Research Paper

Navigating Science: Experiences and Coping Strategies of Grade 12 STEM Students in Laboratory Learning

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Abstract

Laboratory learning is a fundamental component of STEM education, promoting scientific inquiry, hands-on learning, and the application of theoretical knowledge. However, existing studies have primarily focused on laboratory resources, instructional practices, and academic outcomes, offering limited insight into students' lived laboratory experiences and coping mechanisms. Thus, this study explored the experiences, engagement, and coping mechanisms of Grade 12 STEM students at Maria Asuncion Rodriguez Tiñga High School during laboratory activities. Using a phenomenological design, nine STEM students were selected through purposive sampling. Data were gathered through in-depth interviews and analyzed using thematic analysis. Findings showed that laboratory activities promoted hands-on learning, collaboration, and skill development. Nevertheless, limited resources, equipment shortages, and time constraints influenced students' experiences. Despite these challenges, students demonstrated resilience through support-seeking, self-regulation, and sustained motivation. The study extends Kolb's Experiential Learning Theory and Lazarus and Folkman's Psychological Stress and Coping Theory, explaining how laboratory experiences and adaptive coping jointly shape student engagement. Findings also support improved laboratory instruction and student support. To improve laboratory learning, teachers should undergo training on time-efficient and inquiry-based activities, implement structured group roles, and use low-cost materials. Resilience-building strategies may also be integrated. Future research may explore teachers' perspectives and compare schools with varying laboratory resources to further understand laboratory learning.

Keywords: *STEM Education, Phenomenology, Experiential Learning, Science Laboratory, Student Engagement, Coping Strategies, Senior High School*

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education plays a vital role in developing students' critical thinking, problem-solving skills, and scientific literacy, all essential in a technology-driven society. STEM approaches enhance student engagement and help learners apply scientific concepts through inquiry and hands-on activities in meaningful contexts (Le et al., 2023). Through observation, experimentation, and reasoning, science education enables students to understand natural phenomena while strengthening logical thinking and informed decision-making in real-world situations. Consequently, STEM learning prepares students to analyze problems critically and develop practical solutions grounded in scientific understanding.

Within STEM education, laboratory learning is a vital component because it connects theoretical knowledge with practical application through experimentation, observation, and the use of laboratory equipment. By directly participating in laboratory activities, students gain meaningful experiences that deepen their understanding of abstract scientific concepts and improve their ability to apply scientific knowledge in real-world contexts (Hiyan et al., 2025). In this way, laboratory learning supports STEM education goals by promoting active engagement,

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inquiry, and experiential learning. The quality of laboratory instructional materials, as emphasized by Diola (2023), should be clear, accurate, organized, and appropriate for students' level of comprehension, thereby supporting meaningful participation and independent laboratory learning. These instructional materials may shape students' laboratory learning experiences by providing a more structured and supportive learning environment.

Despite its importance, laboratory learning poses several challenges for students. Kranz et al. (2022) described laboratory learning as a complex process requiring cognitive, technical, and procedural skills. Students often struggle to formulate research questions and hypotheses, control variables, and conduct experiments systematically, indicating difficulties with both conceptual understanding and practical competencies. These challenges may affect students' participation, confidence, and overall laboratory learning experience.

Further studies show that STEM students face challenges in laboratory learning that affect their engagement and academic performance. Odo (2022) explained that science-related anxiety reduces students' participation in laboratory experiments, negatively affecting their learning and performance. This is supported by Garcia et al. (2022), who indicate that the absence of laboratory activities under new learning modalities limits meaningful hands-on learning experiences. Similarly, Ortencio et al. (2025) reported that insufficient laboratory resources in chemistry resulted in delayed experiments, more complex lessons, and increased academic pressure. Taken together, these studies demonstrate that psycho-environmental factors shape students' laboratory learning experience.

To address these challenges, students employ various coping mechanisms to manage academic demands, stress, and anxiety during laboratory activities. Coping mechanisms are the cognitive, emotional, and behavioral strategies individuals use to adapt to stressful or demanding situations. Students commonly rely on teacher support, self-regulated learning strategies, collaboration with peers, and careful preparation before conducting experiments. Arnejo et al. (2021) observed that STEM students learn more effectively through teacher demonstrations, guided laboratory procedures, and collaborative learning experiences. Ali et al. (2023) reported that supervised laboratory instruction helps students overcome experimental difficulties while strengthening their conceptual understanding, corroborating the study. Thus, these strategies enable students to adapt to laboratory constraints while maintaining motivation, engagement, and confidence throughout the learning process.

Although previous studies have substantially advanced understanding of STEM education and laboratory learning, the existing body of literature remains limited in explaining how students personally experience laboratory activities and make sense of the challenges they encounter. Most previous investigations have primarily focused on laboratory resources, instructional approaches, academic performance, science anxiety, or students' attitudes toward science. While these studies identify factors influencing laboratory learning, they provide only limited insight into how students interpret these experiences, respond to laboratory-related difficulties, and develop coping strategies throughout the process.

This limitation is evident in recent studies. Aydin et al. (2022) explored students' attitudes and memories of secondary science education but did not examine how students directly experience laboratory activities, how these experiences influence their engagement, or how they shape students' emotional and behavioral responses during laboratory work. Likewise, Ng (2024) identified the academic difficulties encountered by students with weaker STEM backgrounds, including challenges related to scientific terminology, laboratory expectations, and self-confidence, but did not investigate how students cognitively and emotionally interpret these challenges or how they adapt to them while performing laboratory activities. Consequently, existing evidence remains insufficient because it explains what challenges students encounter but provides limited understanding of how students experience these challenges, assign meaning to them, and employ coping mechanisms within authentic laboratory settings. Without this perspective, laboratory instruction may overlook the actual needs, experiences, and adaptive strategies of learners.

Given these gaps, there is a need for qualitative research that examines laboratory learning from students' perspectives. Exploring students' experiences can provide richer insights into their engagement in laboratory activities, the challenges they face, and the strategies they employ to cope with academic, emotional, and procedural demands. Such understanding may contribute to the development of more responsive laboratory instruction, improved student support systems, and a conducive learning environment.

Addressing this need, the present study employed a qualitative phenomenological approach to explore the experiences and coping strategies of Grade 12 STEM students at Maria Asuncion Rodriguez Tiñga High School. Unlike previous studies that primarily emphasized laboratory resources, instructional effectiveness, academic outcomes, or students' attitudes toward science, this study focused on students' firsthand experiences, examining their laboratory engagement, challenges encountered, and coping mechanisms employed throughout the laboratory learning process. By foregrounding students' voices, the study seeks to generate deeper insights into the cognitive, emotional, and behavioral dimensions of laboratory learning. The findings are expected to contribute to the enhancement of laboratory teaching practices and to strengthen student support mechanisms. Beyond its practical significance, this study also extends Kolb's Experiential Learning Theory and Lazarus and Folkman's Psychological Stress and Coping Theory by integrating them into the study, explaining how students' laboratory experiences and coping processes interact to shape engagement and learning in laboratory activities. This provides a richer explanation of laboratory learning, showing that students' engagement is influenced not only by laboratory experiences but also by how they interpret and respond to the challenges encountered throughout the learning process.

Research Questions

1. How do Grade 12 STEM students engage in laboratory activities?
2. What challenges do Grade 12 STEM students encounter in laboratory learning?
3. How do Grade 12 STEM students develop and utilize coping mechanisms to navigate the challenges in laboratory learning?

LITERATURE REVIEW

Laboratory Learning as the Core Experiential Foundation of STEM Science

Laboratory learning is widely recognized as the experiential foundation of STEM education because it enables students to build scientific understanding through direct engagement in experimentation, observation, and problem-solving, rather than through passive acquisition of theoretical knowledge alone (Grancharova, 2024; Hiyan et al., 2025; Nicol et al., 2022). Across diverse educational contexts, researchers consistently argue that laboratory activities help apply abstract scientific concepts to authentic situations, thereby promoting deeper conceptual understanding and sustained engagement. While these studies collectively emphasize the educational value of laboratory instruction, they differ in how they explain the mechanisms through which learning occurs. Grancharova (2024) and Hiyan et al. (2025) primarily highlight the instructional role of hands-on activities, whereas Reeves et al. (2021) contend that learning is equally shaped by students' prior knowledge, previous experiences, and perceptions of the learning environment. This suggests that laboratory experiences alone do not guarantee meaningful learning; rather, their effectiveness depends on how students interpret and engage with these experiences.

Although previous studies generally agree that laboratory learning enhances student engagement, they present conflicting findings on the conditions under which engagement occurs. Horsley and Moeed (2018) reported that students consistently show greater interest and participation during laboratory activities than in text-based instruction, suggesting that the hands-on nature of laboratory work naturally motivates learners. However, studies conducted in the Philippine context challenge this assumption, showing that inadequate laboratory facilities, insufficient materials, and teacher-centered demonstrations can significantly limit students' opportunities for active participation (Gonzales et al., 2025; Monta & Perdio, 2025). These contrasting findings indicate that engagement is influenced not only by the presence of laboratory activities but also by the quality of laboratory resources and instructional implementation.

A similar pattern appears in the literature on skill development. Numerous studies agree that laboratory learning promotes critical thinking, problem-solving, technical competence, and scientific reasoning (Azuuga et al., 2021; Gubat et al., 2023; Side et al., 2024; Thanomsilp, 2018). However, researchers disagree on which instructional approaches most effectively cultivate these competencies. Muhamad Dah et al. (2024) argue that open inquiry offers students greater opportunities to formulate research questions, design procedures, and interpret findings independently, thereby strengthening scientific reasoning and learner autonomy. In contrast, Gericke et al. (2022) caution that inquiry-based learning alone may not yield these outcomes unless teachers provide continuous scaffolding throughout the investigative process. Rather than presenting conflicting conclusions, these studies suggest that inquiry and teacher guidance are complementary components of effective laboratory instruction, with student autonomy developing most successfully when appropriate instructional support is provided.

The literature also shows broad agreement that laboratory learning fosters transferable skills beyond scientific knowledge. Omar and Plumb (2023) and Barosa (2018) likewise found that collaborative laboratory activities promote communication, teamwork, shared decision-making, and cooperative problem-solving. Likewise, Balaoro (2024) emphasized that active learning strategies strengthen students' understanding by requiring them to apply knowledge in authentic laboratory tasks. Collectively, these studies indicate that laboratory learning develops cognitive, technical, and interpersonal competencies essential for STEM education. Nevertheless, most existing research evaluates these outcomes using quantitative measures of achievement, engagement, or instructional effectiveness, offering limited insight into how students personally experience the laboratory environment and navigate its challenges.

Despite the substantial body of literature demonstrating the educational value of laboratory learning, an important gap remains. Existing studies primarily examine laboratory instruction through the lenses of learning outcomes, teaching strategies, or institutional resources, with comparatively little attention to students' lived experiences, particularly in Philippine STEM education. Furthermore, while international research generally assumes well-equipped laboratory environments, Philippine studies increasingly document the realities of resource constraints, suggesting that students' experiences may differ considerably across educational contexts. This study addresses these gaps by adopting a phenomenological approach to explore how Grade 12 STEM students experience laboratory learning, how they interpret the opportunities and challenges encountered during laboratory activities, and how these experiences contribute to the development of scientific knowledge, practical competencies, and coping strategies.

Challenges/Constraints faced by students

Laboratory-based learning is a vital component of Science Education because it enables students to apply theoretical knowledge, develop practical skills, and engage in scientific inquiry.

However, the existing literature consistently indicates that its effective implementation is constrained by interrelated challenges involving laboratory resources, infrastructure, teacher preparedness, and institutional support.

International studies consistently identify inadequate laboratory facilities, insufficient equipment and materials, limited funding, and shortages of trained personnel as major barriers to effective laboratory-based learning (Pereira et al., 2025; Shahzadi et al., 2023). These constraints reduce students' opportunities for meaningful laboratory activities and often shift instruction toward theory-based approaches. Collectively, these findings suggest that laboratory implementation is influenced not only by resource availability but also by institutional conditions, including teacher preparedness, workload, laboratory time, and technical support, all of which directly affect the quality and safety of laboratory instruction.

This relationship is further supported by evidence from public senior secondary schools in Nigeria, where Abbey-Kalio (2024) found that limited access to laboratory resources negatively affects students' academic performance. More importantly, the study showed that even when laboratory resources are available, overcrowding, poor laboratory management, and restricted access continue to limit students' opportunities for hands-on learning. This finding extends previous evidence by showing that resource availability alone is insufficient; rather, the educational value of laboratory-based learning also depends on how laboratory resources are managed, organized, and made accessible to students.

Comparable patterns are evident in the Philippine context, where laboratory implementation remains constrained by institutional and infrastructural factors. Mangarin and Macayana (2024) identified chronic underfunding, mismanagement of funds, inequitable resource distribution, and insufficient teacher training as key factors limiting the functionality of science laboratories in public schools. Likewise, schools in Lanao del Sur face inadequate laboratory facilities, including the absence of laboratory rooms, insufficient equipment and learning materials, defective apparatus, and limited access to water and electricity, which hinder the implementation of science activities required by the Department of Education modules (Hadji Abas & Marasigan, 2020). Similar challenges were reported among schools in Ilocos Norte, where limited laboratory resources, lack of preparedness, time constraints, classroom disruptions, safety concerns, and misalignment of laboratory activities with theoretical lessons further impede laboratory implementation (Remperas, 2025). Taken together, these studies demonstrate that effective laboratory-based learning is influenced by the combined effects of resource adequacy, laboratory management, teacher preparedness, and institutional support rather than by laboratory facilities alone.

Although these studies provide valuable insights into laboratory learning challenges, most focus on institutional issues such as inadequate facilities, limited resources, and teacher-related concerns, while giving less attention to students' personal experiences and coping strategies. In the Philippine context, laboratory limitations have been widely documented (Mangarin & Macayana, 2024), yet few studies explore how Grade 12 STEM students experience these challenges and how they affect their engagement, participation, and learning. Therefore, this study examines the lived laboratory experiences of Grade 12 STEM students, focusing on the emotional barriers and laboratory challenges encountered during laboratory activities.

Coping Mechanisms and Adaptive Strategies

Coping mechanisms are consistently identified as essential for helping students manage the academic and emotional demands of science laboratory learning. Across the literature, adaptive coping strategies, such as problem-solving, seeking support from peers and instructors, collaboration, and positive cognitive reframing, are linked to better emotional regulation, resilience, and sustained engagement in laboratory activities (Shim & Pelaez, 2022; Waterhouse &

Samra, 2025; Ortencio et al., 2025). Taken together, the literature suggests that coping strategies that promote active engagement help students overcome laboratory challenges, strengthen self-efficacy, and improve learning outcomes.

However, the literature also indicates that the effectiveness of coping depends on the strategy employed. Students who encountered research setbacks transformed initial frustration into meaningful learning through support-seeking and adaptive responses, leading to greater confidence and persistence (Shim & Pelaez, 2022). In contrast, avoidance behaviors were predictors of higher perceived stress and poorer academic adjustment, suggesting that coping strategies centered on withdrawal may reduce immediate emotional distress but are less effective in promoting long-term academic adaptation (Ding et al., 2025). Likewise, positive reappraisal and prayer contributed to students' emotional resilience during laboratory activities, although financial resources, access to learning devices, and location significantly influenced their ability to cope (Napoles et al., 2022). Taken together, these findings suggest that successful coping is shaped by both students' individual responses and the learning conditions that facilitate or hinder adaptation.

This perspective is further supported by evidence that students often combine multiple coping strategies rather than relying on a single approach. In addition to seeking support and regulating emotions, students adapt to laboratory challenges through collaboration, self-directed learning, motivation, and resourcefulness, particularly when faced with limited laboratory facilities, complex scientific concepts, and academic pressure (Ortencio et al., 2025). These findings suggest that effective coping extends beyond managing stress, involving active adjustment of learning behaviors and the use of available resources despite laboratory constraints.

Despite the consistent recognition of coping as an important factor in student learning, existing studies primarily examine coping in general academic, higher education, or pandemic-related contexts, with limited attention to students' lived experiences in science laboratory settings (Ding et al., 2025; Waterhouse & Samra, 2025). Furthermore, while previous research identifies effective coping strategies, it offers limited insight into how students develop and apply them while navigating laboratory challenges (Shim & Pelaez, 2022; Napoles et al., 2022). The limited number of localized studies further restricts understanding of how Filipino STEM students adapt to laboratory learning. These gaps highlight the need to explore students' coping mechanisms and adaptive strategies within laboratory environments to provide a more contextualized understanding of their experiences.

Theoretical Framework

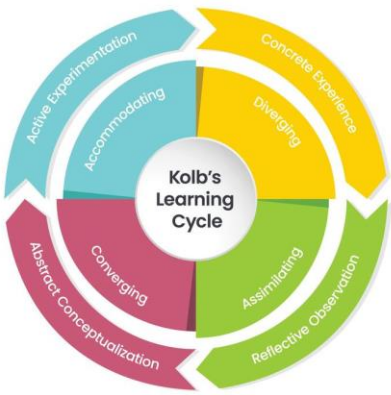

Figure 1. Experiential Learning Theory by Kolb (1984)

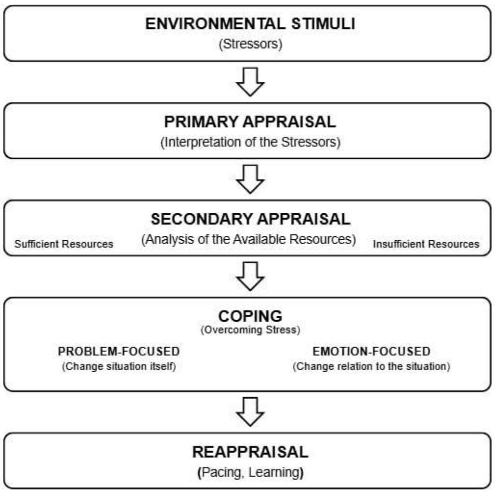

Figure 2. Psychological Stress and Coping Theory by Lazarus and Folkman (1984)

The theoretical foundation of this study integrates Kolb's (1984) Experiential Learning Theory (ELT) and Lazarus and Folkman's (1984) Psychological Stress and Coping Theory to examine laboratory learning as both a cognitive and an adaptive process. Rather than treating learning as passive knowledge acquisition, this framework conceptualizes it as an active, iterative process shaped not only by experience but also by learners' interpretations and responses to challenges in their environment.

Kolb's ELT frames learning as the transformation of experience through a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation. In STEM laboratory contexts, this model is especially relevant because it aligns with the hands-on, inquiry-based nature of scientific learning. Students engage directly in experiments (concrete experience), reflect on outcomes and procedural challenges (reflective observation), connect experiences to scientific principles (abstract conceptualization), and apply their understanding to subsequent tasks (active experimentation). This cycle underscores that knowledge is constructed through continuous interaction between action and reflection rather than through linear instruction.

While ELT provides a strong cognitive framework, its explanatory power is limited in real-world laboratory settings. It assumes learners can progress effectively through each stage, yet this progression is often disrupted by contextual constraints such as time pressure, limited resources, and performance demands. These constraints restrict opportunities for reflection and conceptualization, undermining the integrity of the learning cycle. Empirical evidence supports this limitation. Henríquez et al. (2025) found that although ELT enhances critical thinking and engagement, many implementations fail to operationalize all four stages, particularly reflection and experimentation. Similarly, Cheng et al. (2025) demonstrated that learning outcomes improve significantly only when structured interventions ensure full integration of the cycle. These findings indicate that ELT's effectiveness depends on the systematicity of its implementation.

Moreover, ELT primarily explains cognitive processes while underrepresenting the affective and psychological factors that shape learning. Laboratory environments involve uncertainty, pressure, and the potential for failure, all of which influence student engagement. This limitation necessitates integrating Lazarus and Folkman's Psychological Stress and Coping Theory, which explains how learners interpret and respond to such challenges.

Lazarus and Folkman conceptualize stress as a dynamic interaction between the individual and the environment, mediated by cognitive appraisal. In laboratory settings, students engage in primary appraisal, evaluating whether a task is a threat, a challenge, or an opportunity, followed by secondary appraisal, in which they assess their capacity to cope. These appraisals shape coping strategies, either problem-focused or emotion-focused. Problem-focused strategies, such as skill development and help-seeking, address task demands and are associated with improved performance. Emotion-focused strategies regulate emotional responses and may sustain engagement under pressure, but they can become counterproductive when they replace efforts to resolve academic difficulties.

This perspective shifts analysis from task difficulty to subjective experience, recognizing that identical laboratory conditions may yield different outcomes depending on appraisal and coping capacity. Furthermore, coping is not solely internal but is influenced by contextual factors such as instructional support, collaboration, and autonomy. Shim and Pelaez (2022) highlight these factors, which shape students' responses to laboratory challenges, reinforcing the view that adaptation is both individual and socially mediated.

By integrating ELT with Psychological Stress and Coping Theory, this study advances a comprehensive framework that captures the interaction between cognitive engagement and adaptive response. It argues that effective laboratory learning depends on participation in experiential cycles and on the ability to manage stress and navigate constraints. This perspective enables deeper analysis of how Grade 12 STEM students develop scientific competence and adaptive resilience in laboratory settings.

RESEARCH METHOD

Research Design

This study employs a qualitative phenomenological research design. Phenomenology is appropriate because the research seeks to understand the lived experiences of Grade 12 STEM students in laboratory learning, including the emotional challenges, practical difficulties, and coping mechanisms they use. By using this approach, the researchers aim to explore participants' subjective experiences while setting aside personal assumptions and focusing on authentic perspectives.

Research Participants

The study used a purposive nonprobability sampling approach. Nine (9) Grade 12 STEM students from Maria Asuncion Rodriguez Tiñga High School were selected based on predetermined criteria. Participants were required to have prior experience conducting laboratory experiments, direct interaction with laboratory equipment, participation in specimen dissections, and the ability to articulate and reflect on their laboratory learning experiences.

These criteria ensured that participants had direct and meaningful experience with the phenomenon under investigation, thereby enhancing the relevance and credibility of the collected data. The sample size was considered sufficient because data saturation was achieved, with emphasis placed on obtaining rich, in-depth insights rather than breadth of coverage.

Data Gathering Procedure

Data were collected through in-depth, semi-structured interviews using open-ended questions. This method provided flexibility, allowing the researchers to ask follow-up questions and clarify responses to gain a deeper understanding of participants' experiences. Individual, one-on-one interviews were conducted to obtain comprehensive and authentic accounts of students' laboratory learning experiences and the coping strategies they employed in a constrained learning environment.

Prior to data collection, a formal request for participation was submitted to the school, and approval was obtained from the school principal. Informed consent was secured from all participants, ensuring that their participation was voluntary and that they were fully aware of the study's purpose and procedures. During the interviews, participants were asked about their laboratory experiences, challenges encountered, and coping strategies used. With their consent, all interviews were audio-recorded to ensure the accuracy and completeness of the data. The recordings were subsequently reviewed and prepared for analysis.

Data Analysis

The data gathered from the interviews were analyzed using thematic analysis following Braun and Clarke's (2006) framework. This method was employed to systematically identify, analyze, and interpret patterns of meaning within the experiences and coping mechanisms of STEM students in laboratory learning. An inductive coding approach was applied, allowing themes to emerge directly from participants' responses rather than from pre-existing theories. The analysis followed five phases (1) data familiarization; (2) creating initial codes; (3) clustering similar codes; (4) creating initial themes; (5) finalizing themes.

Ethical Considerations

The study was reviewed and approved by the Ethics Committee of Maria Asuncion Rodriguez Tiñga High School to ensure compliance with established ethical standards for research involving human participants. To ensure the quality and validity of the research instrument, the interview guide was reviewed and validated by the expert. Revisions were made based on the feedback received to improve its clarity, relevance, and alignment with the study's objectives. Additionally, artificial intelligence (AI) was used to generate the initial set of interview questions to enhance efficiency in the research process, but the questions were carefully examined, refined, and validated by the expert to ensure their appropriateness and accuracy. Ethical principles, including voluntary participation, informed consent, confidentiality, and the protection of participants' privacy, were strictly observed throughout the study. Moreover, reflexivity and audit trails were maintained through electronic codebooks to minimize personal biases and assumptions that may shape data interpretation. Lastly, data saturation was achieved through team-based consensus, in which the team independently reviewed the qualitative data and collectively agreed that no new themes emerged.

FINDINGS AND DISCUSSION

1. Grade 12 STEM Students' Engagement in Laboratory

1.1. Collaborative and Strategic Laboratory Engagement

Most participants identified collaborative and strategic engagement in laboratory activities. One participant stated,

> *"It's not just one mind working there; it's really teamwork" – (P4)*

noting that students strategize through shared effort rather than working individually. This is supported by the response

> *"We're brainstorming so we can do the activity correctly" – (P9), and*
> *"I suggested adjusting positions to get the right angle for a clearer microscopic view, such as adjusting the light or lens to improve results" – (P5).*

These responses reflect students' collaborative engagement. They show that combining different tactics allows students to work more effectively, remain attentive, and complete tasks with greater accuracy. This supports the findings of Huri et al. (2024), who found that collaborative learning enhances students' engagement and academic progress, and of Chen et al. (2025), who reported that students with a strategic mindset employ effective learning strategies, leading to improved learning and academic performance.

1.2. Experiential and Conceptual Learning

Most participants identified active conceptual exploration through scientific investigation as an important part of their laboratory engagement. One participant stated,

> *"By experiencing and performing the process yourself, you realize it is not just theory... this is how it actually works" – (P7),*

highlighting how direct involvement in laboratory activities transforms theoretical concepts into meaningful understanding. Another participant shared,

"We gain new knowledge through experiments; we are given opportunities to do those kinds of things, like performance tasks" – (P4),

emphasizing that scientific investigations offer opportunities to acquire new knowledge through active participation. Overall, these responses suggest that engaging in laboratory investigations strengthens students' conceptual understanding by enabling them to move beyond memorizing scientific concepts toward explaining and applying them in practical contexts. This aligns with the findings of Zou et al. (2024), who found that students develop deeper conceptual understanding as they progress from simply recalling scientific concepts to explaining them using scientific reasoning and a deeper understanding of the concepts' underlying nature.

1.3. Laboratory Safety, Preparedness, and Equipment Readiness

Most participants emphasized that laboratory safety, preparedness, and equipment readiness are essential to effective laboratory engagement. One participant stated,

> *"Even if the chemical isn't harmful, you still have to be careful" – (P1),*

highlighting the importance of safety awareness. Another participant added,

> *"We really need gloves. Safety is very important, both physically and through proper preparation by the students." – (P6),*

emphasizing the value of protective measures. Similarly, one participant shared,

> *"The first thing that I do in an experiment is to check my materials first..." – (P8),*

showing that preparing materials and ensuring equipment readiness are important before experiments are conducted.

These responses indicate that students recognize the importance of safety, preparedness, and equipment readiness for responsible and effective laboratory engagement. This aligns with Crase (2022), who found that positive safety attitudes and training influence students' safety behaviors, and with Madamba et al. (2025), who identified preparedness as a key factor in sustaining student engagement.

1.4. Positive Emotional Engagement

Participants demonstrated strong positive emotional engagement through their enthusiasm and active participation in laboratory activities, often describing the activities as fun, interesting, and meaningful for understanding the lessons. One participant described the activity as a "new experience" that was "fun" while also helping them understand

"I also better understand what is going on"– *(P1),*

showing that enjoyment is closely tied to improved comprehension. Another participant shared feeling "nervous" about making mistakes but emphasized that

"it's also fun since it's for experience" – *(P3),*

suggesting that moderate anxiety can coexist with enjoyment and support attentiveness rather than disengagement. Students also expressed excitement when their curiosity was satisfied, with one stating

"I really love science" and feeling "excited when my curiosity… is solved"– *(P4),*

highlighting the role of intrinsic interest in sustaining engagement. Additionally, participants emphasized the novelty of the laboratory tools, describing the experience as

"very interesting," "fascinating," and "very exciting and entertaining"– *(P5),*

which reflects how hands-on exposure enhances emotional engagement.

These findings align with prior research underscoring the importance of motivation in laboratory learning. The study emphasized that motivation is crucial for learning and academic achievement in laboratory skill education and found that greater intrinsic motivation enhanced students' engagement in laboratory tasks. Although the research focused on virtual laboratories, the present findings similarly suggest that students' enjoyment, curiosity, and enthusiasm during physical laboratory activities foster active participation and deeper understanding (Diwakar et al., 2023).

The findings show that Grade 12 STEM students engage in laboratory activities through interconnected experiences that explain how they participate in science laboratory learning. Students' engagement is reflected not only in their active participation during experiments but also in their collaboration with peers, application of scientific concepts, observance of laboratory safety, preparedness, and positive emotional involvement. Rather than functioning independently, these themes interact to create meaningful laboratory experiences, demonstrating that effective laboratory engagement is shaped by the integration of cognitive, behavioral, social, and emotional dimensions.

The findings extend Kolb's Experiential Learning Theory by showing that meaningful laboratory engagement involves not only hands-on experimentation but also collaborative learning, safety-conscious practices, preparedness, and positive emotional engagement. These findings suggest that experiential learning in laboratory settings is strengthened by social interaction, responsible laboratory practices, and emotional investment, offering a more comprehensive understanding of students' engagement in authentic STEM laboratory experiences.

Furthermore, the study addresses the limited qualitative literature on the lived laboratory experiences of Grade 12 STEM students. While previous research has often examined individual aspects of laboratory learning, this study demonstrates how these dimensions interact in real-world laboratory settings. By offering an integrated qualitative perspective, the findings provide new insights that inform future research and support the development of more engaging and meaningful science laboratory experiences.

2. Grade 12 STEM Students' Laboratory Challenges

2.1. Time Pressure

Time pressure caused stress and reduced their ability to perform laboratory tasks accurately. One participant reported,

> *"It is highly pressuring. The time constraint creates a sense of distress, as we are required to execute the task in a specific manner within a limited period. We are repeatedly told to hurry, which makes the situation feel overly intense"– (P7).*

Similarly, another shared,

> *"It's pressuring because we only have 50 minutes per subject. If the experiment takes long, we rush" – (P5).*

This pressure leads students to sacrifice work quality to meet deadlines. As another participant noted,

> *"It affects the results because there's not enough time. It's not finished, so the result isn't what it should be" – (P2).*

These findings suggest that time constraints compromise both quality and accuracy. Supporting research indicates that academic time pressure increases cognitive fatigue and stress, impairing performance (Kesuma et al., 2025). Ineffective time management during limited periods is linked to lower task accuracy (Valente et al., 2024).

2.2. Resources and Environmental Constraints

Resource and environmental constraints emerged as significant barriers to students' effective participation in laboratory learning. Participants described how limited laboratory equipment, insufficient workspace, environmental noise, and the need to share resources disrupted laboratory activities. One participant shared,

> *"We were affected in terms of the equipment distribution because the other equipment is really limited since it's running out too." – (P3).*

Another explained,

> *"It still gets confusing in your mind when you see that your space isn't enough and your materials are incomplete. You really can't finish what you're supposed to do."– (P1).*

Students also reported that environmental distractions hindered their ability to follow laboratory procedures. As one participant stated, *"My classmates are noisy, so when our teacher is speaking, we can't clearly hear how to do the task." – (P4).*

Another participant noted,

"Sometimes we need to wait for others to finish their experiments first, just for us to start ours." – (P8).

These findings suggest that resource and environmental constraints extend beyond logistical inconveniences, affecting students' engagement throughout the laboratory process. Limited equipment, inadequate workspace, and delays in accessing materials interrupt hands-on activities, reducing opportunities to conduct experiments and apply scientific concepts effectively. Likewise, noisy learning environments hinder students' concentration and their ability to follow laboratory instructions, making meaningful participation more difficult. These findings align with Lazaro and Paglinawan (2025) and Cabusor and Antonio (2025), who found that inadequate laboratory resources reduce students' engagement in practical activities. Similarly, Fretes and Palau (2025) reported that noisy and crowded laboratory environments negatively affect students' attention and academic performance.

2.3. Technical and conceptual difficulties

Technical and conceptual difficulties hindered students' ability to perform laboratory tasks accurately and to understand scientific concepts. Participants described challenges with accurate measurements, unfamiliar scientific terminology, and explaining laboratory results. One participant stated,

"Of course, what's needed is the reaction you'll get is really exact. We can't miss it because it needs to be reported...mostly when there are measurements, that's really the most challenging for me... When they say, "Hey, I need a beaker like this,' they do not know what to get because they do not know what a beaker is...Mostly miscommunication because they don't know the name of the tool...The difference in vocabulary and, mostly in jargon, because not all of us know the names of the equipment." – (P1)

Another participant added,

"The hard part is how to explain it, especially when you're given a guide question because you can't explain the science concept about it." – (P8).

These accounts indicate that students' laboratory engagement depends not only on performing experimental procedures but also on understanding scientific concepts and on communicating effectively during laboratory activities.

These findings suggest that technical and conceptual difficulties extend beyond procedural mistakes, limiting students' ability to connect laboratory procedures with the scientific principles they demonstrate. Challenges with measurement, scientific terminology, and interpreting results may reduce students' confidence, hinder group communication, and affect the accuracy of experimental outcomes. These findings align with Geschwind et al. (2024), who reported students' difficulties with measurement accuracy and data interpretation. Similarly, Keen and Sevian (2022) highlighted procedural challenges in laboratory work, while Jantassova et al. (2024) found that limited familiarity with scientific terminology hinders students' comprehension and communication during laboratory learning.

2.4. Emotional Responses to Experimental Uncertainty

An emotional response to experimental uncertainty emerged as a common challenge during laboratory activities. Participants described feeling stressed, frustrated, and disappointed when experiments produced unexpected results. One participant reported,

> *"Stress, especially when we couldn't get the activity going like that" – (P9)*

Similarly, another stated,

> *"Pressure mixed with frustration" – (P2)*

Reflecting the emotional demands of laboratory work, outcomes differ from expectations. Another participant explained,

> *"You don't always get the reaction you want right away"– (P1),*

emphasizing the unpredictable nature of scientific experiments. Together, these responses show that unexpected outcomes often elicit emotional reactions that can affect students' confidence and motivation during laboratory activities.

These findings suggest that unexpected outcomes can be emotionally challenging yet a normal part of scientific inquiry. This interpretation aligns with Agustian et al. (2024), which indicates that laboratory activities often evoke such frustration and stress. Likewise, Kutluk et al. (2025) emphasized that unexpected experimental outcomes are an inherent feature of scientific inquiry and contribute to students' development of scientific thinking and resilience.

2.5. Collaborative Challenges

Collaborative challenges also caused frustration and reduced the effectiveness of teamwork during laboratory activities. One participant shared,

> *"It's not fun and annoying when you see others just standing by while you're scrambling with all the tasks and figuring out what the next step is. It's hard when your groupmates don't help" – (P2).*

Another noted,

> *"The knowledgeable ones just take over, leaving the less experienced not learning properly" – (P6).*

Likewise, one participant emphasized the role of communication in group work, stating,

> *"In cooperation, not everyone cooperates, and the others are just watching. About communication and cooperation, sometimes when it comes to communication, we get messed up because we don't know what is right and what is wrong"– (P9).*

These accounts suggest ineffective collaboration not only due to unequal participation but also to poor communication and unclear coordination among group members. When responsibilities are unevenly distributed and communication is ineffective, opportunities for active participation, peer learning, and shared problem-solving are diminished. Consequently, some students become passive observers, while others assume most of the laboratory tasks, limiting equitable learning experiences and reducing opportunities for all group members to develop practical scientific skills.

These findings highlight that collaborative laboratory learning depends not only on individual competence but also on mutual accountability, effective communication, and equitable participation, which enable students to exchange ideas, co-construct knowledge, and engage more meaningfully in scientific inquiry. According to Meñoza et al. (2025), collaboration and active participation among members foster personal and academic growth and promote a harmonious, productive learning environment. Consistent with this, the present findings suggest that when participation and communication are unbalanced, collaboration becomes less effective, reducing opportunities for meaningful learning and weakening group dynamics during laboratory activities.

3. Grade 12 STEM Students' Laboratory Learning Coping Mechanism

3.1 Peer and Teacher-Supported Coping

Peer- and teacher-supported coping emerged as an important strategy that helped Grade 12 STEM students manage both the emotional and academic demands of laboratory activities. One participant shared,

> *"I feel helped when they cooperate and help me figure things out" – (P2).*

This finding demonstrates that peer collaboration extends beyond simply completing laboratory tasks. Instead, it serves as a support system in which students exchange ideas, clarify uncertainties, and solve problems collectively, thereby strengthening confidence when facing unfamiliar laboratory procedures. Additionally, another participant remarked,

> *"When we fail an experiment, they will always say, 'It's okay, we can do it again" – (P8).*

This suggests that peers help students view failure as an expected part of scientific inquiry rather than a personal inadequacy. Such encouragement reduces frustration, builds emotional resilience, and motivates students to persist despite unsuccessful outcomes. Teacher support also emerged as an essential coping resource. One participant explained,

> *"Tell the professor first when your experiment turns out unexpectedly... ask for help on what steps you should do so that the procedure makes sense" – (P6).*

The response suggests that teacher guidance helps students view unexpected results as opportunities for reflection and improvement rather than as a source of discouragement. Similarly, another participant stated,

> *"The teacher keeps demonstrating until we understand... that really helps us perform independently" – (P2).*

This suggests that repeated demonstrations gradually strengthen students' competence and confidence, enabling them to perform laboratory tasks independently.

Taken together, the participants' responses showed that peer encouragement and teacher scaffolding complemented each other by addressing both the emotional and cognitive challenges of laboratory learning. This supports Caldas et al. (2026), which emphasizes the role of collaborative relationships in fostering resilience, and Petersen (2022), which highlights that structured teacher guidance strengthens students' confidence and problem-solving abilities in laboratory settings.

3.2. Self-Regulated Coping and Laboratory Preparedness

Self-regulated coping and laboratory preparedness were identified as complementary strategies that helped students respond constructively to laboratory challenges by fostering reflective thinking, emotional regulation, and proactive preparation. One respondent stated,

> *"Improve it next time... so that there won't be any more mess like that" – (P9).*

It can be inferred that the participant views mistakes as opportunities for continuous improvement rather than as indicators of failure. This reflects a reflective learning process in which previous experiences are critically examined to refine strategies and improve future laboratory performance. Similarly, another participant shared,

> *"If you make mistakes, there's always a next time. You shouldn't get mad at yourself because making mistakes is normal" – (P2).*

It is inferred that the participant has developed emotional acceptance by recognizing mistakes as an inevitable part of scientific inquiry. This acceptance enables students to manage frustration, maintain motivation, and remain engaged despite setbacks.

Preparedness likewise emerged as a complementary coping strategy. One participant explained,

> *"Preparation takes so much time, and preparation is the most important thing when conducting research" – (P6).*

The response highlights that preparation is viewed as a proactive strategy that minimizes uncertainty and improves readiness before experimentation begins. Another participant remarked,

> *"I become more prepared for the next group activity. The teacher doesn't immediately give the activity—they ask us to prepare the materials first" – (P1).*

This indicates that advance preparation familiarizes students with laboratory procedures and expectations, enabling them to approach experiments with greater confidence and competence.

The participants emphasized that coping with laboratory challenges goes beyond simply overcoming immediate obstacles. Their responses show that resource use and active problem-solving work together as complementary strategies, fostering adaptability, independent inquiry, and critical thinking throughout the learning process. By seeking knowledge independently, maximizing available resources, and applying logical reasoning to resolve experimental difficulties, students become better equipped to manage complex laboratory situations with confidence and persistence. These findings align with Ramos-Galarza et al. (2025), which emphasize that emotional regulation and strategic thinking strengthen self-regulated learning, and with Rathnayaka et al. (2023), which indicate that pre-laboratory preparation enhances students' confidence, engagement, and laboratory performance.

3.3 Active Problem-Solving and Resource Utilization

Active problem-solving and resourcefulness enabled Grade 12 STEM students to cope with laboratory challenges by seeking alternative sources of knowledge, adapting available resources, and developing practical solutions to experimental difficulties. One participant stated,

"I research how to use the equipment before we even use it..." – (P1).

The statement implies that the participant acquires knowledge independently before performing laboratory tasks, reflecting a proactive learning approach that reduces uncertainty and strengthens confidence in handling unfamiliar procedures. Moreover, another participant shared,

"We used an alternative tube... and different materials instead"– (P4).

This indicates that the participant recognizes that successful laboratory learning depends not only on standard equipment but also on the ability to make the most of available resources. Such adaptability demonstrates resourcefulness and flexibility in sustaining learning despite material limitations.

Problem-solving likewise emerged as an important coping strategy. One participant explained,

"That helps with problem-solving because it improves our thinking on how to find ways to solve our problems in our current laboratory activities"– (P4).

It can be inferred that laboratory experiences cultivate analytical thinking by encouraging students to examine challenges critically before selecting appropriate solutions. This perspective is reinforced by another participant, who remarked,

"If you need more explanations, use the internet. Search 'how to cut potatoes, video tutorial,' like that" – (P7).

The statement suggests that the participant applies scientific reasoning by identifying the source of a problem, implementing a solution, and verifying the solution's effectiveness through observation.

The participants emphasized that coping with laboratory challenges goes beyond simply overcoming immediate obstacles. Their responses show that resource use and active problem-solving work together to foster adaptability, independent inquiry, and critical thinking throughout the learning process. By seeking knowledge independently, maximizing available resources, and applying logical reasoning to resolve experimental difficulties, students become better equipped to manage complex laboratory situations with confidence and persistence. These findings support Kilag et al. (2023), who emphasized that alternative learning resources enhance learning continuity despite resource constraints, and Surahman et al. (2022), who found that laboratory-based Problem-Based Learning (PBL) enhances students' problem-solving skills by promoting active engagement and independent inquiry.

The findings indicate that Grade 12 STEM students develop and use coping mechanisms by integrating external support, self-regulation, and active problem-solving to manage the cognitive, emotional, and practical demands of laboratory learning. Peer and teacher-supported coping provides emotional reassurance and academic guidance, self-regulated coping and laboratory preparedness help students regulate emotions and anticipate challenges, and active problem-solving and resource use encourage students to adapt available resources and develop practical solutions during laboratory activities. Together, these themes demonstrate that coping is a dynamic and interconnected process rather than a single strategy.

These findings align with Lazarus and Folkman's Stress and Coping Theory, which holds that individuals cope with stress through cognitive appraisal and by using problem-focused and emotion-focused strategies. Peer and teacher support primarily serve as emotion-focused coping by reducing stress and strengthening students' confidence, whereas self-regulation, preparedness, and active problem-solving reflect problem-focused coping that enables students to address laboratory challenges directly. The interplay of these strategies helps students adapt more effectively to the demands of laboratory learning, promoting resilience, sustained engagement, and improved performance.

The study contributes to literature by extending the application of Lazarus and Folkman's framework to science laboratory learning, demonstrating that coping in laboratory settings is shaped by the ongoing interplay between internal strategies (self-regulation, preparedness, and problem-solving) and external support systems (peers and teachers). Compared with previous studies that focused mainly on higher education, these findings highlight the coping experiences of Grade 12 STEM students in science laboratory settings, addressing the limited evidence on laboratory coping mechanisms. These findings offer a more comprehensive explanation of students' navigation of the unique cognitive, emotional, and practical challenges of laboratory learning, thereby filling an important gap in science education research.

CONCLUSIONS

Drawing on the experiences of Grade 12 STEM students at Maria Asuncion Rodriguez Tiñga High School, this study concludes that laboratory learning is both a valuable learning opportunity and a source of challenge in STEM education. Students actively participated in hands-on experiments, collaborative activities, and inquiry-based tasks that deepened their understanding of scientific concepts and enhanced critical thinking, scientific reasoning, and technical skills. At the same time, their laboratory experiences were affected by limited resources, inadequate equipment, time constraints, and procedural difficulties, prompting them to adjust and develop strategies to cope with these challenges.

The findings contribute to a clearer understanding of Experiential Learning Theory (Kolb, 1984) by demonstrating that effective learning occurs through direct laboratory experiences, reflection on challenges, conceptual understanding, and the application of newly acquired knowledge. The study extends the theory by showing that authentic learning persists even in resource-constrained laboratory environments, where students transform challenges into meaningful learning opportunities through reflection and active experimentation.

The findings also contribute to Coping Theory (Lazarus & Folkman, 1984) by showing that students use both problem-focused strategies, such as collaboration, resourcefulness, and seeking teacher assistance, and emotion-focused strategies, such as maintaining a positive attitude and perseverance, to manage laboratory-related challenges. These results suggest that successful laboratory learning depends not only on scientific competence but also on students' ability to adapt and cope with academic stressors.

The findings emphasize the need to strengthen laboratory instruction by addressing resource limitations and creating learning environments that foster active participation, scientific inquiry, and the development of students' practical skills, confidence, and resilience. They also underscore the importance of institutional support in providing conditions that enable meaningful and effective laboratory learning.

Science teachers are encouraged to participate in professional development focused on designing time-efficient, inquiry-based laboratory activities. Schools should build a collection of validated, low-cost, and improvised laboratory activities using locally available materials to address resource limitations without compromising learning outcomes. Teachers are also encouraged to implement structured collaborative strategies, such as assigning laboratory roles, and to integrate resilience-building practices, including reflective discussions, guided problem-solving, and scaffolded support during experimental tasks, to help students effectively manage laboratory challenges and enhance their overall learning experience.

LIMITATION & FURTHER RESEARCH

This study is limited to the experiences and coping mechanisms of Grade 12 STEM students in laboratory learning at a single public senior high school, making the findings context-specific and not intended for broad generalization. The use of purposive sampling and a relatively small number of participants may not capture the full range of laboratory learning experiences among STEM students across different educational settings. As a qualitative phenomenological study, the findings are based on participants' self-reported experiences and the researchers' interpretation of the data, which may be influenced by subjective perspectives despite efforts to ensure credibility and trustworthiness. Furthermore, the study focused exclusively on students' perspectives and did not include the views of teachers, laboratory instructors, or school administrators, which could have provided a more comprehensive understanding of laboratory learning and coping mechanisms.

Future studies may use comparative designs across public and private schools or institutions with varying laboratory resources to examine how different learning environments shape students' laboratory engagement, challenges, and coping mechanisms. Longitudinal studies are also recommended to investigate how students' coping strategies evolve over time as they gain more laboratory experience. Additionally, mixed-methods research may be conducted to integrate qualitative insights with quantitative evidence, enabling researchers to examine the relationships among laboratory engagement, challenges, coping mechanisms, resilience, and academic performance across diverse institutional contexts.

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