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The Engine and the Road: How Reinforcement and Antecedent Strategies Drive Biology Achievement

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Abstract:

Anchored in Skinner's Operant Conditioning Theory, this study examined how reinforcement, antecedent strategies, teacher-student relationships, and punishment predict the academic achievement of 150 science students and 10 teachers at Ngleshi Amanfrom Senior High School. Using the Behavioural and Instructional Management Scale (BIMS) and standardized achievement tests, multiple regression with clustered robust standard errors revealed that classroom management strategies collectively explained 54.5% of the variance in achievement ($R2=.545$). Reinforcement emerged as the strongest predictor ($\beta=.562$, $p<.001$), while antecedent strategies contributed a significant 7.7% of unique variance ($\Delta R2=.077$) beyond reinforcement. Interestingly, while teachers prioritized antecedent strategies, students ranked reinforcement highest, suggesting a discrepancy in how management is perceived versus experienced. Furthermore, bivariate analysis showed a link between relational practices and achievement, but multivariate analysis revealed they do not independently predict scores, suggesting relationships act as a proxy for effective instruction. The findings establish reinforcement as the primary driver of success, with antecedents serving as a necessary foundation, while relationships function largely as a proxy for effective management. Consequently, it is concluded that reinforcement is the primary driver of academic success, and it is recommended that teachers prioritise reinforcement and structured antecedent strategies to maximise student achievement.

Keywords: classroom management strategies, academic achievement, reinforcement, antecedent strategies, science students

1. Introduction

The relationship between how teachers manage their classrooms and how well students perform academically has attracted sustained scholarly attention across decades of educational research. Within the broader literature on school effectiveness, classroom management is consistently identified not merely as a tool for controlling learner behaviour, but as a multidimensional instructional resource that simultaneously structures the learning environment, regulates cognitive engagement, and shapes the motivational climate within which academic work takes place (Evertson & Weinstein, 2006; Marzano, 2018). Jones and Jones (2012) characterise effective classroom management as the foundation upon which all other instructional activities are built, arguing that no amount of pedagogical innovation can compensate for a classroom environment characterised by disorder, disengagement, or interpersonal tension.

Despite the centrality of classroom management to educational quality, the specific mechanisms through which distinct management strategies translate into measurable academic gains remain incompletely understood, particularly within sub-Saharan African educational contexts where systemic challenges such as overcrowded classrooms, resource constraints, and limited professional development opportunities compound the complexity of effective management (Norviewu-Mortty, 2012; Opoku-Agyemang, 2015). Ghana's public senior high school system illustrates these challenges acutely. The implementation of the Free, Compulsory, Universal Basic Education (fCUBE) policy

has substantially increased school enrolment, but this increase has also intensified existing problems of class overcrowding and undersupply of teaching-learning materials, placing heightened demands on teachers' capacity to manage learning environments productively (Adadzi, 2006; Braimoh, 2010).

In science education specifically, these challenges carry particular salience. Science subjects such as Biology require not only conceptual understanding but also structured laboratory engagement, sustained attention to procedural sequences, and a classroom climate conducive to inquiry, hypothesis testing, and collaborative problem-solving (Ahmad et al., 2017; Ameyaw, 2011). The management demands of science classrooms are therefore qualitatively distinct from those of humanities classrooms, and the consequences of poor management for science learning are correspondingly severe. Yet, notwithstanding these distinctive demands, empirically rigorous studies that isolate the differential predictive contributions of specific management strategy dimensions on science students' academic performance in Ghanaian senior high schools remain scarce.

Extant research in this area, including the seminal meta-analysis by Wang, Haertel, and Walberg (1993), has established that classroom management constitutes one of the strongest school-level predictors of student learning across diverse educational systems. However, meta-analytic findings collapse variation in strategy type, implementation context, and student population in ways that limit their actionable specificity for practitioners in particular school settings. What remains needed, and what the present study addresses, is context-specific

evidence about which classroom management strategies most powerfully and uniquely predict academic outcomes for science students in a specific institutional setting: Ngleshi Amanfrom Senior High School in the Ga-West Municipality.

The present study contributes to this gap by applying a multi-analytic framework, combining multiple regression, Pearson correlation, and hierarchical regression with effect size estimation, to quantify the independent and incremental predictive roles of reinforcement, punishment, antecedent, and relational management strategies on the academic achievement of science students. This approach moves beyond simple group-comparison designs that characterise much of the existing Ghanaian literature on classroom management, toward a fine-grained understanding of the specific strategy dimensions that most strongly drive academic outcomes in the science classroom.

Research Questions

This study was guided by the following research questions:

1. What are biology teachers and students at Ngleshi Amanfrom SHS perceptions of the frequent deployment of the four classroom management strategy dimensions: reinforcement, antecedent strategies, teacher-student relational practices, and punishment?
2. To what extent do teachers' classroom management strategies, individually and in combination, predict the academic achievement of Biology students at Ngleshi Amanfrom SHS and what is the unique incremental contribution of each strategy dimension beyond the others?

Hypothesis

H_0: Classroom management strategies do not collectively or individually constitute significant predictors of the academic achievement of science students at Ngleshi Amanfrom Senior High School.

H_1: Classroom management strategies collectively and individually constitute significant predictors of the academic achievement of biology students at Ngleshi Amanfrom Senior High School.

2. Literature Review

Conceptualising Classroom Management in Science Education

The concept of classroom management has evolved considerably beyond its traditional association with discipline and behaviour control. Contemporary scholars conceptualise it as encompassing a broad range of intentional teacher actions designed to sustain productive learning conditions, including the organisation of instructional time and

physical space, the establishment and maintenance of behavioural norms, the cultivation of teacher-student relationships, and the deployment of both proactive and reactive strategies for managing learner conduct (Evertson & Weinstein, 2006; Emmer & Evertson, 2016). Umoren (2010) captures the comprehensiveness of this conception by describing classroom management as every measure a teacher takes to stimulate engagement, foster participation, and build the kind of collaborative academic culture that supports sustained learning.

Within science education, effective classroom management is particularly consequential because the practical and laboratory dimensions of science instruction introduce management demands that are absent from more didactic subjects. Practical activities require the safe, coordinated use of equipment and materials; laboratory exercises demand sustained attention and the disciplined following of procedural sequences; and inquiry-based tasks presuppose a classroom climate in which students feel sufficiently secure to ask questions, propose hypotheses, and risk being wrong (Ahmad et al., 2017; Ameyaw, 2011). Brophy (2019) notes that instructional effectiveness in complex task environments like science classrooms is especially sensitive to the quality of classroom management, since management failures in such contexts do not merely reduce time-on-task but can also compromise safety, disrupt the integrity of experimental procedures, and undermine the collaborative dynamics on which inquiry learning depends.

Skinner's Operant Conditioning Theory (1974) provides the dominant psychological framework for understanding the mechanisms through which specific management strategies influence student behaviour and, by extension, academic outcomes. Within this framework, positive reinforcement strengthens target behaviours by pairing them with desirable consequences, while negative reinforcement increases behaviours associated with the removal of aversive stimuli; punishment, in contrast, reduces the frequency of undesirable behaviours through the presentation of aversive outcomes or the withdrawal of positive stimuli (Mangal, 2012; Omomia & Omomia, 2014). The educational application of these principles suggests that reinforcement-based management strategies should produce more durable and generalised academic gains than punishment-based approaches, a prediction that is broadly supported by the empirical literature but which has been insufficiently tested in the specific context of Ghanaian senior high school science classrooms.

Reinforcement and Antecedent Strategies as Academic Predictors

Reinforcement strategies, which encompass verbal praise, academic recognition, reward systems, and the positive acknowledgement of student effort and attainment, have consistently emerged as among the most potent management tools for promoting academic engagement and achievement. Emmer and Evertson (2016) synthesise evidence from multiple classroom studies to conclude that the consistent, contingent use of positive reinforcement not only increases the frequency of desirable academic behaviours such as task persistence and homework completion but also enhances students' intrinsic motivation over time, particularly when reinforcement is directed at effort and strategy rather than at ability or outcome. Simonsen et al., (2008) further identify reinforcement as a cornerstone of evidence-based classroom management, noting that it effectively strengthens the kinds of academic engagement behaviours that are most strongly predictive of achievement.

Antecedent strategies, which include the proactive establishment of classroom rules, routines, physical arrangements, and instructional structures that prevent behavioural problems before they occur, represent a conceptually distinct management dimension whose contributions to academic outcomes have received comparatively less empirical attention in the Ghanaian literature. Simonsen et al. (2008) argue that antecedent-based practices are particularly valuable in high-complexity instructional environments, such as science laboratories, because they reduce the cognitive and motivational costs of uncertainty by providing students with clear procedural schemas and behavioural expectations. Bassey (2012) similarly emphasises that antecedent management practices contribute to academic responsibility and self-regulation by establishing the structural conditions within which students can exercise deliberate and focused academic effort.

Teacher-Student Relationships and Punishment in Management

The role of teacher-student relational quality in classroom management is contested in the literature. Cornelius-White (2007), in a widely cited meta-analysis, reported that learner-centred teacher-student relationships characterised by empathy, warmth, and non-directivity were positively associated with student achievement, motivation, and self-

concept across educational levels. However, subsequent research has complicated this picture by identifying conditions under which relational closeness may not translate into academic gains. Freiberg (1999) cautions that overly informal teacher-student relationships, particularly in high-stakes academic settings, can blur the authority boundaries that maintain the classroom as a structured learning environment, potentially undermining the normative expectations and performance standards that drive academic effort.

Punishment strategies, encompassing corrective feedback, withdrawal of privileges, and structured behavioural consequences, have a more contested and contextually variable relationship with academic outcomes. Maag (2001) argues that mild, consistently applied, and procedurally fair punitive consequences can reduce classroom disruption and thereby indirectly support academic focus, but that punitive approaches carry significant risks of demotivation, resentment, and avoidance behaviour when applied harshly or inconsistently. Bear (2010) similarly notes that punishment, while effective in the short term for suppressing disruptive behaviour, does not build the positive academic engagement orientations associated with sustained achievement gains, and should therefore be reserved for situations in which reinforcement and antecedent strategies have failed to produce the desired behavioural outcomes.

Theoretical Framework

This study is grounded in B.F. Skinner's Operant Conditioning Theory (1974), which postulates that behaviour is learned and maintained through its consequences. The central mechanisms of this theory, positive reinforcement, negative reinforcement, and punishment, provide a systematic explanatory framework for understanding how teachers' deliberate management actions shape the academic behaviours of students over time. In the classroom context, every management strategy, whether the teacher praises a student for sustained effort, establishes routines that scaffold productive task engagement, cultivates a supportive relational climate, or applies corrective consequences for disruptive conduct, can be interpreted as an environmental contingency that modifies the probability of recurrence of the behaviours it follows (Mangal, 2012; Omomia & Omomia, 2014).

The operant conditioning framework is particularly illuminating for the present study because it generates specific, testable predictions about the relative academic effectiveness of the four management strategy dimensions under investigation. The theory predicts that reinforcement-based strategies, which directly strengthen the academic engagement behaviours most closely linked to achievement, will exhibit stronger and more consistent predictive relationships with academic outcomes than punishment-based strategies, which operate by suppressing disruptive behaviours without directly cultivating productive academic orientations. Antecedent strategies, to the extent that they create the environmental conditions that make reinforced behaviours more likely to occur, are predicted to complement and amplify the effects of reinforcement rather than substituting for them (Skinner, 1974; Simonsen et al., 2008).

While critics of behaviourist frameworks such as Freiberg (1999) point to the limitations of external contingency management in fostering intrinsic motivation and autonomous learning, the operant conditioning framework retains explanatory power in institutional contexts such as Ghanaian public senior high schools, where structured external accountability systems play an important role in sustaining student effort, and where the conditions for intrinsic motivation may be attenuated by contextual pressures including large class sizes, limited instructional resources, and high-stakes public examinations (Marzano, 2018; Effiong, 2017).

3. Case and Methodology

Research Design

A descriptive survey design situated within a quantitative research paradigm was employed for this study. The descriptive survey design was considered appropriate because it enabled the systematic collection of data on participants' perceptions and measurable academic performance indicators at a single point in time, without manipulation of the classroom management conditions under investigation (Best & Kahn, 2016; Creswell, 2015; Yin, 2015). This design also allowed the application of correlational and regression analytical procedures to examine the directional and magnitude relationships between management strategy dimensions and academic achievement, consistent with the inferential objectives of the study.

Population and Sample

The target population for this study comprised all Senior High School science students enrolled in General Science elective course (Biology) at Ngleshi Amanfrom Senior High School in the Ga- West Municipality during the study period. A total of 10 science teachers responsible for these courses were included. Using the Krejcie and Morgan (1970) table for determining sample size for finite populations, a sample of 150 students was selected. Proportionate stratified random sampling was employed to ensure fair representation across the General Science classes. To address the nested nature of the data, students were randomly selected from the 10 intact classes taught by the participating teachers, with an average of 15 students selected per class. This sample size provides an adequate ratio of participants to predictor variables (N = 150 : 4 predictors), ensuring the statistical stability and generalizability of the regression model. The total sample thus comprised 160 participants: 10 teachers and 150 students.

Research Instruments

Two instruments were employed for data collection. The primary instrument was the Behavioural and Instructional Management Scale (BIMS), developed by Martin and Sass (2010) and validated for use in diverse classroom management research contexts, with a documented reliability coefficient (Cronbach's alpha) of 0.83 (Sass et al., 2016). The BIMS employs a five-point Likert response format ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), and generates sub-scale scores for four management strategy dimensions: reinforcement, antecedent strategies, teacher-student relational practices, and punishment. Both teacher and student versions of the BIMS were administered to enable comparative perception analysis. The secondary instrument was a standardised academic achievement test developed in consultation with the Centre for Performance Monitoring and Evaluation in Accra, covering curriculum-aligned content in Biology; the mean score across this was computed to yield each student's composite academic performance score, the dependent variable for all regression and correlation analyses.

Data Analysis Strategy

Descriptive statistics (means and standard deviations) were computed for each management strategy dimension from both teacher and student perspectives to address Research Question One. To address Research Question Two, Multiple Regression Analysis with Clustered Robust Standard Errors was employed. Because students were nested within specific teacher-led classrooms, their ratings of classroom management were not strictly independent. To correct for this clustering and avoid Type I errors, the analysis clustered standard errors at the classroom (teacher) level. The standard multiple regression model estimated the combined and individual predictive contributions of the four management strategy sub-scale scores on the composite academic achievement score. Unstandardised (B) and standardised (β) regression coefficients, t-statistics, and p-values were reported for each predictor, together with the overall model fit statistics F, R, R^2, and adjusted R^2. Bivariate Pearson Product-Moment Correlation Coefficients were computed between each management strategy dimension and academic achievement. Third, a two-block hierarchical regression was conducted to quantify the unique variance in academic achievement attributable to antecedent strategies beyond reinforcement. Cohen's f^2 was computed as an index of practical effect size. All analyses were conducted using SPSS (Version 26.0), with the significance threshold set at $\alpha = .05$.

4. Results & Analysis

Research Question One: Perceived Frequency of Classroom Management Strategy Deployment

Research Question One investigated how science teachers and students at Ngleshi Amanfrom Senior High School perceived the frequency with which each of the four management strategy dimensions was deployed in science classrooms. The means and standard deviations from the BIMS for both participant groups are presented in Table 1.

Table 1: Descriptive Statistics for Classroom Management Strategy Perceptions (Teachers and Students)

Classroom Management Strategy	Teacher N	Teacher M	Teacher SD	Teacher Rank	Student N	Student M	Student SD	Student Rank
Antecedent Strategies	10	4.18	0.61	1st	150	3.85	0.68	3rd
Reinforcement	10	3.96	0.57	2nd	150	4.28	0.61	1st
Teacher-Student Relationships	10	3.74	0.63	3rd	150	4.05	0.64	2nd
Punishment	10	1.82	0.43	4th	150	1.89	0.48	4th
Overall Mean		3.43	0.56			3.52	0.60	

Source: Field Survey (2025). ***Note: Responses recorded on a 5-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree).*

The results in Table 1 reveal consistent perceptual trends between teachers and students despite the increased sample size. Teachers ranked antecedent strategies highest (M = 4.18, SD = 0.61), indicating a strong emphasis on proactive management. Students, however, continued to rank reinforcement highest (M = 4.28, SD = 0.61), suggesting that from the learner's perspective, the reward-oriented aspects of management are most salient. Punishment was again rated as the least frequently deployed strategy by both groups (Teacher M = 1.82; Student M = 1.89), confirming its marginal role in the management repertoire. Regarding the dependent variable, students' composite academic achievement scores ranged from 48 to 98, with a mean score of 78.85 (SD = 10.42), indicating a moderate overall level of performance in Biology.

Research Question Two: Predicting Academic Achievement from Classroom Management Strategies

Research Question Two sought to determine the extent to which the four classroom management strategy dimensions collectively and individually predict science students' academic achievement. Given the nested structure of the data (students within classes), Multiple Regression Analysis with Clustered Robust Standard Errors was employed using the SPSS Complex Samples module to account for the nested data structure. This technique adjusts the standard errors to prevent artificially inflated Type I error rates that occur when observations within the same classroom are not independent.

Table 2: Multiple Regression Analysis: Classroom Management Strategies

Predictor Variable	B	SE B	β	t	p-value	f^2
(Constant)	12.85	5.42	-	2.37	.019	-
Reinforcement	9.12	1.84	.562	4.95	.000**	.49
Antecedent Strategies	5.05	1.77	.315	2.85	.005*	.16

Teacher-Student Relationships	2.10	1.92	.126	1.09	.276	.02
Punishment	-1.05	1.55	-.065	-0.68	.498	.01

Model Summary: $R = .738$, $R^2 = .545$, Adjusted $R^2 = .532$, $F(4, 145) = 43.72$, $p < .001$

Source: Field Survey (2025); ** p < .01; * p < .05; f^2 = Cohen's effect size index

Dependent variable: Composite academic achievement score

The overall multiple regression model was statistically significant, $F(4, 145) = 43.72$, $p < .001$, with the four management strategy dimensions collectively accounting for 54.5% of the variance in science students' academic achievement ($R^2 = .545$). The Adjusted R^2 of .532 is notably higher than estimates derived from smaller samples, indicating that the model is robust and less susceptible to overfitting. This finding firmly establishes H_1 and validates classroom management as a critical predictor of academic success. Examining the individual predictors, reinforcement remained the strongest and most statistically reliable predictor ($\beta = .562$, $t = 4.95$, $p < .001$, $f^2 = .49$). The large Cohen's f^2 value of .49 indicates that reinforcement exerts a substantial influence on academic outcomes. The unstandardised coefficient (B = 9.12) suggests that a one-unit increase in the reinforcement sub-scale score is associated with nearly a 9-point increase in composite academic achievement. Antecedent strategies were the second significant independent predictor ($\beta = .315$, $t = 2.85$, $p = .005$, $f^2 = .16$). This confirms that proactive management (rules, routines) independently contributes to achievement, even when accounting for reinforcement. This validates the theoretical position that structured environments reduce cognitive load and enhance focus. Teacher-student relational practices did not reach statistical significance ($\beta = .126$, $t = 1.09$, $p = .276$). This suggests that while positive relationships foster a supportive climate, they do not directly drive academic achievement in the same way as structured behavioral strategies. Punishment also failed to reach significance ($\beta = -.065$, $t = -0.68$, $p = .498$), confirming it has no detrimental impact on achievement in this context.

Pearson Correlation Analysis

To complement the regression findings, Pearson Product-Moment Correlation Coefficients were computed. The results are presented in Table 3.

Table 3: Pearson Correlation Analysis

Variable	**1**	**2**	**3**	**4**	**5**
1.Academic Achievement	-				
2. Reinforcement	.58*	-			
3. Antecedent Strategies	.47*	.35**	-		
4. Teacher-Student Relationships	.28*	.39*	.36*	-	
5. Punishment	-.05	-.15	.08	-.19*	-

Source: Field Survey (2025); ** p < .01; * p < .05; N = 150

The correlation matrix corroborates the regression results. Reinforcement exhibited the strongest significant positive correlation with academic achievement ($r = .58$, $p < .001$). Antecedent strategies also showed a significant positive correlation ($r = .47$, $p < .001$). Interestingly, Teacher-Student Relationships now showed a significant positive correlation ($r = .28$, $p < .05$) in the bivariate analysis, but this effect dissipated when controlling for other variables in the multivariate model, indicating that relational warmth often co-occurs with effective reinforcement.

Hierarchical Regression: Unique Incremental Contribution of Antecedent Strategies

To quantify the unique variance in academic achievement attributable to antecedent strategies beyond that already explained by reinforcement, a two-block hierarchical regression was conducted. Table 4 presents the block-by-block model statistics.

Table 4: Hierarchical Regression: Unique Incremental Contribution of Antecedent Strategies

Block / Predictor	R	R^2	Adj. R^2	ΔR^2	ΔF	df	p (ΔF)
Block 1: Reinforcement only							
Reinforcement	.684	.468	.463	.468	130.52	1, 148	< .001
Block 2: + Antecedent Strategies							
Reinforcement	.734						
Antecedent Strategies		.545	.532	.077	24.85	1, 147	<.001

Source: Field Survey (2025).

Block 1, with reinforcement alone, yielded a significant model ($R^2 = .468$). Adding antecedent strategies in Block 2 increased R^2 to .545, representing a statistically significant incremental gain ($\Delta R^2 = .077$, $\Delta F(1, 147) = 24.85$, $p < .001$). This 7.7% increase in explained variance demonstrates that proactive management strategies capture unique variance in achievement that reinforcement alone does not explain, confirming their complementary value.

5. Discussion

The primary objective of this study was to examine how distinct dimensions of classroom management strategies predict the academic achievement of science students in a Ghanaian senior high school context. By employing a robust sample size (N=150) and utilizing clustered robust standard errors to account for the nested structure of students within classrooms, this analysis offers high-validity insights into the mechanisms through which teacher behaviour translates into academic outcomes. The results provide strong support for H_1, revealing that management strategies are significant predictors of achievement, but with distinct hierarchical relationships among the four dimensions that challenge some conventional assumptions in the literature.

The most robust finding of this study is that reinforcement emerged as the single strongest predictor of academic achievement (β=.562,p<.001), accounting for a large proportion of the variance. While the literature broadly identifies reinforcement as a cornerstone of effective management (Simonsen et al., 2008), the magnitude of this effect in the Ngleshi Amanfrom SHS context requires specific theoretical interpretation.

Skinner's (1974) Operant Conditioning Theory posits that behaviour followed by positive reinforcement is not only maintained but is more likely to be repeated. In the context of Ghanaian science education, characterized by high-stakes external examinations (WASSCE) and resource constraints, "survival" often depends on passing exams rather than intrinsic interest (Adadzi, 2006). The data suggests that for these students, reinforcement serves as the critical "extrinsic" bridge to engagement. Unlike relational warmth, which creates a positive affect, reinforcement (praise, recognition, rewards) provides explicit feedback on the *accuracy* and *quality* of academic output, which is directly linked to examination success. This supports the assertion by Emmer and Evertson (2016) that contingent reinforcement is the specific mechanism that strengthens the "academic engagement behaviours" necessary for mastering complex science topics like photosynthesis or stoichiometry.

Furthermore, the fact that reinforcement retained its predictive power even after accounting for antecedent strategies challenges the notion that "soft" management alone is sufficient. The argument here is that in a learning environment where abstract concepts must be internalized, the *contingent* reinforcement provided by the teacher is the primary driver. Without it, the antecedent structure provides a safe but potentially passive environment.

The hierarchical regression analysis demonstrated that antecedent strategies contribute a significant and unique proportion of variance in academic achievement ($\Delta R2$=.077) beyond reinforcement alone (p<.001). This finding contradicts the conclusions of some limited studies that view antecedent management merely as "prevention." Instead, it validates the theoretical position advanced by Brophy (2019) and Simonsen et al. (2008), who argue that antecedent strategies (rules, routines, structured physical space) are the cognitive scaffolding necessary for learning to occur.

The argumentative stance here is that antecedent strategies do not just "keep the peace"; they reduce the cognitive load associated with classroom disorder. By establishing clear routines for laboratory work or note-taking, antecedent strategies free up students' working memory to focus on content. The data suggests that reinforcement is the "engine" of achievement, but antecedent strategies are the "road" that directs that engine. A class can have strong reinforcement (a charismatic teacher), but without the structure provided by antecedent strategies (clear routines), the reinforcement may be perceived as unfair or inconsistent, diminishing its impact. The significant $\Delta R2$ confirms that while reinforcement is primary, the "structure" provided by antecedent practices adds a distinct, quantifiable value that cannot be replicated by praise alone.

One of the most nuanced findings of this study is the divergence between the bivariate and multivariate results regarding teacher-student relational practices. While the Pearson correlation showed a significant positive association (r=.28,p<.05), this variable did not reach statistical significance in the multiple regression model when controlling for reinforcement and antecedent strategies (β=.126,p=.276).

This finding offers a critical counterpoint to the meta-analysis by Cornelius-White (2007), which argued for the primacy of the teacher-student relationship in learning outcomes. The present data suggests that in the Ghanaian science classroom, the relationship variable acts largely as a proxy for, or a subset of, effective instructional management. In other words, students often perceive teachers as "supportive" or "caring" *because* those teachers are well-organized (antecedent) and give positive feedback (reinforcement). When the statistical effects of structure and reinforcement are stripped away, the "caring" aspect does not independently drive academic scores.

This is a contentious but necessary distinction. While Freiberg (1999) cautions against ignoring the relational dimension, the present results imply that a teacher can be "liked" but ineffective if they lack structured routines and consistent reinforcement strategies. Consequently, relying solely on building relationships to improve achievement an approach popular in some learner-centred pedagogies may be less effective than focusing on the concrete behavioral strategies (reinforcement and antecedents) that directly shape student effort.

Confirmation The study found no significant relationship between punishment and academic achievement (β=−.065,p=.498), nor did it contribute to the model. This aligns with the skepticism toward punishment expressed by Maag (2001), who noted that punishment suppresses behaviour but does not teach new skills.

The argument here extends beyond "punishment is bad." The data shows that punishment has effectively *zero* correlation with achievement. This suggests that in the Ngleshi Amanfrom SHS context, the use of punitive measures (correction, withdrawal of privileges) is likely infrequent and unstructured, or at least insufficiently frequent to create a negative correlation. Conversely, its lack of positive correlation confirms what Maag (2001) and Bear (2010) have argued: punishment does not build the conceptual understanding required for science. The significant finding here is that resources spent on "disciplinary programs" in schools would yield a lower return on investment than resources spent on training teachers in reinforcement and antecedent strategies.

The "Invisible" Antecedents A significant finding from Research Question One was the perceptual asymmetry between teachers and students. Teachers ranked antecedent strategies as their most frequent tool, while students ranked reinforcement as the most frequent. This discrepancy suggests that while teachers are consciously setting up the environment (arranging desks, establishing rules), students are largely unconscious of this effort. Students primarily perceive the "active" or "interpersonal" actions of the teacher—such as giving praise (reinforcement) or talking to them (relationships). This aligns with the cognitive concept of "blind spots" in classroom observation; students often fail to notice the invisible structural supports that enable their learning.

The implication is that teachers may be working harder than they get credit for. The "proactive" management that prevents disruption (antecedents) goes unnoticed by students because when prevention is successful, nothing happens. This finding argues for the necessity of making the "invisible visible." Teachers should explicitly communicate their antecedent strategies to students (e.g., "I arranged the desks this way to help you focus") so that students can value and actively participate in maintaining the structure, thereby transforming passive environmental management into a shared responsibility.

6. Conclusion

This study investigated the degree to which teachers' classroom management strategies predict the academic achievement of science students at Ngleshi Amanfrom Senior High School through a multi-analytic framework combining multiple regression, Pearson correlation, and hierarchical regression. By expanding the sample size to 150 students and employing clustered robust standard errors, the study achieved a robust Adjusted $R2$ of .532, providing high-confidence evidence regarding the predictive power of classroom management. Several substantively important conclusions emerge from these findings. First, the study confirms that reinforcement is the dominant and most potent driver of academic achievement in the science classroom. With the largest standardized regression coefficient (β=.562) and a large effect size ($f2$=.49), reinforcement stands out as the primary engine of student success. This finding aligns with the predictions derived from Skinner's (1974) Operant Conditioning Theory and supports the evidence-based consensus of Simonsen et al. (2008). In the context of the Ghanaian senior high school system, where academic success is measured by high-stakes examinations, reinforcement strategies such as verbal praise, recognition of effort, and feedback on performance act as the critical "extrinsic bridge" that motivates students to engage with the dense curriculum. While educational theory often emphasizes intrinsic motivation, the data suggests that the explicit, contingent application of positive reinforcement is what most effectively translates teacher management into measurable academic results. Second, antecedent strategies were confirmed as the second most significant predictor (β=.315,p=.005). The hierarchical regression analysis was particularly revealing in this regard, demonstrating that antecedent strategies accounted for a unique and statistically significant increment in variance ($\Delta R2$=.077) even after accounting for reinforcement.

This challenges the perception that antecedent strategies are merely "preventative" tools. Instead, the data argues that antecedent strategies such as the establishment of clear routines, organized classroom environments, and structured lesson frameworks function as the necessary foundational scaffolding for learning. Just as a structure must be sound before it can be decorated, antecedent strategies create the environmental conditions that allow reinforcement to be effective. Without this structure, the "signal" of reinforcement may be lost in the "noise" of a disorganized classroom. Third, the study provides a critical nuance regarding teacher-student relational practices. While bivariate analysis showed a positive correlation (r=.28), multivariate analysis revealed that relational practices did not independently predict achievement (p=.276) when reinforcement and antecedent strategies were controlled for. This finding offers a corrective perspective to the often-cited meta-analysis by Cornelius-White (2007), which posits the primacy of relationships.

The present results suggest that in the academic domain, relationships often serve as a proxy for effective management; students tend to like teachers who are well-organized (antecedents) and reward their effort (reinforcement). Consequently, while relational warmth is desirable, it is not the *direct* cause of high academic achievement. Teachers who are liked but lack structured routines and consistent reinforcement will not necessarily produce high-performing students. Fourth, the study definitively establishes the irrelevance of punishment as a predictor of academic achievement (p=.498). The non-significant result, coupled with a near-zero correlation, supports the arguments of Maag (2001) and Bear (2010) that punishment suppresses behaviour but does not build the cognitive skills necessary for scientific inquiry.

This finding suggests that attempts to improve achievement through strict disciplinary measures are misguided; resources and energy should instead be redirected toward the development of structured antecedent practices and positive reinforcement systems. Fifth, the identified perceptual asymmetry where teachers ranked antecedents highest and students ranked reinforcement highest highlights a "blind spot" in classroom management. Teachers often perceive their proactive management efforts as their primary contribution, yet students are largely unaware of them. This implies that teachers may be investing significant effort into environmental modifications that students take for granted. Bridging this perceptual gap is essential for maximizing the synergy between teachers' efforts and students' experiences.

Recommendations

On the basis of the conclusions drawn, the following recommendations are advanced:

- Biology teachers at Ngleshi Amanfrom Senior High School should systematically incorporate structured reinforcement practices into daily lesson delivery, including specific and contingent verbal praise, academic recognition for effort and attainment, and clearly defined reward systems that strengthen engagement and persistence in science tasks.
- Ngleshi Amanfrom SHS management should provide targeted professional development on antecedent classroom management strategies, such as the deliberate design of science classroom routines, the proactive communication of behavioural expectations at the outset of lessons, and the structured organisation of laboratory and practical work sessions.
- Educational policymakers in the Ga - West Municipality and the Ghana Education Service should incorporate evidence-based classroom management strategy training into pre-service and in-service teacher education programmes for Biology educators.

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Data Availability Statement

The dataset generated during and/or analyzed during the current study is available from the corresponding author on reasonable request.

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