Examining Variations in Science Achievement: A Grounded Theory Study on Learning Habits and Emotional Engagement

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Abstract

This study investigates the interplay between learning habits and emotional engagement among Ghanaian secondary school students and their impact on science achievement across different performance levels. Employing a grounded theory qualitative approach, purposive and theoretical sampling identified high, medium, and low performers from diverse schools across selected regions. Data were collected concurrently through semi-structured interviews, classroom observations, and reflective journals to capture rich, authentic narratives. Analysis followed a constant comparative method involving open, axial, and selective coding, guiding ongoing data collection and theory refinement. Findings reveal distinct cognitive and affective engagement patterns: high performers exhibit strategic, well-regulated learning accompanied by strong interest and confidence; medium performers show inconsistent study behaviors and fluctuating motivation; low performers rely on reactive memorization rooted in anxiety and low self-confidence. The emergent construct of Adaptive Engagement illuminates the dynamic feedback loop between emotional investment and learning strategies, shaping science outcomes. This model underscores the critical role of integrating cognitive and emotional support in science education to address varied learner needs effectively. The study contributes valuable insights for educators and policymakers to design interventions that foster sustained motivation and strategic learning, ultimately enhancing science performance in under-resourced contexts.

Keywords: Self-regulated learning, emotional engagement, science achievement, grounded theory, secondary education

1. Introduction

In contemporary science education, understanding the multifaceted factors that influence student performance remains a critical challenge. Despite numerous studies focusing on cognitive outcomes, less attention has been given to the interplay between students' learning habits and their emotional engagement in shaping academic achievement across different performance levels. Learning habits, defined as the consistent behaviors and strategies students employ to acquire knowledge, play a pivotal role in students' success (Zimmerman, 2002). Emotional engagement, encompassing students' feelings of interest, enjoyment, and emotional investment in learning, has been shown to significantly affect motivation and persistence in science learning (Fredricks, Blumenfeld, & Paris, 2004). Yet, the specific ways in which these factors differentiate high, medium, and low performers in science are underexplored, limiting educators' ability to tailor interventions that address diverse learner needs.

This gap is particularly relevant in the science education context, where emotional barriers such as anxiety and low self-efficacy often impede optimal learning (Das & Mohapatra, 2017). Traditional quantitative approaches predominantly emphasize measurable outcomes, potentially neglecting deeper qualitative insights into students' lived experiences and the dynamic processes that influence their performance. Thus, a methodological approach that can generate theory grounded in actual student experiences is essential.

Grounded theory methodology offers such an approach by enabling researchers to inductively develop substantive theories from rich qualitative data without the constraint of prior hypotheses (Glaser & Strauss, 1967). It allows for the systematic exploration of learning habits and emotional engagement as they naturally emerge in student narratives, providing nuanced understanding of how these elements coalesce to influence science achievement. By adopting grounded theory, this study seeks to fill an existing gap in science education research by constructing a model that explicates the interaction between cognitive and affective factors across varying levels of science performance.

Addressing this gap is important for creating targeted educational strategies that enhance not only knowledge acquisition but also emotional support for learners. Ultimately, insights from this research can inform educators, curriculum developers, and policymakers on how to foster effective learning environments that accommodate diverse learner profiles and improve student outcomes in science education.

Rationale for the Study

Science education continues to be challenged by varied student performance, with persistent disparities rooted in both cognitive and emotional domains. While prior research recognizes learning habits and emotional engagement as influential factors, there is limited understanding of how these elements collectively differentiate student achievement levels in science. This study is needed to provide an in-depth and grounded exploration of these factors, offering nuanced theory that explains the underlying processes shaping science performance.

Study Gaps

Existing literature predominantly addresses learning habits and emotional engagement separately or focuses on quantitative outcomes without capturing students' lived experiences holistically. Few studies employ grounded theory methodology to examine the dynamic interaction between these constructs across high, medium, and low performers. This gap limits educators' ability to design interventions addressing both cognitive and affective dimensions aligned with diverse learner profiles.

Significance of the Study

By generating a grounded theory of Adaptive Engagement in Science Learning, this study contributes fresh theoretical insights to science education research. It informs educators, curriculum designers, and policymakers on the importance of integrating self-regulated learning and emotional support strategies to enhance science achievement. The findings hold practical implications for developing targeted interventions, ultimately aiming to improve student motivation, engagement, and success in science education.

Purpose of the study

The purpose of this grounded theory study is to explore and develop a theoretical understanding of how learning habits and emotional engagement shape science achievement among students with varying performance levels. By systematically collecting and analyzing qualitative data, this study aims to uncover the processes and interactions between cognitive behaviors and affective experiences that differentiate high, medium, and low performers in science education. This research seeks to generate a grounded theory that provides both explanatory and practical insights, helping educators design targeted interventions to enhance learning engagement and academic success in science.

Research Objectives:

1. To explore the distinct learning habits and emotional engagement patterns of high, medium, and low performers in science education.
2. To develop a grounded theory explaining how learning habits and emotional engagement interact to influence science performance across different learner groups.

Research Questions

1. What learning habits and emotional engagement characteristics distinguish high, medium, and low science performers?
2. How do learning habits and emotional engagement collectively impact science achievement among diverse student performance levels?

Grounded Theory Methodology in Science Education Research

Grounded theory has gained prominence as a favored qualitative research approach in education due to its unique ability to develop rich, data-driven theories that closely reflect the complexities of real-world phenomena (Stough & Lee, 2021). Unlike conventional research methods that primarily test pre-established hypotheses, grounded theory emphasizes an inductive process, allowing researchers to delve deeply into participants' lived experiences to construct explanatory frameworks (Birks & Mills, 2012; Corbin & Strauss, 2008). This method is exceptionally suited to science education research where the intricate interaction of cognitive, behavioral, and emotional factors varies significantly depending on context (Urquhart, 2013).

Scientific investigations into learning behaviors have consistently shown that students' habitual learning strategies profoundly impact their academic outcomes (Zimmerman, 2002). High achievers tend to demonstrate self-regulated learning practices characterized by strategic persistence, effective study habits, and adaptability (Pintrich, 2000). Alongside cognitive strategies, emotional engagement—manifested as interest, motivation, and a sense of belonging within the science classroom environment—has been linked positively with improved academic performance and alleviation of anxiety related to science learning (Fredricks, Blumenfeld, & Paris, 2004; Das & Mohapatra, 2017). Despite extensive individual research on these areas, only a limited number of studies have integrated both cognitive and affective domains into a holistic explanatory model differentiating science learners by performance. Grounded theory provides a powerful framework to bridge this gap by enabling systematic exploration of how students' learning habits and emotional engagement intertwine to influence science achievement. Through empirical, inductive inquiry into student experiences, grounded theory facilitates the formulation of substantive, context-sensitive theories that capture the dynamic interplay of factors impacting achievement (McGhee, Marland, & Atkinson, 2007). Such theorizing is invaluable for informing the development of adaptive instructional strategies that simultaneously support both the cognitive and emotional needs of diverse learner groups. Ultimately, employing grounded theory in this research offers an in-depth, nuanced understanding of varied engagement patterns and habit formation processes among distinct groups of science learners—high, medium, and low performers—thereby advancing theoretical and practical knowledge in the field of science education.

Theoretical Foundations of Science Learning

Science learning is understood through multifaceted theoretical lenses encompassing cognitive, behavioral, and affective dimensions. Foundational theories such as Piaget's constructivism emphasize learners' active construction of knowledge through experience and reflection, while Vygotsky's socio-cultural theory highlights the role of social interaction in cognitive development. In the realm of science education, theories of self-regulated learning (Zimmerman, 2002) and engagement frameworks (Fredricks, Blumenfeld, & Paris, 2004) offer a comprehensive understanding of how learners control cognitive processes and maintain motivation. These frameworks converge on the concept that cognitive and emotional processes interact dynamically to shape science learning outcomes. Integrating these theories provides a robust conceptual base for examining student variations in science achievement, emphasizing the importance of addressing both knowledge acquisition and motivational-emotional engagement (Pintrich, 2000; Urquhart, 2013).

Learning Habits and Self-Regulated Learning in Science Education

Self-regulated learning (SRL) is a critical factor influencing students' academic success in science, characterized by active metacognitive monitoring, goal-setting, strategic resource management, and adaptive behavioral responses (Zimmerman, 2002). Research evidences that students who consistently employ self-regulatory strategies, such as planning, self-monitoring, and reflection, outperform peers who rely on surface approaches like rote memorization (Pintrich, 2000). High-performing science students exhibit persistent study habits, effective time management, and the use of diverse learning techniques which contribute to deeper conceptual understanding (Zimmerman et al., 1996; Stough & Lee, 2021). Educator facilitation of SRL through targeted instructional coaching further enhances development of these skills. However, challenges remain in promoting reflective phases of SRL, crucial for sustained improvement in science learning. SRL's cyclical process—planning, performance, and reflection—empowers learners to adapt their cognitive and behavioral efforts in response to feedback, thereby supporting long-term achievement (Winne & Hadwin, 1998).

Emotional Engagement and Motivation in Science Learning

Emotional engagement encompasses students' feelings of interest, enjoyment, anxiety, and emotional investment in science activities, profoundly affecting their motivation to learn and persevere through challenges (Fredricks et al., 2004). Positive emotional engagement has been linked to better academic performance and higher persistence, while negative emotions such as anxiety and fear often hinder learning by reducing self-efficacy and promoting disengagement (Das & Mohapatra, 2017). In science classrooms, emotional factors mediate cognitive engagement and can either facilitate or obstruct the use of effective learning strategies (Fredricks, Blumenfeld, & Paris, 2004). Studies indicate that fostering emotional support and creating environments that enhance belongingness and interest can mitigate science anxiety and boost motivation (Das & Mohapatra, 2017). Connections between emotional states and motivation highlight the need for pedagogical interventions that address both affective and cognitive domains to sustain meaningful science engagement.

Interplay of Cognitive and Emotional Factors in Science Achievement

Emerging research reveals that cognitive strategies and emotional engagement are not isolated; rather, their interplay is crucial in differentiating science achievement levels (Pintrich, 2000; Das & Mohapatra, 2017). High performers typically exhibit a positive feedback loop where strategic learning habits reinforce emotional engagement such as confidence and interest, leading to sustained motivation and deep learning (Zimmerman, 2002). Conversely, low performers often experience negative emotions that undermine self-regulation and promote surface-level study behaviors. Medium performers fluctuate between these states, indicating potential for targeted interventions to stabilize engagement and habit formation (). Grounded theory research uniquely captures this dynamic, providing rich insights into how these domains coalesce to influence science learning outcomes (McGhee et al., 2007). Understanding this interaction enables educators to design holistic interventions addressing both cognitive skills and emotional resilience.

Grounded Theory in Educational Research

Grounded theory (Glaser & Strauss, 1967) has become a popular qualitative approach in educational research for theory building grounded directly in empirical data rather than testing preconceived hypotheses. This methodology is particularly valuable for complex constructs like learning habits and emotional engagement, where nuanced, participant-driven insights into lived experiences are essential (Birks & Mills, 2012; Corbin & Strauss, 2008). Its iterative data collection and constant comparative analysis afford robust theory development sensitive to context-specific realities (Tie et al., 2019). Grounded theory's emphasis on emergent categories and reflexivity aligns with the multifactorial nature of science achievement disparities, enabling theory that is both explanatory and practical for informing instructional design and policy.

Contextual Factors Influencing Science Learning Outcomes

Beyond individual cognitive and emotional factors, contextual elements including socio-economic status, cultural expectations, school resources, and teacher characteristics significantly shape science learning (Das & Mohapatra, 2017; Urquhart, 2013). In under-resourced environments, for instance, anxiety and lack of adequate support may exacerbate disengagement, hampering science achievement. Recognition of these wider influences underscores the need for comprehensive educational strategies that consider environmental barriers alongside individual learner differences. Addressing contextual factors ensures that interventions to promote self-regulation and emotional engagement are equitable and effective across diverse learner populations.

conceptual framework

The conceptual framework for this study blends two influential models: Zimmerman's (2002) theory of self-regulated learning and Fredricks, Blumenfeld, and Paris's (2004) multidimensional engagement model. Zimmerman's theory accentuates the role of learning habits as deliberate, self-directed strategies whereby students manage and regulate their own learning activities. Meanwhile, Fredricks et al. emphasize emotional engagement as a vital dimension of student involvement, characterized by feelings of interest, enjoyment, and emotional responsiveness to educational tasks.

This integrated conceptual approach proposes that students' self-regulatory learning behaviors are both influenced and reinforced by their emotional engagement, which together shape their performance in science education. The emotional connection spark motivation and sustain commitment to learning strategies, while effective regulation of learning behaviors enhances the capacity for positive emotional experiences within the academic context. Grounded theory methodology serves as the guiding lens for data collection and analysis in this study, offering flexibility to identify emerging themes and new theoretical insights driven directly by participants' lived experiences and perspectives.

Methodology

Research Design

This study employs a grounded theory research design, which is well-suited for exploring complex social processes and generating theory grounded in data. Grounded theory allows for inductive development of a substantive theory explaining how learning habits and emotional engagement influence science achievement across performance levels (Glaser & Strauss, 1967; Tie et al., 2019).

Research Setting

The study was carried out in carefully selected Ghanaian secondary schools where science subjects are taught, creating an enriched setting to investigate students' real-life experiences concerning their learning habits and emotional engagement. These schools were chosen to represent diverse educational environments, encompassing variations in resources, teaching methods, and student demographics, thereby providing a comprehensive context for the study. The focus on secondary education enables an examination of the critical developmental stage where students deepen their scientific understanding and develop autonomous learning skills. By situating the research within these schools, the study seeks to capture the nuanced ways students regulate their learning strategies and emotionally connect with science content amid the typical pressures and opportunities of secondary curricula. Considerations such as school location, teacher expertise, availability of instructional materials, and classroom dynamics are acknowledged as influential parameters that shape students' interactions with science learning, ensuring the findings reflect the complexity of real-world educational settings.

Participants and Sampling

The study utilizes purposive sampling initially to deliberately select students categorized as high, medium, and low performers in science. This targeted selection ensures that participants possess the specific characteristics necessary to provide rich, relevant insights into the research questions. Following this, theoretical sampling is employed as the study progresses, whereby additional participants are chosen based on emerging themes and data requirements to comprehensively explore and saturate categories, thereby refining and developing the theory further (Tie et al., 2019). This dynamic sampling approach allows the research to remain flexible and responsive—continuously guiding participant selection toward those individuals who can best contribute to deepening the understanding of learning habits and emotional engagement in science education. By leveraging both purposive and theoretical sampling, the study prioritizes depth over breadth, enhancing the quality and relevance of collected data, and ensuring that the generated theory is robust, contextually grounded, and reflective of diverse student experiences across varying performance levels.

Data Collection

In this study, data collection is conducted through a combination of semi-structured interviews, classroom observations, and reflective journals, each designed to elicit comprehensive and nuanced narratives surrounding students' learning habits and emotional engagement in science. Semi-structured interviews provide the flexibility to explore individual experiences in depth while allowing the emergence of unanticipated insights. Observations offer contextualized, real-time understanding of student behaviors and interactions within the natural classroom environment. Reflective journals supplement these data sources by capturing students' personal reflections and evolving perceptions over time. Crucially, data collection and analysis are carried out simultaneously and iteratively, following the grounded theory approach outlined by Glaser (1992). This concurrent process facilitates continuous refinement of interview questions and observational focus based on emerging analytical insights, enhancing theoretical sensitivity and ensuring that data collection remains responsive to developing patterns. By integrating collection with analysis in this cyclic manner, the study promotes thorough saturation of categories and robust theory development, firmly grounding findings in participants' authentic experiences.

Data Analysis

Data analysis in grounded theory follows the iterative and systematic constant comparative method, where raw data are first broken down into discrete segments through open coding. During this phase, meaningful units of information are labeled and categorized. Subsequently, axial coding is conducted to identify relationships and connections among these initial codes, organizing them into broader conceptual categories. The final step, selective coding, integrates and refines these categories around a core concept that best explains the phenomena under study—in this case, the relationship between students' learning habits, emotional engagement, and their science performance (Tie et al., 2019; Lumivero, 2025). This analytical process is cyclical and recursive, continually revisiting data to ensure emerging concepts remain grounded and robust.

Memo Writing

Throughout data analysis, the researcher maintains detailed analytical memos capturing evolving insights, interpretations, and category development. These memos provide reflexive documentation of analytical decisions and support transparency, facilitating auditability of the emerging grounded theory (Glaser, 1992). Memo writing serves as a critical intermediary step enabling the synthesis of raw data into abstract theoretical constructs and aids in maintaining theoretical sensitivity.

Theoretical Saturation

Theoretical saturation marks the stage when ongoing data collection fails to yield new, significant information or categories, indicating that the theory is sufficiently developed and stable. This saturation ensures that the grounded theory is comprehensive, well-substantiated, and reflective of participants' experiences (Tie et al., 2019). Reaching this point signifies that data analysis has achieved a dense, nuanced conceptual understanding necessary for finalizing the grounded theory.

Trustworthiness of the Study

Ensuring the trustworthiness of this qualitative study is fundamental to its rigor and integrity, affirming that the findings authentically represent the participants' experiences. Drawing on Lincoln and Guba's (1985) framework, trustworthiness is established through four interrelated criteria: credibility, transferability, dependability, and confirmability, which correspond to the established quantitative concepts of internal validity, generalizability, reliability, and objectivity, respectively.

Credibility is achieved by methods that enhance the accuracy and truthful representation of participants' perspectives. This study employs member checking, allowing participants to review and validate the interpreted data. Prolonged engagement in the research setting enables the researcher to build rapport and gain nuanced understanding of the context. Triangulation of data sources and collection methods strengthens confidence in the consistency of findings.

Transferability is addressed by providing detailed, 'thick' descriptions of the research context, participant demographics, and methodological procedures. This enables readers to discern the extent to which the findings may be applicable to other settings, thereby facilitating informed judgments about the relevance of the results beyond the immediate study population.

Dependability is maintained through a comprehensive audit trail documenting all decisions made throughout the research process, ensuring transparency and allowing for replication or external scrutiny. This systematic record supports consistency and reliability in data analysis and reporting.

Finally, *confirmability* is ensured by reflexive practices whereby the researcher critically reflects on potential biases and maintains an objective stance, grounding conclusions firmly in the data. The emphasis on reflexivity and contextual sensitivity distinguishes qualitative inquiry from quantitative approaches, focusing on richness and depth rather than standardization.
Together, these elements ensure that this study upholds rigorous qualitative standards, providing trustworthy and meaningful insights into Inquiry-Based Learning in physics education within under-resourced contexts.

Ethical Considerations

This research strictly adhered to ethical standards to protect participants and uphold research integrity. Institutional ethical approval was obtained prior to data collection, ensuring compliance with established protocols. Participants provided informed consent after being thoroughly informed about the study's aims, procedures, potential risks, and benefits. Confidentiality was maintained by anonymizing participant data and securely storing sensitive information. Moreover, participants were made aware of their right to withdraw from the study at any time without penalty. The research process was conducted with respect and equity, aiming to minimize any potential harm and safeguard participant welfare. These measures align with best practice guidelines in educational research ethics.

Results

Learning Habits and Emotional Engagement Patterns by Performance Level

Analysis revealed distinct differences in how high, medium, and low science performers engage cognitively and emotionally in their learning.

High Performers: These students consistently exhibited strategic and well-regulated learning habits. They regularly set learning goals, employed effective revision techniques, and engaged deeply with science concepts. Emotionally, they reported strong interest, enjoyment, and confidence, which fueled sustained motivation.
Illustrative quote: "When I enjoy the topic, I dedicate more time and try different methods until I understand. It keeps me motivated."

Medium Performers: This group demonstrated inconsistent and fluctuating habits. Their study routines were often irregular, characterized by bursts of late or last-minute studying and varied use of learning strategies. Emotionally, they experienced moments of motivation, often linked to the perceived relevance or challenge of the material, punctuated by frustration or boredom.

Illustrative quotes: "Sometimes I feel motivated, especially when I see how science applies to real life, but other times I get frustrated and just want to finish quickly."

"I study mostly when exams are near, not consistently."

Low Performers: Students in this category tended to rely on reactive, surface-level learning strategies such as rote memorization shortly before assessments. Their emotional engagement was marked by anxiety, fear, and reduced confidence, often leading to disengagement and avoidance.

Illustrative quote: "Science feels scary and difficult; I often give up because I'm afraid of failing."

Adaptive Engagement: An Integrative Grounded Theory Model

A key finding was the identification of *Adaptive Engagement in Science Learning* as a core process driving performance differences. Emotional engagement and learning habits were found to be dynamically linked—their interaction forming feedback loops that either support or inhibit effective learning. Positive emotions encourage strategic habits in high performers, while negative emotions undermine learning efforts among low performers. Medium performers sit in a transition zone with precarious engagement.

Performance Level	Learning Habits	Emotional Engagement	Illustrative Quote
High	Strategic, self-regulated	Interest, confidence, enjoyment	"When I enjoy the topic, I dedicate more time and try different methods until I understand."
Medium	Inconsistent, irregular study routines	Fluctuating motivation and frustration	"Sometimes I feel motivated... other times I get frustrated."
Low	Reactive, surface memorization	Anxiety, fear, low confidence	Science feels scary; I often give up because I'm afraid of failing."

Summary Table of Results

Discussion

These findings align with Zimmerman's (2002) theory emphasizing the critical role of self-regulated learning strategies in academic success and Fredricks et al.'s (2004) framework highlighting how emotional engagement sustains motivation. The medium performer group highlights the fluidity of engagement states and the potential for targeted interventions to promote more consistent and adaptive learning behaviors. The emergent grounded theory model supports the integration of cognitive and affective domains, echoing Pintrich (2000) and Das & Mohapatra (2017), emphasizing that addressing both is essential for optimizing science learning outcomes.

Delimitations and Limitations

This study was deliberately delimited to secondary school students within selected science classrooms, focusing on learning habits and emotional engagement as key factors influencing science performance. Other contextual variables such as socio-economic conditions, teacher characteristics, and school infrastructure were beyond this study's scope to maintain a focused, manageable inquiry.

Limitations arise primarily from the qualitative grounded theory design, which prioritizes depth and theory development over broad generalizability. The purposive and theoretical sampling methods, while ideal for saturation, may limit transferability of findings beyond the study's settings. The reliance on self-reported data through interviews and reflective journals may introduce bias, including social desirability and recall inaccuracies. Additionally, practical constraints such as time and resources may have limited prolonged engagement, possibly affecting the depth of data saturation.

Despite these constraints, rigorous methodological strategies—such as member checking, triangulation, and reflexive memoing—were employed to enhance the trustworthiness and credibility of the emergent grounded theory.

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