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Drivers of Laboratory Instruction in Science Education

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Abstract

Laboratory instruction is crucial for promoting experiential learning, analytical reasoning, and scientific investigation, which are fundamental for academic achievement in fields such as General Chemistry. Anchored on SDG 5 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure), this study sought to determine the principal determinants affecting laboratory instruction in one of the private higher education institutions in Misamis Occidental, specifically investigating the correlation among institutional, educator, and student-related variables and the academic achievement of first-year Criminology students. The study utilized a descriptive-correlational research approach, including researcher-developed questionnaires and regression analysis for data collection and analysis. The results indicated that school-related factors, including laboratory facilities, material availability, and technician support, as well as teacher-related factors such as content understanding and pedagogical competency, did not substantially correlate with students' academic achievement. In contrast, among the elements related to students, motivation had a weak yet substantial positive correlation with academic performance. Although there are no significant predictors for the quality of laboratory instruction, the study emphasizes the necessity for ongoing enhancement of laboratory supplies, teacher professional development, and techniques to engage students. Academic institutions are advised to invest in programs that foster student enthusiasm and curiosity, thus advancing the overarching objectives of equitable, quality, and creative education.

Keywords: *laboratory instruction, academic performance, student motivation, General Chemistry, Philippine Science Education*

Introduction

Science education is the field of study that centers on the teaching and learning of science. According to De La Cruz (2022), its primary goal is to cultivate scientifically literate individuals who can make responsible decisions and apply scientific knowledge to address community problems. This field is designed around three domains of learning science: understanding and using scientific knowledge, performing scientific processes and skills and developing and demonstrating scientific attitudes and values. Hence, science education includes science laboratory instruction to help students achieve scientific literacy.

Since the dawn of scientific pursuit, laboratory instruction has played a crucial role in science education, especially Chemistry education. Numerous scholars have contended that science needs more significance for students without valuable practical experiences within the school laboratory (Hofstein & Naaman, 2007). According to De Borja and Marasigan (2020), a laboratory is the core of scientific inquiry, enabling individuals to apply theoretical concepts in practical settings. Laboratory instruction offers practical experience and encourages students to implement scientific concepts and principles. It promotes student engagement in scientific inquiry through the formulation of hypotheses, experimental design, and observational testing of those hypotheses.

While laboratory instruction plays a crucial role in science education, previous studies have revealed that science laboratory instruction has been facing problems from different angles affecting science education. According to Pareek (2019), laboratory facilities in India need to be improved, which is characterized by a shortage of qualified laboratory technicians, resulting in the absence of science experiments in most schools. Similarly, in the Philippines, Caballes et al. (2023) showed the critical importance of laboratory resources, including facilities and materials, to the overall efficacy of science education.

The school plays a crucial role in shaping the learning environment for students by providing resources such as laboratory facilities, materials, and technicians. Well-equipped laboratories enhance the quality of instruction and foster student engagement. However, the quality of teaching and learning experience is influenced by the adequacy of these resources and the effectiveness of teachers in utilizing them. Laboratory instruction is essential for science educators as scientific knowledge cannot be acquired solely through reading. Teachers' expertise and instructional approach are critical determinants of laboratory instruction quality. Understanding students as a factor influencing laboratory instruction is essential, as motivation and learning styles directly influence lab instructions. Actively engaged students tend to grasp scientific concepts better and develop a deeper understanding of the subject matter.

Based on the findings of studies which highlighted challenges in science laboratory instruction due to various factors, this study in one of the private higher education institutions investigated if similar issues exist within the institution. This study sought to profile the factors influencing laboratory instruction, including school, teacher, and student factors. The study's scope encompassed science laboratory courses, focusing on General Chemistry, during the final grading period for the academic year (A.Y) 2023-2024. By aligning the research objectives with the broader context of challenges faced in science education, the researchers aimed to contribute to the existing body of knowledge and provide valuable insights that can inform targeted improvements, contributing to the enhancement of

laboratory instruction and the overall quality of science education at the university

Research Questions

The study assessed the factors influencing laboratory instruction in the General Chemistry course at a private higher education institution for the second semester of AY 2023-2024. Specifically, it sought answers to the following questions:

1. What is the profile of the respondents for each of the following factors:
 - 1.1. school factor;
 - 1.2. teacher factor; and
 - 1.3. student factor?
2. What is the student's academic performance level in science laboratory courses?
3. Is there a significant relationship between each factor and students' level of academic performance in science laboratory courses?
 - 3.1. Are school factors significantly related to students' academic performance?
 - 3.2. Are teacher factors significantly related to students' academic performance?
 - 3.3. Are student factors significantly related to students' academic performance?
4. Which of the factors best predicts laboratory instruction?

Literature Review

Profile of the Factors that Influence Laboratory Instruction in Science Education.

The Cambridge Dictionary (2024) defines a profile as a concise characterization encompassing someone's life, work, or interests, reflecting the notion of capturing key attributes. Also, the Collins English Dictionary (2024) views profiles as representations showcasing various tested characteristics, emphasizing the act of describing specific traits. On the other hand, in the context of laboratory instruction in science education, a profile refers to the factors perceived to influence laboratory instruction, academic performance, and their relationship.

School Factors

According to Mohammadpour (2013), school plays a vital role in students' learning process. Since students gain part of their knowledge in school, school-related factors are crucial to consider. According to Wekwe et al. (2024) and Zengele and Alemayehu (2016), these factors include the availability of laboratory facilities, laboratory materials, and qualified laboratory technicians.

Availability of Laboratory Facilities

According to the National Institutes of Health (2022), a laboratory facility is a dedicated space equipped with specialized tools, safety precautions, and resources to conduct scientific experiments, investigations, and analyses. These facilities are crucial for various scientific disciplines, including Biology, Chemistry, Physics, and more. Furthermore, Omiko (2007) stated, "A laboratory facility is a room or building set apart for practical or experimental studies to take place." He sees the laboratory as the heart of an excellent scientific program that allows students in the school to have experiences consistent with scientific literacy goals. This coincides with Pareek (2019), who stated that a school laboratory in education can be classified as a laboratory facility for teaching science.

Availability of Laboratory Materials

The Collins English Dictionary (2024) defines laboratory materials as equipment, apparatus, and consumables in a building or room equipped for conducting scientific research or carrying out scientific experiments, among other activities. Olaniyan (2017) defines laboratory equipment as more significant, durable items used in the laboratory, such as microscopes, centrifuges, spectrophotometers, incubators, autoclaves, and balances. These items are only sometimes disposable and are used repeatedly over an extended period. Meanwhile, apparatus refers to specific devices or instruments used for a particular purpose or experiment. This can include Bunsen burners, pipettes, pH meters, distillation setups, chromatography columns, and more. While some apparatus may be disposable, many are reusable and durable. Conversely, consumables are items that are used up or depleted during experiments or analyses. They include reagents, solutions, indicators, gloves, disposable Petri dishes, masks, filters, vials, and other disposable supplies. Consumables are typically single-use or have a limited lifespan before requiring replacement (Wiltronics, 2022).

Availability of Laboratory Technician

According to the Canadian Centre for Occupational Health and Safety (2024), a laboratory technician is a person who performs practical, hands-on work in laboratories. Laboratory technicians operate in various environments, including healthcare, industry, research, and educational organizations. In academic institutions, a laboratory technician prepares chemicals, laboratory equipment, and student workspaces for instruction in a school laboratory (University of Mexico, 2017). Wu et al. (2020) further stated that laboratory technicians provide both educational support and management services simultaneously. Their duties include preparing for classes, ensuring a clean and safe environment, implementing safety protocols, installing and maintaining laboratory equipment, and

overseeing the planning and organization of the laboratory. Moreover, laboratory technicians play a vital role in safely handling chemicals within the laboratory. As highlighted in a study by Rossette et al. (2021), they are key personnel in understanding chemical hazard communication, further underscoring their indispensable role in maintaining a safe and functional laboratory environment.

Teacher Factors

According to Weaver (2019), teacher factors refer to the collective influence of various elements that impact a teacher's performance in educating learners. Moreover, teacher factors include content knowledge and pedagogical skills (Hammond & Grossman, 2019; Fives & Gill, 2020). In this study, teacher factors pertain to content knowledge and pedagogical skills that have influenced science education, especially in laboratory instruction in Chemistry.

Content knowledge

According to Hammond and Grossman (2019), content knowledge refers to the teacher's deep and comprehensive understanding of the subject matter they teach, including its core concepts, theories, and principles, as well as interconnections with other knowledge areas. Yoon and Klopfer (2020) added that content knowledge extends beyond simply memorizing facts and information. It encompasses meaningfully connecting and integrating different aspects of the subject matter. This includes recognizing relationships and applications between various concepts, principles, and theories within the discipline.

Pedagogical skills

Shulman (1986) opined that pedagogical skills encompass the art and science of effective teaching, encompassing a range of methods, strategies, lectures, demonstrations, laboratory teaching methods, and techniques to facilitate learning, engage students, and promote understanding. Hammond and Grossman (2019) also supported this, saying that pedagogical skills signify the teacher's expertise in planning, delivering, and assessing instruction. It refers to various strategies, methods, and techniques for effectively facilitating student learning and engagement. Nevertheless, pedagogical skills involve planning engaging and practical lessons, using multiple instructional approaches, such as lectures, discussions, group work, and technology integration, to deliver the content clearly and concisely (Hattie, 2009).

In teaching laboratory classes, the pedagogy that a science teacher mostly uses is inquiry-based learning, demonstration method, laboratory method, and argument-driven inquiry. According to Llewellyn (2005), inquiry-based learning encourages students to engage with scientific concepts actively. Students learn more effectively when encouraged to explore and inquire rather than memorize facts. This deeper understanding arises because students actively construct knowledge through exploration and investigation. Bruner (1961) emphasized that discovering knowledge through inquiry enhances a student's motivation to learn. Inquiry-based activities foster a heightened curiosity among students regarding the subject matter, ultimately contributing to a more favorable disposition toward science and the broader learning experience.

Student Factors

According to Handelsman et al. (2007), student factors in laboratory instruction encompass students' individual attitudes and prior knowledge that influence their engagement, learning, and performance in laboratory activities. Simpson (1966) expands on this concept by including preferred learning styles, students' motivation, and cognitive abilities as relevant student factors. As highlighted by Handelsman et al. (2007), these factors play a significant role in shaping students' laboratory experiences and outcomes. However, the present study focused on students' preferred learning styles and motivation as these specifically relate to potential influences on laboratory instruction.

Learning Styles

Learners should be the primary focus of any education system and policy and be picked up quickly, captivated comfortably, and satisfied perfectly (Alamgir, 2000). However, every learner is diverse. They differ in how they go about learning, thinking, and problem-solving. According to Castolo and Rebusquillo (2008), some students like to study and work alone, while some like to work in groups, some also comprehend more when they see graphs, tables, and figures, while some understand better, even just merely reading a text or hearing a lecture. These are the varied learning styles of the students.

Numerous theories exist regarding learning styles

One prevalent categorization of learning styles is Fleming's VARK model (1987), which expands upon the VAK model proposed by Barbe et al. (1979). The VAK model classifies learning styles into three categories: visual, auditory, and kinesthetic. The VAK model posits that individuals typically exhibit a dominant or preferred learning style, although some may demonstrate a mixed and balanced combination of all three learning styles. The visual learning style encompasses observed elements, such as images, diagrams, demonstrations, displays, handouts, films, and flip charts. This style posits that students acquire knowledge primarily through visual observation. The auditory learning style encompasses acquiring information via listening to spoken language, whether from oneself or others, and various sounds and noises. In this style, students learn through listening to sounds and noises in the environment. The kinesthetic learning style involves physical experience -touching, feeling, holding, and practical hands-on experiences. Furthermore, Chislett and Chapman (2005) stated that these three learning styles are present in every person, but there is one that dominates them.

This learning style that dominates is a person's learning preference or capability.

Motivation

Motivation is characterized in the Cambridge Dictionary (2024) as a multifaceted concept that includes an individual's eagerness to participate in a specific activity and the underlying necessity or rationale for doing so. Intrinsic motivation drives individuals to thrive in particular domains (Austin, 2015) and is a crucial factor in active engagement in laboratory instruction (Brown & Miller, 2019). High motivation is evident when students pay attention, derive enjoyment, and set goals for learning tasks (Kuterbach, 2013). However, Whorrall (2018) warns that a lack of motivation may lead to academic disinterest, resulting in difficulties and school withdrawal.

Level of Academic Performance of the Students in Science Laboratory Courses

According to Marzano et al. (1999), students' performance levels represent the degree of achievement or competency attained about predefined learning outcomes or standards. It includes students' ability to demonstrate understanding, apply concepts, and engage in higher-order thinking tasks. This level of performance is assessed through various means, including performance assessments, tests, projects, and other forms of evaluation, to determine the extent to which students have met the specified criteria or expectations for learning.

In this study, academic performance was measured by consolidating students' final grades, encompassing students' scores across various assessments, including lab reports, quizzes, and hands-on activities. This comprehensive approach thoroughly evaluated their understanding and application of laboratory concepts during the specified final period at a private higher education institution for the second semester of the AY 2023-2024.

Relationship Between each of the Factors and Students' Level of Academic Performance in Science Laboratory Courses School Factors

According to Pareek (2019), school factors such as the availability of laboratory facilities directly affect students' level of performance. Dzama (2006) also stated that the absence of laboratory equipment, materials, and laboratory technicians has a direct negative effect on the performance of science students. The lack of necessary equipment was identified as contributing to poor student performance in science. Wekwe et al. (2024) further stated that qualified laboratory technicians play an essential role in laboratory instruction, ensuring that students gain the necessary practical experiences since they have detailed knowledge of valuable techniques and, often, more excellent expertise than science teachers. This correlates with Olubu (2016) findings, which mentioned exploring the specific relationship between school factors such as the availability of laboratory materials and resources and students' level of performance in science laboratory courses. The result of the study revealed a strong positive correlation between well-equipped laboratory facilities and improved student performance in laboratory-based science courses. Furthermore, Akanbi and Omosewo (2018) identified school factors as predictors influencing lab instruction, revealing that students exposed to available laboratory facilities and materials outperformed those without such exposure. Collectively, these studies demonstrate that access to adequate laboratory facilities and materials, coupled with qualified technicians, significantly contributes to students' level of performance in science laboratory courses.

Methodology

Research Design

This study utilized a descriptive-correlational research design. This research design seeks to delineate the variables pertinent to the study and investigate the relationships among two or more variables, offering insights into the predictive capacity of one variable over another (Bailey et al., 2010). This design was used because the study had to describe the factors influencing laboratory instruction in the General Chemistry course, determine the relationships between these factors and students' level of academic performance, and identify which factor best predicts laboratory instruction.

Respondents

This study focused on BS Criminology students enrolled in the General Chemistry course during the second semester of the academic year 2023-2024. Out of 88 enrolled students, 82 were present during the distribution of the questionnaire. The respondents were intentionally selected from Blocks I and III to provide insights into their experiences and perceptions within the educational context. Block I consisted of 30 students, while Block III had 27 students. Block II, which comprised 25 students, was excluded from primary study and utilized for pilot testing due to its smaller class size. This deliberate sampling ensured the reliability and relevance of the collected data, aligning with the study's objectives.

Instrument

A researcher-made questionnaire was used to assess the factors that influence laboratory instruction. It was purposively constructed due to the limited literature on questionnaires related to the study. In addition, the questionnaire was contextualized in the setting of laboratory learning. This Likert-type questionnaire uses a scale of 1-5, with one representing "strongly disagree" and five representing

"strongly agree." There were 40 indicators for school factors, 19 for teacher factors, and 44 for student factors.

The questionnaires for evaluating laboratory facilities and materials under school factors were adapted from the Philippine Accrediting Association of Schools, Colleges, and Universities (PAASCU, 2018). The questions for laboratory technicians were researcher-made based on related literature. These instruments were meticulously developed to align with the context of the study, tailored queries aimed specifically at experiences within the laboratory environment, focusing predominantly on aspects pertinent to general chemistry laboratory settings. In determining the teacher factor, a researcher-made questionnaire was made with 19 indicators focusing on content knowledge and pedagogical skills for laboratory instruction. It was purposefully constructed due to the limited literature of questionnaires relating to the study. Questions are created to cover different aspects of teaching in the laboratory, focusing on how content is taught and the strategies used for instruction. The questionnaire utilized for the motivation component under student factors was adapted from Meydan (2021) and Huda and Rohaeti (2023). Meanwhile, the original questionnaire by Meydan (2021) comprised four parts intrinsic motivation, extrinsic motivation, self- efficacy, and anxiety, only the intrinsic and extrinsic motivation components were adapted for this study. Items 1, 3, 5, 6, 8, 10, and 12 pertain to extrinsic motivation, whereas items 2, 4, 7, 9, 11, 13, and 14 address intrinsic motivation. For learning styles under student factors, the questionnaire was adopted from Chislett and Chapman's (2005) Visual-Auditory-Kinesthetic Learning Style Self-Assessment Questionnaire (VAK Learning Style Self-Assessment Questionnaire).

Since the survey questionnaires were both researcher-made and adapted, pilot testing was conducted on the 25 students of Block II. This was to diagnose points for revisions and ensure the instrument's validity and reliability. The reliability of the questionnaires was assessed using Cronbach's alpha to provide a high level of internal consistency for each instrument. Specifically, the questionnaire measuring school factors achieved a reliability coefficient of 0.910. The high-reliability score demonstrates that the items in the school factors questionnaire consistently measure the intended construct, thereby ensuring dependable and accurate results. The questionnaire addressing teacher factors exhibited a reliability coefficient 0.944, indicating strong internal consistency among the related items. The motivation questionnaire, categorized under student factors, attained a reliability coefficient of 0.888. The high score validates the questionnaire as an accurate measure of student motivation, yielding consistent and reliable data. Finally, the learning style questionnaire, derived from established literature, exhibited a reliability coefficient 0.791. Although marginally lower than the other coefficients, this value still demonstrated a satisfactory level of internal consistency, indicating that the items effectively assessed the construct of learning styles.

Ethical Considerations

In this study, ethical considerations are most important throughout the data- gathering process. The authors ensured that all relevant studies were properly cited, acknowledging the intellectual contributions of others while strictly avoiding plagiarism. By upholding academic integrity, the researchers maintained transparency and honesty in their work, respecting the intellectual property rights of fellow scholars. The research followed established ethical guidelines, emphasizing privacy, consideration of time and location, commitment to goodwill, and adherence to voluntary participation and informed consent principles. The guidelines stressed the researchers' responsibility to conduct their study ethically and responsibly. This study implemented ethical guidelines as recommended by Strauss et al. (2001).

Respect for privacy. This ensured that individuals' personal information and identities were kept confidential and secure throughout the research process. The respondents were not compelled to disclose their names on the survey questionnaire. This approach ensured that individuals' confidentiality was preserved, allowing them to participate without concerns about their personal information being revealed.

Time and venue. For data gathering, respondents were allowed to select a venue that suited them best for survey completion, while participation time was tailored to fit their schedules, ensuring comfort and convenience.

Beneficence. This study guaranteed that participants would not suffer any harm. This ensured strict protection of participants' personal information and responses. Furthermore, assurances were given that survey questionnaires were securely discarded post-research, preventing any potential risks or harm.

Voluntary participation and informed consent. Prior to participation, all respondents were fully informed about the study's purpose, procedures, and potential outcomes. They were guaranteed that their involvement was entirely voluntary and that opting out would not affect their academic status. Each participant was provided with written consent authorizing their participation and permitting access to their academic records from the registrar's office, ensuring transparency and respect for their choice.

Results and Discussion

Profile of the Factors that Influence Laboratory Instruction in Science Education

School Factor

Mohammadpour (2013) emphasizes schools' significant role in shaping students' learning experiences. Examining school-related factors becomes essential since a portion of students' knowledge is acquired in school settings. As noted by Wekwe et al. (2024) and Zengele and Alemayehu (2016), these factors encompass the availability of laboratory resources, proper laboratory facilities, and skilled laboratory technicians.

Availability of Laboratory Facilities. Hamedu et al. (2014) highlighted that laboratory facilities improve science education by facilitating students' comprehension and retention of concepts through experiential learning; as the adage suggests, "seeing is believing." Yara (2010) observed that there is a broad consensus among science educators regarding the critical importance of laboratories in effective science instruction. Table 1 illustrates the school factors associated with the availability of laboratory facilities

Table 1. *School Factors in Relation to Availability of Laboratory Facilities*

No.	Indicator	Weighted Mean	Verbal Interpretation
1	Students are instructed in the use of the fire extinguisher.	4.86	Strongly Agree
2	There is an orientation in laboratory safety for students and staff using or working in laboratories.	4.19	Agree
3	Each laboratory table is provided with water and gas outlets per work area.	4.12	Agree
4	A fire extinguisher (shower heads, sand buckets, etc.) is placed near the door so that students can quickly access this equipment.	4.07	Agree
5	The building and laboratories have sufficient water supply.	4.05	Agree
6	The laboratory provides me with an environment that helps my learning.	4.04	Agree
7	Electrical outlets are provided.	4.00	Agree
8	The laboratories have two or more exits.	3.89	Agree
9	The laboratory is well-maintained and clean.	3.79	Agree
10	Gas, water, and electricity are readily available in rooms and places where their use would generally be demanded.	3.77	Agree
11	Each room has a master shut-off electrical switch and master shut-off valve for gas.	3.77	Agree
12	Separate storage space, conveniently located, is provided for chemicals, laboratory equipment, and supplies.	3.70	Agree
13	Separate storage space, under lock and key, is provided for inflammable and toxic chemicals as a preventive measure against their misuse.	3.70	Agree
14	Each laboratory table has at least one sink.	3.54	Agree
15	There is sufficient ventilation to clear laboratory rooms of gases.	3.54	Agree
16	At most, two students are assigned to each work area.	3.51	Agree
17	The laboratory space is adequately equipped with the necessary tools and materials for conducting experiments.	3.47	Agree
18	Laboratory tabletops are chemical resistant.	3.47	Agree
19	The floors are non-skid or at least not slippery.	3.47	Agree
20	Shelves are provided for storing chemicals or reagents made accessible to students.	3.46	Agree
21	Students have lockers, one per group of two students.	3.35	Neutral
22	The laboratories are adequately illuminated.	3.32	Neutral
23	The laboratory has sufficient space for conducting experiments.	3.28	Neutral
24	Laboratories are adequate in size for the students.	3.25	Neutral
25	There are fume hoods where toxic and/or obnoxious gases are produced.	3.25	Neutral
26	Laboratories have adequate ventilation.	3.12	Neutral
Average Weighted Mean		3.69	Agree

Legend: 4.21–5.00: Strongly Agree; 3.41–4.20: Agree; 2.61–3.40: Neutral; 1.81–2.60: Disagree; 1.00–1.80: Strongly Disagree.

The adequacy of laboratory facilities, as shown in Table 1, is reflected in an overall weighted mean of 3.69, interpreted as agreeable. This indicates a generally positive perception, with students acknowledging core elements such as safety training and accessible equipment. However, the analysis reveals opportunities for improvement in aspects like facility quality, storage, lighting, space, and ventilation. While students agree that their laboratory facilities meet basic expectations for functionality and safety, these areas of

enhancement could elevate the facilities from merely functional to fully optimized for safe, organized, and effective scientific learning. The overall score reflects a basic level of agreement with the facilities' essential features but highlights the need for targeted improvements to better address students' needs. Availability of Laboratory Materials refers to the accessibility and sufficient supply of equipment, apparatus, and consumables required for scientific research or experimentation (Olaniyan, 2017). This includes items such as microscopes, centrifuges, reagents, and glassware (Wiltronics, 2022). Adequate availability of these materials is essential for conducting effective and reliable scientific investigations (Okebukola, 1997). Table 2 presents school factors about the availability of laboratory materials.

Table 2. *School Factors about Availability of Laboratory Materials*

No.	Indicator	Weighted Mean	Verbal Interpretation
1	The laboratory equipment and apparatus are functional and usable.	3.81	Agree
2	The laboratory materials are well-organized, labeled, and readily available.	3.72	Agree
3	The laboratory provides all the necessary materials for conducting experiments.	3.63	Agree
4	There have been instances where essential materials could have been improved during experimentation.	3.53	Agree
5	The laboratory provides materials for advanced experiments.	3.47	Agree
6	The quality of laboratory reagents and solutions is satisfactory.	3.46	Agree
7	The laboratory provides the consumables required for experiments.	3.39	Neutral
Average Weighted Mean		3.57	Agree

Legend: 4.21–5.00: Strongly Agree; 3.41–4.20: Agree; 2.61–3.40: Neutral; 1.81–2.60: Disagree; 1.00–1.80: Strongly Disagree.

The analysis of school factors related to laboratory materials, as rated by students, highlights a generally adequate provision of functional equipment and resources, with an overall average weighted mean of 3.57. This suggests that students agree their laboratory materials are sufficient for conducting standard experiments. However, the results also point to areas needing improvement, particularly in the consistent availability of consumables and access to advanced experimental materials. Addressing these gaps could enhance the learning experience, better support students' scientific explorations, and foster a more comprehensive and engaged approach to laboratory learning. By ensuring access to both essential and advanced materials, schools can elevate the quality of laboratory education and fully meet students' experimentation needs. Availability of Laboratory Technicians. A laboratory technician is an individual who performs hands-on laboratory work, including preparing equipment, chemicals, and student materials (University of Mexico, 2017). They support scientific education and research by ensuring a safe and functional laboratory environment (Rossette et al., 2021). Table 3 presents school factors regarding the availability of laboratory technicians.

Table 3. *School Factor about Availability of Laboratory Technician*

Indicator	Weighted Mean	Verbal Interpretation
1. The presence of a laboratory technician significantly improves learning experiences and outcomes...	4.04	Agree
2. Laboratory technicians reduce teachers' time to prepare for experiments, allowing better planning.	4.02	Agree
3. The laboratory technicians ensure better maintenance and functioning of laboratory equipment.	3.95	Agree
4. Laboratory technicians prepare chemicals and equipment for teaching.	3.89	Agree
5. The presence of a laboratory technician improves the efficiency and effectiveness of experiments.	3.84	Agree
6. The presence of laboratory technicians would reduce the preparation time required for experiments.	3.79	Agree
7. There is a qualified laboratory technician in the chemistry laboratory.	1.53	Strongly Disagree
Average Weighted Mean	3.57	Agree

Legend: 4.21–5.00: Strongly Agree; 3.41–4.20: Agree; 2.61–3.40: Neutral; 1.81–2.60: Disagree; 1.00–1.80: Strongly Disagree.

The students' ratings of the availability of laboratory technicians highlight their generally positive perception of the technicians' contributions to the quality of laboratory sessions. The average weighted mean of 3.58, corresponding to an "Agree" response, indicates that students recognize the value of laboratory technicians in enhancing their learning experience and improving the quality of laboratory activities. However, the notable discrepancy in response to the presence of qualified technicians in chemistry labs (WM = 1.53) signals a critical gap that must be addressed for laboratory learning to reach its full potential.

Teacher Factor

Teacher Factor involves teachers' influence on students' learning outcomes, primarily through their pedagogical and content knowledge (Hattie, 2009). In this study, the teacher factor explicitly signifies the level of instructional support and encouragement teachers provide to their students (Skaalvik & Skaalvik, 2010). The teacher factor includes content knowledge and pedagogical knowledge.

Content Knowledge encompasses teachers' deep understanding of the subjects they instruct, which significantly shapes how they plan and deliver lessons (Shulman, 1986). In this context, content knowledge refers to the teachers' command over subject-specific information, which enables them to clarify complex ideas for students (Hammond & Grossman, 2019). Table 4 presents the teacher factors about content knowledge.

Table 4. *Teacher Factor – Content Knowledge*

<i>Indicator</i>	<i>Weighted Mean</i>	<i>Verbal Interpretation</i>
1. I am satisfied with the instructor's content knowledge.	4.51	Very Knowledgeable
2. The instructor is open to questions and discussions.	4.44	Very Knowledgeable
3. The instructor demonstrates expertise in laboratory techniques.	4.33	Very Knowledgeable
4. The instructor effectively explains complex concepts before the experiment.	4.25	Very Knowledgeable
5. The instructor provides additional resources for further learning.	4.23	Very Knowledgeable
6. The instructor encourages critical thinking and inquiry.	4.19	Knowledgeable
7. The instructor provides real-life situations and examples to clarify concepts.	4.18	Knowledgeable
8. The instructor demonstrates a strong understanding of the subject matter.	4.16	Knowledgeable
9. The instructor effectively processes complex concepts after the experiment.	4.11	Knowledgeable
Average Weighted Mean	4.27	Agree

Legend: 4.21–5.00 = Very Knowledgeable; 3.41–4.20 = Knowledgeable; 2.61–3.40 = Moderately Knowledgeable; 1.81–2.60 = Slightly Knowledgeable; 1.00–1.80 = Not Knowledgeable

The students' ratings of the teacher factor about content knowledge reflect a generally positive perception of their instructors' mastery of the subject and ability to engage students in the learning process effectively. With an average weighted mean of 4.27, indicating Very Knowledgeable, students express intense satisfaction with their instructors' content knowledge, showing that they recognize their teachers as experts capable of effectively delivering complex subject matter. The highest-rated item, "I am satisfied with the instructor's content knowledge" (WM = 4.51), underscores the students' trust in their instructors' expertise. This finding is supported by research, including a study by Hill et al. (2008), which suggests that students' perceptions of instructors' subject knowledge directly influence their engagement and learning outcomes. Locally, Alampay and Garcia (2019) found that students in the Philippines value instructors who display a high level of expertise, as it fosters trust and improves academic performance.

Pedagogical Skills are the techniques and methods that teachers use to facilitate learning and manage the classroom, which are essential for delivering content effectively and engaging students (Shulman, 1987). In this study, pedagogical skills refer to teachers' strategies to promote understanding, encourage participation, and adapt instruction to meet diverse student needs (Hammond & Grossman, 2019). Table 5 presents the teacher factor in terms of pedagogical skills.

Table 5. *Teacher Factor about Pedagogical Skills*

<i>No.</i>	<i>Indicators</i>	<i>Weighted Mean</i>	<i>Verbal Interpretation</i>
1	The instructor monitors student progress during laboratory experiments.	4.54	Very Effective
2	The instructor is approachable and responsive to student needs.	4.54	Very Effective
3	I am satisfied with the instructor's pedagogical skills.	4.53	Very Effective
4	The instructor provides clear guidelines for laboratory assignments.	4.44	Very Effective
5	The instructor fosters a supportive learning environment.	4.44	Very Effective
6	The instructor encourages collaborative learning.	4.42	Very Effective
7	The instructor motivates students to perform their best during experiments.	4.37	Very Effective
8	The instructor provides students with step-by-step instructions for each laboratory experiment phase.	4.26	Very Effective
9	The instructor offers examples to illustrate key concepts and procedures before students conduct experiments.	4.18	Effective
10	The instructor engages students effectively during experiments.	4.14	Effective
	Average Weighted Mean	4.27	Agree

Legend: 4.21–5.00: Very Effective; 3.41–4.20: Effective; 2.61–3.40: Moderately Effective; 1.81–2.60: Slightly Effective; 1.00–1.80: Not Effective

The students' ratings of the teacher factor about pedagogical skills reveal a highly positive perception of their instructors' ability to facilitate laboratory learning effectively. With an average weighted mean of 4.39, and verbal interpretation of Very Effective, students believed that their science laboratory teachers are very effective as they employed appropriate pedagogical approaches in their teaching, monitored their student progress, provided clear instructions to students and fostered a supportive and engaging learning environment.

Student Factor

Handelsman et al. (2007) suggest that student-related factors in laboratory instruction include individual attitudes and prior knowledge, which affect students' engagement, learning, and performance in lab activities. Simpson (1966) further develops this idea by adding students' preferred learning styles and motivation as important components. In this study, the student factor focuses on students' preferred learning styles and motivation.

Learning styles are the mental processes and instructional settings students use most effectively while learning (Cano & Hughes, 2000). These processes include organizing, perceiving, encoding, recalling, and reasoning. The students' learning styles were identified by their most dominant primary learning style, determined, and categorized through the VAK Self-Assessment Questionnaire (Chislett & Chapman, 2005). In this assessment, students were grouped into three learning styles: visual, auditory, and kinesthetic. Table 6 provides a summary of the respondents' learning styles. Table 6 presents student factors about learning styles.

Table 6. Student Factor about Learning Styles

Learning Styles	No. of Respondents	Percent
Visual	30	52.63%
Auditory	16	28.07%
Kinesthetic	11	19.30%
Total	57	100%

The majority of students identify as visual learners, followed by auditory and kinesthetic learners. This diversity in learning styles highlights the need for educators to adopt a multi-modal approach to instruction. Research supports tailoring teaching strategies to address different learning preferences to enhance student engagement, understanding, and retention. Teachers can incorporate various methods, such as visual aids, discussions, and hands-on activities, to create an inclusive and effective learning environment. This aligns with the principles of differentiated instruction, which emphasizes catering to the diverse needs of students to promote equity.

Motivation is the internal drive or external influence that stimulates and directs an individual's behavior toward achieving specific goals (Deci & Ryan, 2000). It includes intrinsic factors, such as personal interest and enjoyment, and extrinsic factors, like rewards or external recognition, that impact task effort and persistence (Wigfield & Eccles, 2000). Table 7 presents student factors about motivation.

Table 7. Student Factor about Student's Motivation

Indicator	Type of Motivation	Weighted Mean	Verbal Interpretation
1. I am curious about discoveries made through chemistry lab experiments.	Extrinsic	4.16	Highly Motivated
2. I enjoy challenging chemistry lab sessions.	Intrinsic	4.07	Highly Motivated
3. The chemistry lab skills I have acquired will help me in my career.	Extrinsic	4.07	Highly Motivated
4. The chemistry lab knowledge I have acquired has practical value for me.	Intrinsic	4.04	Highly Motivated
5. I find performing experiments in the chemistry lab interesting.	Extrinsic	4.00	Highly Motivated
6. Chemistry lab learning will contribute to my overall academic success.	Extrinsic	3.96	Highly Motivated
7. I reflect on how learning chemistry in the lab relates to my goals.	Intrinsic	3.95	Highly Motivated
8. I consider how to use the chemistry lab skills I have acquired in practical situations.	Extrinsic	3.89	Highly Motivated
9. If I don't understand a chemistry lab experiment, I must learn it.	Intrinsic	3.75	Highly Motivated
10. The chemistry lab experiments I perform are relevant to my interests.	Extrinsic	3.75	Highly Motivated
11. The chemistry lab experiences I have gained relate to my life.	Intrinsic	3.72	Highly Motivated
12. Learning chemistry lab techniques will help me find a good job.	Extrinsic	3.67	Highly Motivated
13. Conducting chemistry lab experiments makes my life more meaningful.	Intrinsic	3.63	Highly Motivated
14. Learning chemistry lab techniques is more important for me than my score in the class.	Intrinsic	3.51	Highly Motivated
Average	—	3.87	Highly Motivated

Legend: 4.21–5.00 = Very Highly Motivated; 3.41–4.20 = Highly Motivated; 2.61–3.40 = Moderately Motivated; 1.81–2.60 = Slightly Motivated; 1.00–1.80 = Not Motivated at All.

Students' motivation for chemistry laboratory experiences is generally high, with an average weighted mean of 3.87. Intrinsic motivation is 3.84, while extrinsic motivation is slightly higher at 3.9. Despite differences in motivation across various aspects of the experience, students remain "Highly Motivated" across all indicators. The study emphasizes the importance of fostering connections between academic tasks and personal and career goals to enhance motivation. Research suggests that when students see the relevance of their learning, their motivation remains robust, suggesting that linking academic activities with real-life applications could lead to higher levels of student engagement and achievement.

As shown in Table 8, a summary of the factors influencing laboratory instruction highlights key areas that impact their overall effectiveness, including school factors, teacher factors and student factors.

Table 8. *Summary of the factors that influence laboratory instruction*

<i>Factors</i>	<i>Mean</i>	<i>General Description</i>
School Factor		
Availability of Laboratory Facilities	3.69	Agree
Availability of Laboratory Materials	3.57	Agree
Availability of Laboratory Technicians	3.58	Agree
Teacher Factor		
Content Knowledge	4.27	Very Knowledgeable
Pedagogical Knowledge	4.39	Very Effective
Student Factor		
Learning Style (Dominant: Visual)	52.63%	—
Motivation	3.87	Highly Motivated

Among the school factors, the availability of laboratory facilities (WM = 3.69), materials (WM = 3.57), and technicians (WM = 3.58) all received a rating of "Agree," indicating that these resources are adequately available but could still be improved to enhance their impact on laboratory instruction. For teacher factors, content knowledge (WM = 4.27) and pedagogical knowledge (WM = 4.39) were rated as "Very Knowledgeable" and "Very Effective," respectively, emphasizing the significant strength and competence of teachers in delivering effective laboratory instruction and regarding student factors, learning style, and motivation received a mean score of 3.87, described as "Highly Motivated," reflecting that students are generally engaged and capable of adapting to laboratory learning. The data also indicate that the dominant learning style is Visual, with 52.63% of students preferring visual learning approaches. This suggests that laboratory instruction, which often incorporates diagrams, demonstrations, and visual aids, aligns well with the learning preferences of the majority of students. Overall, the findings suggest that while teacher effectiveness is a notable strength, improvements in school facilities and resources could further enhance the quality of laboratory instruction.

Academic performance in science laboratory courses

Academic performance is a crucial indicator of educational quality (Magulod, 2019). In this study, academic performance is represented by the student's final grade in the general chemistry course. Table 9 presents students' level of academic performance during finals.

Table 9. *Level of Academic Performance*

<i>Grades</i>	<i>Frequency</i>	<i>%</i>	<i>General Description</i>
100 – 93	0	0.00	Outstanding
92 – 86	2	3.51	Very Good
85 – 81	13	22.81	Good
80 – 75	42	73.68	Fair
74 – Below	0	0.00	Failed
General Weighted Average:	78.30	100%	Fair

Legend: 93–100 = Outstanding; 92–86 = Very Good; 85–81 = Good; 80–75 = Fair; 74–Below = Failed

The academic performance of 1st-year criminology students in chemistry is classified as "Fair" with a GWA of 78.30. This indicates that while most students meet the basic requirements, they still need to have a solid grasp of the subject matter. Chemistry is a foundational course for criminology students, connecting theoretical knowledge to real-world applications like forensic science. However, many struggle with fully engaging with these concepts. This highlights the need for strategic interventions, such as constructive feedback and personalized learning strategies, to enhance student outcomes.

Relationship Between Each of the Factors and Academic Performance

School Factors and Academic Performance

Table 10 presents the relationship between variables like laboratory facilities, lab materials, and technician presence and their correlation with academic performance.

Table 10. *Relationship Between School Factors and Students' Academic Performance*

<i>School Factor Variables vs Academic Performance</i>	<i>r</i>	<i>Verbal Interpretation</i>	<i>p-value</i>	<i>Decision</i>	<i>Interpretation</i>
Laboratory Facilities	-0.172	Weak negative correlation	0.200	Failed to reject H_0	Not significant
Lab Materials	-0.008	Weak negative correlation	0.955	Failed to reject H_0	Not significant
Technician	0.211	Weak positive correlation	0.114	Failed to reject H_0	Not significant

$\alpha = .05$

The study reveals that while well-equipped laboratories can improve hands-on learning experiences, they don't significantly impact students' academic performance. It supports Millar's theory that good laboratory facilities are necessary for practical learning but not always lead to better outcomes. The presence of a technician doesn't significantly impact students' academic performance. Instead, effective teaching and student involvement are more important. A comprehensive approach to educational support focusing on teaching quality and student engagement can lead to better performance and success.

Teacher Factors and Academic Performance

Table 11 presents these variables' correlation coefficients, p-values, and corresponding interpretations.

Table 11. *Relationship Between Teacher Factors and Students' Academic Performance*

<i>Teacher Factor Variables vs Academic Performance</i>	<i>r</i>	<i>Verbal Interpretation</i>	<i>p-value</i>	<i>Decision</i>	<i>Interpretation</i>
Content Knowledge	0.006	Weak positive correlation	0.967	Failed to reject H_0	Not significant
Pedagogical Skill	0.024	Weak positive correlation	0.858	Failed to reject H_0	Not significant

$\alpha = .05$

The data in Table 11 indicates a weak positive correlation between content knowledge ($r = .006$, $p = .967$) and pedagogical skill ($r = .024$, $p = .858$) with students' academic performance. Still, these correlations were not statistically significant ($p > .05$). This suggests that while content knowledge and pedagogical skills are essential elements of effective teaching, they negatively impact students' academic performance. These findings align with previous research by Hattie (2009), who emphasized that teaching quality, while essential, interacts with other factors, such as student motivation and engagement, which have a more substantial influence on learning outcomes. Hattie (2009) noted that while teacher effectiveness is essential, student-related factors such as motivation, prior knowledge, and engagement play a crucial role in determining academic achievement.

The results of this study suggest that while teachers' content knowledge and pedagogical skills are essential components of effective instruction, their direct influence on academic performance appears limited if they consider student-related factors. This highlights the need for a more comprehensive approach to improving academic performance that integrates teaching effectiveness and strategies to foster student motivation, engagement, and self-regulated learning. The findings also underline the importance of providing support to students in areas such as time management and study strategies, and personal motivation, which can complement the efforts of educators in enhancing student outcomes.

Student Factors and Academic Performance

Table 12 displays the correlation coefficients and p-values for these student factors and interpretations for each result.

Table 12. *Relationship Between Student Factors and Students' Academic Performance*

<i>Student Factor Variables vs Academic Performance</i>	<i>r</i>	<i>Verbal Interpretation</i>	<i>p-value</i>	<i>Decision</i>	<i>Interpretation</i>
Learning Style	0.004	Weak positive correlation	0.975	Failed to reject H_0	Not significant
Motivation	0.269	Weak positive correlation	0.043	Reject H_0	Significant

$\alpha = .05$

The study found a weak positive correlation between students' preferred learning styles and their academic performance, with a high p-value exceeding the conventional threshold of .05. This contradicts the idea that matching instructional methods with students' learning styles leads to improved academic performance. The research also suggests that teaching methods and student engagement are more strongly associated with academic success than learning style preferences alone. However, the study found a significant weak positive correlation for motivation, indicating that motivation has a measurable effect on academic performance. This aligns with previous studies, such as Schunk and DiBenedetto (2020), Deci and Ryan's (2000) self-determination theory, and Pintrich and De Groot's (1990) study. Thus, motivation appears to be a significant factor in students' academic success, confirming its importance as a

psychological driver of academic success.

4. Predictor of Laboratory Instruction

The regression analysis reveals no significant predictor of laboratory instruction, as the p-value is greater than the 0.05 significance level. This suggests that the relationship between school, teacher, and student factors does not have a meaningful or reliable influence on the quality of laboratory instruction. The model does not offer statistical evidence to support these factors as significant predictors. Previous research has found limited or no significant relationships between similar factors and educational outcomes. For example, Rebulanan and Samala (2021) found that neither the usage of laboratory equipment nor teachers' competence in science instruction significantly impacted students' academic performance. Libres and Dalman (2021) identified a negative relationship between the adequacy of laboratory facilities and academic achievement. Okeke (1995) also observed no significant relationship between laboratory facility adequacy and essential science performance. Holvio (2022) found that teacher content knowledge did not significantly impact student achievement. Hill and Chin (2018) found no significant relationship between teachers' understanding and student achievement. Isa et al. (2021) reported no significant correlation between learning style preferences and academic performance. Dohn et al. (2016) found no significant correlation between student motivation in laboratory work and academic performance.

Conclusions

Laboratory instruction, a vital component of science education, promotes experiential learning, analytical reasoning, and scientific inquiry. Its effectiveness depends on addressing several interconnected factors, including institutional support, educator expertise, and learner engagement, which could eventually affect students' academic performance. However, this study proves that there are other diverse and stronger factors, not covered in this study, that significantly influence students' academic performance in laboratory classes. Considering diverse influences such as technology integration, parental involvement, socioeconomic status, students' academic preparation, and others could contribute to more meaningful learning experiences, thereby increasing students' academic gains.

To enhance the quality of laboratory instruction, school administrators are encouraged to allocate sufficient funding for modern laboratory equipment, materials, and the hiring of skilled laboratory technicians. Policies must also be crafted to ensure the regular maintenance, upgrading, and sustainability of laboratory facilities. It is recommended that lecture and laboratory classes be handled by the same teacher to promote instructional continuity and coherence. Teachers are advised to employ varied and interactive teaching strategies, including hands-on activities, group work, and multimedia resources, to cater to diverse learning styles and improve student engagement. Additionally, teachers should pursue continuous professional development, consistently implement pre-lab and post-lab activities, and provide constructive feedback to enhance student learning and performance.

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