines for assessment and instruction in statistics education II (GAISE II): A framework for statistics and data science education. American Statistical Association.
10. Ben-Zvi, D., Gravemeijer, K., & Ainley, J. (2018). Design of statistics learning environments. In D. Ben-Zvi, K. Makar, & J. Garfield (Eds.), *International handbook of research in statistics education* (pp. 473–502). Springer.
11. Brookhart, S. M. (2018). *How to assess higher-order thinking skills in your classroom* (2nd ed.). ASCD.
12. Brookhart, S. M. (2019). Appropriate criteria: Key to effective rubrics. *Frontiers in Education*, 4, Article 22. <https://doi.org/10.3389/feduc.2019.00022>
13. Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approach* (5th ed.). SAGE.
14. Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, 24(2), 97–140. <https://doi.org/10.1080/10888691.2018.1537791>
15. De Las Peñas, M. L. A. N., Loyola, M. L., Sarmiento, J. F., Tolentino, M. A. C., & Verzosa, D. M. B. (2020). Designing mobile apps to promote numeracy and statistical reasoning. In *Proceedings of the 25th Asian Technology Conference in Mathematics* (pp. 167–182).
16. De Las Peñas, M. L. A. N., Verzosa, D. M. B., Aberin, M. A. Q., Garciano, A., Sarmiento, J. F., & Tolentino, M. A. C. (2021). Designing performance tasks in mathematics using technological tools. In *Proceedings of the 26th Asian Technology Conference in Mathematics*.
17. Department of Education. (2026). DepEd Order No. 15, s. 2026: Revised Guidelines on Classroom Assessment, Grading System, and Awards and Recognition for the K to 12 Basic Education Program.

- <https://www.deped.gov.ph/2026/06/04/june-4-2026-do-015-s-2026-revised-guidelines-on-classroom-assessment-grading-system-and-awards-and-recognition-for-the-k-to-12-basic-education-program/>
18. Department of Education. (2022). DepEd Order No. 24, s. 2022: Adoption of the Basic Education Monitoring and Evaluation Framework. (Enclosure showing the Bureau of Education Assessment Mean Percentage Score proficiency descriptors).
 19. Department of Education. (2026). Revised guidelines on classroom assessment, grading system, and awards and recognition for the K to 12 Basic Education Program (Department Order No. 15, s. 2026).
 20. DeVellis, R. F., & Thorpe, C. T. (2021). Scale development: Theory and applications (5th ed.). SAGE.
 21. Engel, J., Biehler, R., Frischmeier, D., Podworny, S., Schiller, A., & Martignon, L. (2020). Data science in school mathematics: Introducing a first data cycle. *Statistics Education Research Journal*, 19(1), 262–278. <https://doi.org/10.52041/serj.v19i1.178>
 22. Ennis, R. H. (2018). Critical thinking across the curriculum: A vision. *Topoi*, 37(1), 165–184. <https://doi.org/10.1007/s11245-016-9401-4>
 23. Evans, J. St. B. T. (2019). Reflections on reflection: The nature and function of Type 2 processes in dual-process theories of reasoning. *Thinking & Reasoning*, 25(4), 383–415. <https://doi.org/10.1080/13546783.2019.1623071>
 24. Evans, J. St. B. T., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. *Perspectives on Psychological Science*, 8(3), 223–241. <https://doi.org/10.1177/1745691612460685>
 25. Facione, P. A., Facione, N. C., & Gittens, C. A. (2020). What the data tell us about human reasoning. In D. Fasko Jr. & F. Fair (Eds.), *Critical Thinking and Reasoning: Theory, Development, Instruction, and Assessment* (pp. 272–297). Brill. https://doi.org/10.1163/9789004444591_016
 26. Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, 41(4), 1149–1160. <https://doi.org/10.3758/BRM.41.4.1149>
 27. Field, A. (2018). *Discovering statistics using IBM SPSS Statistics* (5th ed.). SAGE.
 28. Fisher, A. (2020). *Critical thinking: An introduction* (3rd ed.). Cambridge University Press.
 29. Franklin, C., & Bargagliotti, A. (2020). Introducing GAISE II: A guideline for precollege statistics and data science education. *Harvard Data Science Review*, 2(4). <https://doi.org/10.1162/99608f92.246107bb>
 30. Goos, M., Geiger, V., & Dole, S. (2019). Conceptualizing and enacting mathematical reasoning in the middle years. In *Research in Mathematics Education in Australasia 2016–2019* (pp. 181–205). Springer. https://doi.org/10.1007/978-981-15-4269-5_8
 31. Herbert, S., Vale, C., White, P., & Bragg, L. A. (2022). Engagement with a formative assessment rubric: A case of mathematical reasoning. *International Journal of Educational Research*, 111, Article 101899. <https://doi.org/10.1016/j.ijer.2021.101899>
 32. Johnson, R. B., & Christensen, L. (2020). *Educational research: Quantitative, qualitative, and mixed approaches* (8th ed.). SAGE.
 33. Keith, T. Z. (2019). *Multiple regression and beyond* (3rd ed.). Routledge.
 34. Kim, H.-Y. (2019). Statistical notes for clinical researchers: Post-hoc analysis after ANOVA. *Restorative Dentistry & Endodontics*, 44(1), e5. <https://doi.org/10.5395/rde.2019.44.e5>
 35. Mislevy, R. J. (2018). *Sociocognitive foundations of educational measurement*. Routledge.
 36. Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). A brief introduction to evidence-centered design (ETS Research Report RR-03-16). Educational Testing Service. <https://doi.org/10.1002/j.2333-8504.2003.tb01908.x>
 37. Mislevy, R. J., Steinberg, L. S., & Almond, R. G. (2003). On the structure of educational assessments. *Measurement: Interdisciplinary Research and Perspectives*, 1(1), 3–67. https://doi.org/10.1207/S15366359MEA0101_02
 38. Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). TIMSS 2019 international results in mathematics and science. TIMSS & PIRLS International Study Center, Boston College. <https://timssandpirls.bc.edu/timss2019/frameworks/>

39. National Academies of Sciences, Engineering, and Medicine. (2018). Data science for undergraduates: Opportunities and options. National Academies Press. <https://doi.org/10.17226/25104>
40. National Council of Teachers of Mathematics. (2018). Catalyzing change in high school mathematics: Initiating critical conversations. National Council of Teachers of Mathematics.
41. Norqvist, M., Jonsson, B., Lithner, J., Qwillbard, T., Holm, L., & Liljekvist, Y. (2021). The effect of creative mathematical reasoning on students' conceptual knowledge, transfer, and retention. *Frontiers in Education*, 5, 590786. <https://doi.org/10.3389/educ.2020.590786>
42. Organisation for Economic Co-operation and Development. (2019). OECD learning compass 2030. OECD Publishing.
43. Organisation for Economic Co-operation and Development. (2023). PISA 2022 assessment and analytical framework: Mathematics, reading, science, financial literacy and creative thinking. OECD Publishing. <https://doi.org/10.1787/dfe0bf9c-en>
44. Organisation for Economic Co-operation and Development. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. <https://doi.org/10.1787/53f23881-en>
45. Piaget, J. (1970). *Science of education and the psychology of the child*. Viking Press.
46. Philippine Statistics Authority. (2023). Income and expenditure estimates from the 2021 Family Income and Expenditure Survey (FIES). <https://psa.gov.ph/>
47. Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, 32, 77–112. <https://doi.org/10.1007/s10648-019-09498-w>
48. Santos-Trigo, M., & Reyes-Martínez, I. (2019). High school prospective teachers' problem-solving reasoning that involves the coordinated use of digital technologies. *International Journal of Mathematical Education in Science and Technology*, 50(2), 182–201. <https://doi.org/10.1080/0020739X.2018.1489003>
49. Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia & Analgesia*, 126(5), 1763–1768. <https://doi.org/10.1213/ANE.0000000000002864>
50. Schunk, D. H. (2020). *Learning theories: An educational perspective* (8th ed.). Pearson.
51. Second Congressional Commission on Education. (2024). *Miseducation: The failed system of Philippine education—EDCOM II-year one report*.
52. Second Congressional Commission on Education. (2025). *Fixing the foundations: A matter of national survival—EDCOM II-year two report*.
53. Stemler, S. E., Matthews, M. S., Tsai, J., & Kindelberger, C. (2022). *Measurement matters: An introduction to measurement in the social sciences*. Routledge.
54. Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 31(2), 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
55. Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Pearson.
56. UNESCO. (2023). *Global Education Monitoring Report 2023: Technology in education—A tool on whose terms?* UNESCO. <https://unesdoc.unesco.org/ark:/48223/pf0000385723>
57. Verzosa, D. M. B. (2020). Pre-service elementary teachers' reasoning in introducing multidigit subtraction. *International Journal of Mathematical Education in Science and Technology*, 51(6), 876–892. <https://doi.org/10.1080/0020739X.2019.1647573>
58. Verzosa, D. M. B., & Vistro-Yu, C. P. (2019). Prospects and challenges in implementing a new mathematics curriculum in the Philippines. In C. P. Vistro-Yu & T. L. Toh (Eds.), *School mathematics curricula: Asian perspectives and glimpses of reform* (pp. 207–226). Springer. https://doi.org/10.1007/978-981-13-6312-2_11