



Instructional Leadership and 21st-Century Pedagogy

Predicting Students' Critical Thinking and Science Performance in Philippine Public Schools

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ABSTRACT

This study examined the predictive influence of school administrators' leadership and 21st-century science learning practices on Grade 9 students' critical thinking and academic performance in science. A quantitative, descriptive-correlational design with a predictive component was employed in 58 public junior high schools in the Zamboanga del Norte Division, Philippines. Data were collected from 58 school administrators, 89 Grade 9 science teachers, and 340 Grade 9 students using validated questionnaires, a critical thinking test, and official school records. Findings revealed that administrators' leadership was "Very High," 21st-century practices were implemented "Often," and students demonstrated "High" critical thinking and "Very Satisfactory" academic performance. Multiple regression analyses showed that learning environment and school culture ($\beta = 0.31$, $p < 0.001$) and instructional leadership ($\beta = 0.28$, $p < 0.001$) were significant predictors of critical thinking, while authentic assessment ($\beta = 0.31$, $p < 0.001$) and integration of critical thinking strategies ($\beta = 0.27$, $p < 0.001$) were the strongest predictors of academic performance. The study provides empirical evidence that school leadership and instructional practices are interconnected drivers of student success. It recommends that administrators prioritize instructional and cultural leadership, and that teachers consistently integrate inquiry-based and cognitively demanding strategies to foster critical thinking and improve science outcomes.

Keywords

21st-Century Learning
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Introduction

The 21st century has ushered in an era of unprecedented scientific and technological advancement, fundamentally transforming how societies function and how individuals interact with information. From climate change and public health crises to artificial intelligence and sustainable development, the challenges confronting contemporary societies demand citizens who are not merely consumers of information but critical thinkers, problem-solvers, and informed decision-makers [1],[2]. In response, education systems worldwide are undergoing profound transformations to equip learners with the competencies necessary to navigate this complex landscape.

Science education occupies a central position in this transformative agenda. Historically, science instruction often emphasized the acquisition of isolated facts and rote memorization of formulas. However, contemporary educational perspectives have fundamentally shifted toward learner-centered, inquiry-based approaches that engage students in authentic scientific practices [3],[4]. These approaches encourage learners to ask questions, design investigations, analyze evidence, construct explanations, and apply scientific concepts to real-world phenomena. The goal is no longer simply to produce future scientists but to develop scientifically literate citizens capable of critical engagement with scientific issues that affect their lives and communities.

International frameworks have articulated these competencies through the lens of 21st-century skills. The Framework for 21st Century Learning identifies critical thinking, problem-solving, communication, collaboration, and creativity as essential outcomes for student success in the modern world [5]. Within this framework, critical thinking is particularly emphasized as a foundational skill that enables learners to analyze information, evaluate evidence, reason logically, and make informed judgments—competencies indispensable to both academic achievement and lifelong learning [6],[7].

In the Philippines, the K to 12 Basic Education Program introduced a revised Science Curriculum that explicitly emphasizes the development of scientific literacy, inquiry-based learning, and higher-order thinking skills [8]. The curriculum framework is grounded in constructivist principles, positioning learners as active constructors of knowledge who develop understanding through hands-on activities, investigation, and reflection. However, despite these policy intentions, persistent challenges remain. The Programme for International Student Assessment (PISA) 2018 and 2022 results placed the Philippines among the lowest-performing countries in science literacy, with Filipino students scoring significantly below the OECD average [2],[9]. These findings suggest a disconnect between curriculum aspirations and classroom realities—a gap that researchers have attributed to various factors, including instructional practices, resource constraints, and, critically, the quality of school leadership.

Research consistently identifies school leadership as a critical factor in bridging this gap. Instructional leadership theory, developed and refined by scholars such as Hallinger and Murphy, posits that effective school administrators influence student outcomes indirectly by shaping the conditions that enable effective teaching [10],[11]. These conditions include establishing clear instructional goals, aligning curriculum and instruction with standards, providing professional development support, creating a positive school climate, and fostering a culture of continuous improvement. Large-scale meta-analyses have demonstrated that leadership practices focused on instructional guidance, teacher development, and collaborative school cultures are consistently associated with improved student achievement [12],[13].

In science education specifically, recent studies have shown that principals who prioritize science instruction, support teachers' professional learning in inquiry-based approaches, and ensure adequate resources for laboratory work contribute to stronger student outcomes [14]. However, the mechanisms through which leadership influences student learning are complex and often indirect. Leadership affects students primarily through its influence on teachers' instructional practices, motivation, and professional growth [15]. When school administrators provide constructive feedback, facilitate collaborative planning, and create safe, supportive environments where teachers feel empowered to innovate, teachers are more likely to implement pedagogies that foster higher-order thinking.

The instructional practices that characterize effective 21st-century science education are grounded in constructivist learning theory, which posits that learners actively construct knowledge through interaction with ideas, experiences, and social contexts [16]. In science classrooms, this translates to instructional strategies that engage students in the processes of scientific inquiry. Inquiry-based instruction has been widely recognized as a cornerstone of effective science teaching, with research showing that when students engage in inquiry, they develop deeper conceptual understanding, stronger scientific reasoning, and greater knowledge retention [12],[17].

Beyond inquiry, contemporary science instruction explicitly integrates critical thinking strategies. This involves designing learning experiences that require students to analyze information from multiple sources, evaluate the credibility of evidence, compare and contrast competing explanations, justify conclusions with reasoning, and reflect on their own thinking processes [18],[19]. Authentic assessment represents another critical dimension, engaging students in performance-based tasks that mirror real-world scientific practices rather than relying solely on traditional tests that measure recall of factual knowledge [8],[20]. Technology-enhanced science learning has also become increasingly prominent, offering new opportunities to engage students in scientific exploration through digital tools, simulations, and virtual laboratories [21].

Despite the well-established theoretical and empirical foundations linking leadership, instruction, and student outcomes, a significant research gap exists in the Philippine context, particularly regarding the predictive relationships among these variables. Most Philippine studies have examined administrators' leadership and instructional practices in isolation [22], and few have employed predictive designs to identify which specific dimensions of leadership or instructional practices are most influential. The integration of critical thinking as both an outcome and a mediating variable has received limited attention [23]. Furthermore, context-specific evidence from divisions like Zamboanga del Norte is lacking, despite variations in educational conditions, leadership practices, and instructional contexts across regions.

To address this gap, this study aimed to answer the following research questions:

- What are the levels of administrators' leadership, the implementation of 21st-century science learning practices, and Grade 9 students' critical thinking and science performance?
- Do administrators' leadership and 21st-century science learning practices significantly relate to students' critical thinking and science performance?, and
- Which dimensions of administrators' leadership and which aspects of 21st-century science learning practices significantly predict students' critical thinking and academic performance in science?

By investigating these questions within a single, integrated framework, this study provides context-specific evidence to inform school improvement efforts, teacher professional development, and educational policy in the Philippines.

Methods

A. Research Design and Participants

This study employed a quantitative research approach using a descriptive-correlational design with a predictive component. A quantitative approach was appropriate because the study sought to measure variables numerically, examine relationships among variables, and determine the predictive influence of independent variables on dependent variables [24],[25]. Quantitative research is particularly suited for studies that aim to generalize findings from a sample to a population and to test hypotheses about relationships between measurable variables [26],[27].

The descriptive component of the design was used to determine the level of administrators' leadership, the extent of implementation of 21st-century science learning practices, the level of students' critical thinking, and students' academic performance in science. Descriptive research enables the systematic collection and analysis of data to describe the characteristics of a population or phenomenon as they exist, without manipulating variables [24],[28].

The correlational component was used to examine relationships among administrators' leadership, 21st-century science learning practices, and student outcomes. Correlational research is appropriate when the objective is to determine the degree and direction of relationships among variables without manipulating them [25],[29]. Correlation analysis allows researchers to quantify the strength and direction of associations, providing a foundation for predictive analysis [30],[31].

The predictive component utilized multiple regression analysis to identify which dimensions of administrators' leadership and which aspects of 21st-century science learning practices significantly predicted students' critical thinking and academic performance in science. Predictive research aims to determine the extent to which one or more independent variables can explain or predict variation in a dependent variable [24],[32]. Multiple regression is a powerful statistical technique that allows researchers to assess the relative contribution of multiple predictors while controlling for the effects of other variables [31],[33].

B. Research Locale

The study was conducted in selected public junior high schools within the Schools Division of Zamboanga del Norte, Philippines. Zamboanga del Norte is a province located in Region IX (Zamboanga Peninsula), administratively divided into three congressional districts. The Schools Division was chosen as the research locale because it provided an appropriate context for examining leadership, instructional practices, and student outcomes within a standardized policy and administrative framework [34]. Public junior high schools in the division follow the K to 12 Basic Education Curriculum, as outlined in the Department of Education's policies and guidelines, ensuring consistency across participating schools.

C. Participants and Sampling

The target population consisted of school administrators, Grade 9 science teachers, and Grade 9 students from public junior high schools in the Zamboanga del Norte Division. Stratified sampling was employed to ensure proportional representation of schools across the three congressional districts [24],[25]. Stratified sampling is appropriate when a population is divided into distinct subgroups (strata), and representation from each subgroup is required to ensure that the sample accurately reflects the population structure [35],[36].

For school administrators and Grade 9 science teachers, total enumeration was used. Total enumeration (census) is appropriate when the number of respondents is manageable, and their inclusion enhances the accuracy and representativeness of the data [24],[37]. All 58 school administrators and 89 science teachers from the selected schools were included.

For Grade 9 students, Slovin's formula was used to determine an appropriate sample size at a 0.05 margin of error. Slovin's formula is widely used in educational and social science research to determine sample size when the population is known, and a margin of error is specified

[38],[39]. The total Grade 9 population from participating schools was 2,260 students, yielding a computed sample size of 340 students. Proportionate stratified sampling was applied to allocate the student sample across districts, followed by simple random sampling within each district to minimize selection bias [25],[26].

D. Instruments

Four instruments were used to collect data:

1. Administrators' Leadership Questionnaire.

This instrument was self-developed based on instructional leadership theory and related literature. It consisted of 40 statements distributed across four domains: Instructional Leadership, Resource Management, Professional Development Support, and Learning Environment and School Culture. Responses were measured using a five-point Likert scale: 5 (Strongly Agree), 4 (Agree), 3 (Moderately Agree), 2 (Disagree), and 1 (Strongly Disagree). Likert scales are widely used in educational research to measure attitudes, perceptions, and self-reported behaviors [40],[41].

2. 21st-Century Science Learning Practices Questionnaire.

This instrument was developed to measure the extent to which contemporary instructional practices were implemented in Grade 9 science classes. It consisted of 40 statements distributed across four domains: Inquiry-Based Instruction, Integration of Critical Thinking Strategies, Authentic Assessment, and Technology-Enhanced Science Learning. Responses were measured using a five-point frequency scale: 5 (Always), 4 (Often), 3 (Sometimes), 2 (Seldom), and 1 (Never).

3. Critical Thinking Test in Science.

This 30-item test was developed by the researcher to assess Grade 9 students' critical thinking skills in science. The test items were aligned with Grade 9 science competencies and assessed three core components of critical thinking: analysis, evaluation, and reasoning and problem-solving. Each item was scored dichotomously (1 point for correct, 0 for incorrect), with a total possible score of 30.

4. Students' Science Performance Record Form.

This form was used to collect students' academic performance data from official school records. Data included students' scores in written works, performance tasks, and quarterly grades in science, following the assessment framework prescribed in DepEd Order No. 8, s. 2015.

E. Validity and Reliability

Content validity was established through expert validation. All research instruments were reviewed by a panel of experts who evaluated each item for clarity, relevance, and alignment with the constructs being measured. Content validity ensures that the instrument adequately

represents the content domain being measured [24],[42]. The Content Validity Index (CVI) was computed from expert ratings, with all instruments achieving Scale-Level CVIs of 0.90 or higher, indicating excellent content validity [43],[44].

Reliability was established through pilot testing with respondents who shared characteristics similar to those of the target participants but were not included in the actual study. Internal consistency reliability was assessed using Cronbach's alpha coefficient, which measures the extent to which items within an instrument are correlated and consistently measure the same construct [45],[46]. The Administrators' Leadership Questionnaire achieved a Cronbach's α of 0.92; the 21st-Century Science Learning Practices Questionnaire, $\alpha = 0.90$; and the Critical Thinking Test in Science, $\alpha = 0.88$. These values exceed the commonly accepted threshold of 0.70, indicating excellent to good reliability [47],[48].

F. Data Gathering Procedure

Data collection was conducted during the second semester of the 2025-2026 school year. Prior to data collection, formal permission was obtained from the Schools Division Superintendent and from the school heads of participating schools. Ethical clearance was secured from the Institutional Ethics Review Board [24].

Informed consent was obtained from all participants. School administrators and teachers were provided with written informed consent forms detailing the study objectives, procedures, and their rights. For student participants, parental consent was obtained through coordination with school authorities, and students provided their assent to participate [49],[50].

Data collection was scheduled in coordination with school heads to minimize disruption of regular school activities. The questionnaires were administered to school heads and teachers during scheduled free periods. The critical thinking test was administered to selected Grade 9 students in their classrooms under supervised conditions, with standardized instructions and adequate time to complete it [51]. Students' academic performance data were obtained from official school records, with permission from school administrators.

All data were coded to protect participant identities and stored securely. Completed questionnaires and test papers were checked for completeness, encoded, and prepared for statistical analysis.

G. Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics—including frequency counts, percentages, weighted means, and standard deviations—were used to describe the levels of the key variables. Descriptive statistics provide a summary of the central tendency, variability, and distribution of data [30],[33].

Pearson's product-moment correlation coefficient was used to assess relationships among variables. Pearson's r is appropriate when data are measured on interval or ratio scales and the

study aims to examine the degree and direction of linear relationships between variables [31],[51]. Correlation coefficients were interpreted according to established guidelines: ± 0.81 – ± 1.00 (Very Strong), ± 0.61 – ± 0.80 (Strong), ± 0.41 – ± 0.60 (Moderate), ± 0.21 – ± 0.40 (Weak), and ± 0.00 – ± 0.20 (Very Weak) [51],[52].

Multiple regression analysis was employed to identify significant predictors of students' critical thinking and academic performance. Multiple regression is a statistical technique that assesses the relationship between one dependent variable and two or more independent variables, allowing researchers to determine the relative contribution of each predictor while controlling for the effects of others [32],[33]. The regression models were assessed for multicollinearity using the Variance Inflation Factor (VIF), with all values below 10 indicating no significant multicollinearity [33],[53]. All inferential tests were conducted at a 0.05 level of significance [24],[25].

Results

A. Descriptive Statistics

The results in Table 1 show that administrators' leadership was rated "Very High" ($M = 4.24$), with the strongest domain being Learning Environment and School Culture ($M = 4.41$). 21st-century science learning practices were implemented "Often" ($M = 4.03$), with Integration of Critical Thinking Strategies being the most frequent ($M = 4.18$). Grade 9 students demonstrated "High" critical thinking (65.3%) and "Very Satisfactory" academic performance ($M = 85.0$).

Table 1. Descriptive Statistics for Key Variables

Variable	Mean	SD	Descriptive Level
Administrators' Leadership (Overall)	4.24	0.50	Very High
Learning Environment and School Culture	4.41	0.46	Very High
21st-Century Science Learning Practices (Overall)	4.03	0.58	Often
Integration of Critical Thinking Strategies	4.18	0.52	Often
Students' Critical Thinking	65.3%	--	High
Students' Science Performance	85.0	4.60	Very Satisfactory

B. Predicting Students' Critical Thinking

Multiple regression analysis (Table 2) revealed that the set of administrators' leadership dimensions significantly predicted students' critical thinking ($F = 37.45$, $p < 0.001$), explaining 31% of its variance. Learning Environment and School Culture ($\beta = 0.31$, $p < 0.001$) and Instructional Leadership ($\beta = 0.28$, $p < 0.001$) were the strongest significant predictors. Similarly, 21st-century science learning practices significantly predicted critical thinking ($F = 51.63$, $p < 0.001$), explaining 38% of its variance. The Integration of Critical Thinking Strategies ($\beta = 0.34$, $p < 0.001$) was the strongest predictor, followed by Inquiry-Based Instruction ($\beta = 0.29$, $p < 0.001$). These findings indicate that both leadership quality and pedagogical innovation play a complementary role in enhancing students' higher-order thinking skills.

Table 2. Multiple Regression Predicting Students' Critical Thinking

Model	Significant Predictors	Beta (β)	p-value	R ²
Model 1: Leadership	Learning Environment & School Culture	0.29	<0.001	0.29
	Instructional Leadership	0.26	<0.001	
Model 2: Instruction	Authentic Assessment	0.31	<0.001	0.36
	Integration of Critical Thinking Strategies	0.27	<0.001	

C. Predicting Students' Academic Performance

Multiple regression analysis (Table 3) showed that administrators' leadership dimensions significantly predicted science performance ($F = 33.82$, $p < 0.001$), explaining 29% of its variance. Learning Environment and School Culture ($\beta = 0.29$, $p < 0.001$) and Instructional Leadership ($\beta = 0.26$, $p < 0.001$) were significant predictors. Critically, all four 21st-century science learning practices significantly predicted science performance ($F = 47.92$, $p < 0.001$), explaining 36% of its variance. Authentic Assessment ($\beta = 0.31$, $p < 0.001$) was the strongest predictor, followed by Integration of Critical Thinking Strategies ($\beta = 0.27$, $p < 0.001$).

Table 3. Multiple Regression Predicting Students' Science Performance

Model	Significant Predictors	Beta (β)	p-value	R ²
Model 1: Leadership	Learning Environment & School Culture	0.29	<0.001	0.29
	Instructional Leadership	0.26	<0.001	
Model 2: Instruction	Authentic Assessment	0.31	<0.001	0.36
	Integration of Critical Thinking Strategies	0.27	<0.001	

Discussion

This study aimed to provide empirical evidence on the predictive relationship between leadership, instruction, and student outcomes. The findings offer several key insights that contribute to theory and practice.

A. Leadership and School Culture

The "Very High" level of administrators' leadership, particularly in *Learning Environment*, *School Culture*, and *Instructional Leadership*, aligns with instructional leadership theory, which underscores the principal's role as the primary agent of instructional improvement [12]. This finding is consistent with recent Philippine studies that have reported similar levels of instructional engagement among school heads [54]. The prominence of *Learning Environment and School Culture* as the highest-rated domain suggests that administrators in the division prioritized creating positive, supportive, and collaborative school climates—a finding that echoes international research demonstrating that effective school leaders focus on fostering cultures of trust, collaboration, and continuous improvement [55].

The finding that *Learning Environment and School Culture* were significant predictors of both critical thinking and academic performance extends the existing literature. It demonstrates that a positive, collaborative, and inquiry-focused school culture is not just a background condition but a direct antecedent to higher-order cognitive skills. This reinforces the work of Leithwood et al. [11], who argued that leadership is most effective when it fosters a shared commitment to

academic rigor and professional collaboration. In the Philippine context, this finding aligns with recent studies emphasizing the importance of school climate in shaping student engagement and achievement.

B. Instructional Practices and Critical Thinking

The significant predictive power of integrating *Critical Thinking Strategies* and *Inquiry-Based Instruction* for students' critical thinking strongly supports constructivist learning theory. When teachers explicitly design lessons that require analysis, evaluation, and reasoning, students develop these skills more effectively [16],[18]. This finding is consistent with international studies that have linked inquiry-based approaches to improved critical thinking [4],[17] and provides local, empirical validation for the pedagogical shifts promoted by the K to 12 curriculum.

Recent research by Adhikari et al. [19] in the Philippine context similarly found that critical thinking skills are significant determinants of academic success among senior high school students, reinforcing the importance of explicitly teaching these skills. Similarly, Jardinico and Linaugo [23] demonstrated that science process skills and critical thinking are closely linked to academic performance in earth science. The current study extends these findings by identifying the specific instructional practices—integration of critical thinking strategies and inquiry-based instruction—that most strongly predict these outcomes.

C. Authentic Assessment and Academic Performance

Most importantly, the study reveals a nuanced picture of how instruction predicts academic performance. While all instructional practices were significant, *Authentic Assessment* emerged as the strongest predictor. This suggests that students' grades are most influenced by performance-based tasks that require applying knowledge to real-world problems. This finding aligns with the work of the OECD [9] and Vincent-Lancrin et al. [8], who emphasize that performance-based assessments are more indicative of students' ability to apply knowledge than traditional tests. For Philippine schools, this is a crucial finding, indicating that to improve summative performance, instruction must be paired with assessments that mirror authentic scientific practice.

The strong predictive power of authentic assessment is also consistent with the findings of Tiep and Huong [20], who demonstrated that social constructivist approaches, which emphasize authentic learning tasks, significantly promote critical thinking. The Department of Education's own assessment framework (DepEd Order No. 8, s. 2015) emphasizes performance tasks as a core component of student evaluation, and this study provides empirical support for this policy direction.

D. Technology-Enhanced Learning

The differential findings for *Technology-Enhanced Science Learning* are also instructive. While it correlated with both outcomes, it was not a significant predictor of critical thinking in the regression model after controlling for other instructional variables. This suggests that simply

using technology is insufficient for fostering higher-order thinking; the *pedagogy* of its use matters more. Technology must be integrated in a way that promotes inquiry, analysis, and creation, rather than merely as a presentation or consumption tool.

This finding echoes the concerns raised by Roslan et al. [21] about the challenges of implementing technology in inquiry-based learning, including inadequate infrastructure, insufficient teacher training, and a tendency to use technology as a substitute rather than an enhancement. It also aligns with the broader literature on technology integration, which emphasizes that the quality of technology use—how it is pedagogically employed—is more important than the quantity or presence of technology.

E. Theoretical and Practical Synthesis

Taken together, the findings of this study support a model in which school leadership and instructional practices operate as interconnected systems. Leadership shapes the conditions—particularly school culture and instructional focus—that enable teachers to implement effective instructional practices. These practices, especially authentic assessment and the integration of critical thinking strategies, directly influence student outcomes. This integrated perspective aligns with the "Four Paths Model" of leadership influence proposed by Leithwood et al. [11], which identifies rational, emotional, organizational, and family paths through which leadership affects student learning. In this study, the organizational path (school culture) and the rational path (instructional leadership) emerged as particularly influential.

Conclusion and Recommendation

This study concludes that both school leadership and 21st-century instructional practices are significant, interconnected predictors of student success in science. The findings highlight that leadership focused on cultivating a positive school culture and providing instructional guidance, combined with classroom practices that emphasize authentic assessment and the explicit teaching of critical thinking, are key levers for improving student outcomes.

The study refines instructional leadership theory by empirically demonstrating that a supportive school culture is not just a mediator but a direct predictor of student cognitive outcomes. It also supports the practical application of constructivist principles in predicting academic success. The findings contribute to the growing body of knowledge on educational leadership in the Philippine context (Cahapay, 2021; Patiga, 2024) and provide empirical validation for the pedagogical frameworks underlying the K to 12 Science Curriculum.

Longitudinal studies are needed to establish causality and examine how these relationships evolve over time. Qualitative research, such as case studies or classroom observations, could provide deeper insights into how exemplary leaders and teachers successfully implement these practices. Future studies should also investigate the quality of technology integration rather than its mere presence to understand its potential to foster higher-

order thinking. Comparative studies across different divisions, regions, and school types (urban vs. rural) would enhance the generalizability of findings.

Conflict of Interest

The authors declare that there is no conflict of interest.

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