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### Pre-Laboratory Schema for General Biology

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#### Abstract

This study developed and implemented a Pre-Laboratory Schema to improve students' readiness and performance in senior high school Biology laboratories. Guided by the Educational Design Research framework, it validated the schema's content and examined its effect on science process skills among 75 Grade 11 STEM-Medical students. Expert evaluations confirmed its clarity, relevance, and accuracy,

while results showed significantly higher gains in the experimental group's post-test scores. Students described the schema as clear, helpful, and engaging, improving confidence and reducing confusion. Overall, the schema effectively enhanced science process skills and supported more organized laboratory learning.

**Keywords:** Pre-Laboratory Schema, Educational Design Research, Science Process Skills, STEM

#### Introduction

In science education, hands-on laboratory experiments play a vital role in developing students' science process skills, such as observing, classifying, measuring, inferring, predicting, and experimenting, which form the foundation of the scientific method (Padilla, 1990). The K to 12 Science Curriculum of the Philippine Department of Education (DepEd) underscores the importance of experiential learning, requiring students to perform laboratory activities in Biology, Chemistry, Physics, and Earth Science. These laboratory engagements are designed to provide students with authentic experiences in scientific investigation, allowing them to apply theoretical knowledge to real-world scenarios (DepEd, 2013)<sup>[13]</sup>.

However, despite these curriculum goals, laboratory implementation faces persistent challenges, most notably, time constraints. DepEd Order No. 13, s. 2018<sup>[18]</sup> allocates only 80 hours per semester for each Senior High School subject, including specialized science courses. This limited time results in laboratory periods that are often restricted to just one hour per week, which must cover briefing, safety reminders, actual experimentation, and post-lab processing. In practice, this short timeframe often proves insufficient.

Compounding the issue, many students arrive at the laboratory session unprepared, encountering the procedures for the first time during the experiment itself. This lack of pre-lab familiarity frequently results in procedural errors, confusion, and inefficiency, further reducing the effectiveness of the already limited lab period. Conchas *et al.* (2022)<sup>[11]</sup> noted that in Philippine classrooms, teachers spend a substantial portion of laboratory time clarifying procedures, which limits opportunities for students to engage in higher-order thinking and inquiry. As a result, instructional time is diverted from meaningful analysis to procedural guidance.

These systemic issues, time constraints, student unpreparedness, and teacher-dominated laboratory instruction have a significant cumulative effect: they impede the development of essential science process skills. When students lack adequate time and preparation to actively engage in experimentation, they miss opportunities to practice making predictions, formulating hypotheses, drawing conclusions, and reflecting on data, skills that are foundational not only to scientific inquiry but to future academic success in STEM fields. Repeated exposure to passive, procedural laboratory tasks without conceptual clarity reinforces rote learning and diminishes students' ability to apply scientific reasoning independently.

In response to these interrelated challenges, this study aims to develop and implement a structured Pre-Laboratory Schema, a strategic pre-laboratory tool that enables students to read, internalize, and visualize experiment procedures through illustrations before the actual session. Rather than relying on traditional last-minute instructions, this schema emphasizes student preparation through step-by-step illustrations, procedural comprehension, and encourages both mental rehearsal and conceptual

clarity. In doing so, the Pre-Laboratory Schema is expected to create the necessary cognitive and procedural scaffolding for students to meaningfully develop their science process skills in a constrained instructional environment.

### Research Questions:

This study aimed to develop and implement a structured Pre-Laboratory Schema, a strategic pre-laboratory tool that enabled students to read, internalize, and visualize experiment procedures through illustrations before the actual session, guided by the Educational Design Research (EDR) Framework. It sought to determine the schema's validity, its impact on students' science process skills, and the perceptions of both students and teachers regarding its classroom usability.

Specifically, this study sought to answer the following questions:

1. What are the key components of an effective pre-laboratory schema for pre-laboratory experiments in biology classes?
2. To what extent is the developed pre-laboratory schema valid in terms of content, relevance, clarity, acceptability, and accuracy?

### Literature Review

Effective science education hinges on students' ability to meaningfully engage with laboratory activities. However, time constraints, unstructured preparation, and teacher-dominated instruction often limit the benefits of practical work. This chapter discusses literature and studies that highlight the significance of cognitive preparation through structured pre-laboratory tools and how these support the theoretical and methodological foundation of this research, which develops and validates a Pre-Laboratory Schema for Senior High School Biology students.

This study is anchored on Schema Theory, first introduced by Frederic Bartlett in 1932 and later expanded by cognitive psychologists such as Richard Anderson (1977). Schema Theory posits that individuals understand and learn new information by activating and organizing prior knowledge into mental structures or "schemas." These schemas serve as cognitive frameworks that help learners make sense of complex concepts, anticipate outcomes, and guide behavior. In the context of science education, this theory supports the idea that students must have a clear mental representation of a laboratory task before they can meaningfully engage in it. According to Abrahams and Millar (2008)<sup>[1]</sup>, students often enter laboratory sessions unprepared, reading the procedures for the first time during the activity, which results in confusion, procedural errors, and inefficient time use. By introducing a Pre-Laboratory Schema, a structured tool requiring students to illustrate step-by-step procedures and all metadata fields such as student name, grade, and section, date, experiment number, score, and title, this approach seeks to activate relevant schemas before the laboratory session begins. By presenting a Pre-Laboratory Schema, learners do not acquire new knowledge in isolation; instead, they process new information by relating it to previously formed mental frameworks, or schemas, which help them interpret and organize incoming stimuli (Bartlett, 1932; Anderson, 1977)<sup>[8, 4]</sup>.

In this context, according to Bartlett (1932)<sup>[8]</sup> and Anderson (1977)<sup>[4]</sup>, each component of the Pre-Laboratory Schema is intentionally designed to trigger relevant prior knowledge

and organize new information into coherent mental structures before the laboratory session begins. For example, firstly, when students write the experiment's title and objectives, they activate general schemas about the scientific method and experimental design, helping them form expectations about the purpose and direction of the activity. Secondly, familiarizing the materials and tools activates procedural schemas in which students begin to visualize how each item will be used, which prepares them for hands-on application. Thirdly, drawing a step-by-step procedure allows students to simulate the experiment cognitively. This visual rehearsal is a key manifestation of Schema Theory in action, as it strengthens procedural memory and anticipatory understanding, reducing confusion during actual execution. By engaging with these elements before the actual lab, students are not merely memorizing steps but actively constructing, reinforcing, and refining their mental models, a process that Schema Theory identifies as essential for deep learning and transfer of knowledge. This structured pre-lab preparation transforms the lab from a passive, teacher-dependent experience into an active, student-driven inquiry, as students already possess a mental scaffold that supports procedural accuracy, critical thinking, and efficient time use. Thus, the Pre-Laboratory Schema serves as a concrete educational strategy that operationalizes Schema Theory in science education. The schema enables students to mentally simulate the experiment, anticipate critical steps, and visualize the process in advance, thus reducing cognitive overload during the actual experiment. In doing so, the Pre-Laboratory Schema bridges the gap between theoretical instruction and practical application, improving both student preparedness and instructional efficiency. Anchored in Schema Theory, this study supports the premise that well-structured cognitive tools can enhance learning outcomes, foster independent scientific inquiry, and maximize limited instructional time in Senior High School science laboratories.

Following the foundational framework of Schema Theory, which posits that learners process new information by integrating it into existing mental structures or "schemas" (Bartlett, 1932; Anderson, 1977)<sup>[8, 4]</sup>, it is equally important to consider the cognitive limitations that influence how these schemas are formed, accessed, and applied. To address this, the current study also draws on Cognitive Load Theory (CLT), introduced by John Sweller in the late 1980s, as a complementary framework that deepens the understanding of how instructional design can affect learning outcomes in science education.

Cognitive Load Theory is grounded in the premise that working memory has a limited capacity for processing new information (Sweller, 1988)<sup>[46]</sup>. It proposes that instructional strategies should be optimized to prevent overloading this limited cognitive resource, thereby promoting the effective transfer of knowledge into long-term memory, where schemas reside and are organized. According to CLT, learning is most efficient when instructional materials reduce extraneous load (irrelevant or poorly designed information), manage intrinsic load (inherent complexity of the material), and optimize germane load (mental effort invested in schema construction and automation) (Sweller, van Merriënboer, & Paas, 1998). In relation to Schema Theory, CLT helps explain how learners process and structure information into schemas under varying instructional conditions. While Schema Theory focuses on

the structure of knowledge and how it is internalized, CLT emphasizes the conditions under which schema acquisition is either enhanced or hindered. Thus, the two theories are inherently interdependent: the formation and refinement of schemas depend on minimizing unnecessary cognitive load, especially during complex tasks such as laboratory procedures.

This theoretical intersection is particularly relevant in the context of Senior High School biology laboratory sessions. Laboratory experiments are cognitively demanding, requiring students to simultaneously interpret instructions, recall scientific concepts, manipulate equipment, observe phenomena, and document results, all within a constrained timeframe (DepEd Order No. 13, s. 2018) [18]. In many cases, students encounter procedural instructions for the first time during the actual experiment, contributing to cognitive overload and reducing their ability to engage in meaningful inquiry or develop science process skills (Abrahams & Millar, 2008; Talisayon, 2012) [1, 49]. Consequently, the limited working memory is consumed by surface-level procedural concerns, leaving little room for conceptual understanding or hypothesis generation, which are essential components of scientific reasoning.

The Pre-Laboratory Schema developed in this study is designed precisely to mitigate cognitive overload by front-loading cognitive processing, encouraging students to visualize and internalize the steps of an experiment before entering the laboratory. This structured, illustrated schema allows students to process procedural information in manageable segments, organize it meaningfully, and store it as an integrated schema in long-term memory. By engaging with the schema beforehand, students are less likely to be overwhelmed during the actual experiment, freeing up working memory resources for observation, data interpretation, and reflection, activities aligned with germane cognitive load. Moreover, the schema reduces extraneous cognitive load by providing a simplified, visually guided structure that prevents students from becoming confused by complex or text-heavy lab manuals. It also manages intrinsic load by sequencing information in a way that scaffolds complexity, starting from objectives and materials to step-by-step visual procedures and safety reminders. In doing so, the Pre-Laboratory Schema serves not only as a cognitive aid but also as a tool for schema automation, helping students transition from novice to more expert-like processing over time.

While Schema Theory explains how knowledge structures are developed and accessed, Cognitive Load Theory offers insight into how instructional design affects that development. Together, these theories form a robust conceptual framework for the Pre-Laboratory Schema, ensuring that it supports both cognitive efficiency and schema construction in a constrained, high-demand learning environment such as the senior high school science laboratory. This theoretical integration strengthens the rationale for using structured pre-laboratory tools to improve not just content comprehension but also the procedural fluency and scientific reasoning skills essential for long-term academic success in STEM.

Grounded in Schema Theory and Cognitive Load Theory, this study acknowledges that effective learning occurs when instructional tools support both the construction of mental frameworks and the optimization of cognitive effort. While these theories provide the psychological foundation for

understanding how students process and internalize laboratory procedures, there remains a need for a systematic, classroom-based approach to design, test, and refine such instructional tools in real educational settings. To address this, the present study adopts the Educational Design Research (EDR) framework, which complements the cognitive theories by offering a methodological structure for developing and evaluating the Pre-Laboratory Schema through iterative, practice-informed phases. The integration of EDR ensures that the intervention is not only theoretically grounded but also contextually responsive and empirically validated in authentic teaching environments.

This study is anchored in the Educational Design Research (EDR) Framework developed by McKenney and Reeves (2012) [33], which serves as the methodological foundation for the study. The EDR framework is particularly suited to addressing complex educational problems within authentic classroom environments, making it ideal for interventions that must be both theoretically sound and practically viable. EDR emphasizes a dual goal: solving real instructional problems and contributing to the advancement of educational theory. In this context, the study aims to design, implement, and evaluate a Pre-Laboratory Schema intended to address students' inadequate laboratory preparedness and the time constraints often encountered in Senior High School Biology classes.

The EDR framework consists of four interconnected and iterative phases: (1) analysis and exploration, (2) design and construction, (3) evaluation and reflection, and (4) implementation and dissemination. In the first phase, analysis and exploration, researchers work closely with key stakeholders, such as science teachers and curriculum coordinators, to deeply understand the instructional issues. This includes reviewing literature, analyzing curriculum mandates (e.g., DepEd Order No. 13, s. 2018) [18], and conducting interviews or focus group discussions to determine contextual constraints and learner needs. In this study, teacher input and classroom observations were used to examine how time limitations and a lack of structured preparation reduce the effectiveness of laboratory instruction and hinder the development of students' science process skills.

The second phase, design and construction, involves developing a prototype intervention, in this case, the Pre-Laboratory Schema, based on insights gained from Phase 1. The schema was designed as a visual, structured pre-laboratory worksheet that guides students in illustrating the steps of an experiment before performing it. It incorporates metadata and prompts aligned with scientific inquiry, such as identifying materials, outlining procedures, and anticipating outcomes. This phase also includes validation by science education experts to ensure content relevance, accuracy, and alignment with curriculum standards.

The third phase, evaluation and reflection, entails empirical testing of the prototype in actual classroom settings. This phase is both formative and summative, assessing the intervention's usability, clarity, and effectiveness. The Pre-Laboratory Schema underwent pilot testing and the results were the baseline of improvements. Data were collected using pre- and post-tests on science process skills, quality rubrics for the pre-laboratory schema, and student feedback through FDG. Revisions were made based on both expert validation and field results, ensuring that the schema would be practical and impactful.

The fourth and final phase, implementation and dissemination, involves the full integration of the Pre-Laboratory Schema into actual Biology laboratory instruction. This stage includes the systematic application of the tool across multiple lab sessions, continued teacher facilitation, and the collection of long-term feedback. The findings, together with practical recommendations, will be shared with relevant stakeholders in science education to support wider application, replication, or adaptation in similar educational contexts.

By grounding this study in the EDR framework, the research ensures that the Pre-Laboratory Schema is both pedagogically grounded and field-tested through rigorous, iterative cycles. This methodological alignment affirms that educational innovations should not be static solutions but should evolve through real-world classroom application, data-driven refinement, and thoughtful dissemination for broader educational impact.

In addition to being grounded in sound theoretical and methodological frameworks, this study is also aligned with national policy directives that shape professional teaching standards and instructional quality in the Philippines. A legal basis that supports this study is the DepEd Order No. 42, s. 2017<sup>[13]</sup>, promulgates the Philippine Professional Standards for Teachers (PPST), a comprehensive framework designed to enhance teacher quality and guide professional practice across various domains of teaching. This study aligns closely with several key PPST domains that emphasize not only mastery of subject matter but also the design and delivery of learner-centered instruction. Domain 1 – Content Knowledge and Pedagogy highlights the teacher's responsibility to demonstrate deep understanding of the subject matter and employ appropriate teaching strategies that promote meaningful learning (DepEd, 2017)<sup>[13]</sup>. In the context of this study, the development of a Pre-Laboratory Schema exemplifies the application of pedagogical content knowledge, where biology teachers facilitate cognitive preparation and scientific inquiry by guiding students through structured pre-laboratory tasks.

In Domain 4 – Curriculum and Planning, it is also prominently reflected in this study. This domain emphasizes the importance of preparing developmentally appropriate, responsive, and well-sequenced learning plans. The Pre-Laboratory Schema is a direct response to this expectation, as it is thoughtfully designed to help students engage with key elements of the laboratory experience, including experiment titles, objectives, materials, procedural steps, and conceptual pre-lab questions. In time-constrained settings like Senior High School Biology laboratories, such a tool enables teachers to maximize instructional time while ensuring that students are mentally and procedurally prepared, promoting greater efficiency and deeper learning (DepEd, 2017)<sup>[13]</sup>.

Furthermore, Domain 2-Learning Environment is addressed by fostering a safe, collaborative, and well-managed laboratory experience. By requiring students to review safety protocols and visualize procedural steps ahead of time, the schema helps prevent common errors, encourages accountability, and minimizes risks during actual experiments (DepEd, 2017)<sup>[13]</sup>. It also promotes student independence and confidence, thereby contributing to a more positive and learner-centered environment.

The study also embodies the spirit of Domain 6 – Personal Growth and Professional Development, which calls on

teachers to continually improve their practices through reflection, innovation, and responsiveness to student needs. The researcher, as a teacher-practitioner, demonstrates this domain by identifying a recurring instructional challenge, students' lack of lab preparedness, and proactively developing a context-sensitive solution rooted in theory and best practices (DepEd, 2017)<sup>[13]</sup>. By designing, testing, and refining the Pre-Laboratory Schema through a design-based approach, the teacher exemplifies the adaptive, research-informed mindset advocated by the PPST.

Through its alignment with these domains, the study not only fulfills the professional teaching standards set by DepEd Order No. 42 but also contributes to the broader goal of elevating science education in the Senior High School context. The Pre-Laboratory Schema thus becomes more than just a tool; it is a practical manifestation of the PPST's vision of competent, reflective, and innovative teaching that nurtures scientific literacy, procedural fluency, and inquiry-driven learning among students.

## Research Methodology

### Research Design

This study employed a mixed-methods research design to examine the effectiveness of the Pre-Laboratory Schema in enhancing student preparedness and performance during Senior High School Biology laboratory sessions. Two groups of Grade 11 STEM students from Holy Name University were involved: an experimental group, which utilized the Pre-Laboratory Schema as a preparatory activity prior to laboratory work, and a control group, which followed conventional laboratory preparation methods. Data were gathered through focus group discussions, classroom observations, and performance-based assessments to capture both quantitative and qualitative insights into students' development of science process skills, as well as the perceptions and experiences of both learners and teachers. To ensure the systematic development and refinement of the instructional innovation, the study was anchored in the Educational Design Research (EDR) framework, which guided the iterative processes of designing, validating, and improving the Pre-Laboratory Schema.

### Participants

The participants in this study were Grade 11 STEM-Medical strand students enrolled in the Integrated Basic Education Department (IBED) at Holy Name University (HNU) for the Academic Year 2025–2026. The STEM-Medical strand consisted of six sections. From these six sections, two were purposively selected to participate in the experimental phase of the study, based on the schedule and availability of the assigned Biology teacher, as well as the comparability of class sizes. The total number of student participants was approximately 75.

For the purpose of experimental comparison, the two participating sections were grouped according to the official sectioning designated by the department. One section was assigned as the experimental group, which utilized the Pre-Laboratory Schema as a preparatory tool before laboratory sessions. The other section served as the control group, following traditional laboratory preparation methods without the schema. To ensure fairness and minimize selection bias, the assignment of which section became the experimental or control group was determined through random sampling by drawing lots. In this process, the names of the two selected

sections were written on slips of paper, placed in a container, and randomly drawn by the researcher in the presence of the subject teacher. The first section drawn was designated as the experimental group, while the second was automatically assigned as the control group. This method of randomization helped ensure impartiality and strengthened the internal validity of the study.

For the pilot test, which was a requirement under Phase 2 of the Educational Design Research (EDR) Framework, the teacher had already administered the Pre-Laboratory Schema to address recurring problems observed during the limited 1-hour laboratory period immediately. The teacher introduced the schema and its procedures during subject orientation, ensuring that students understood its purpose and format. Two laboratory experiments were conducted using the teacher-made Pre-Laboratory Schema, serving as a pilot test that informed subsequent revisions and improvements to the schema, and a total of three laboratory experiments were conducted for actual data gathering.

A total of seven science teachers participated in the expert validation of the Pre-Laboratory Schema. These teachers were drawn from across the Integrated Basic Education Department (IBED), representing a range of grade levels and science specializations, including Biology, Chemistry, and Physics. Their participation ensured that the tool was evaluated through multiple scientific and pedagogical lenses. All validators held relevant degrees in science education or related fields, and the majority had more than five years of experience in teaching. Their familiarity with both junior and senior high science curricula made them particularly qualified to assess the clarity, accuracy, and educational relevance of the Pre-Laboratory Schema. During the validation process, these teachers evaluated the schema using a standardized rubric focusing on content validity, degree of relevance, clarity, acceptability, and accuracy. Their feedback served as the basis for refining the schema's format, instructions, and alignment with current science teaching practices within the IBED context.

Additionally, a semi-structured focus group discussion (FGD) was conducted among selected top-performing students from the experimental group after the intervention period. Six students were purposively chosen based on their active engagement, consistent laboratory performance, and demonstrated understanding of the Pre-Laboratory Schema. The FGD aimed to gather qualitative insights into their perceptions, experiences, and suggestions regarding the use of the schema as a preparatory and instructional tool.

Participants were informed of their right to withdraw from the study at any time without penalty or academic disadvantage. Withdrawal was permitted if students felt uncomfortable with the procedures, experienced stress or time constraints, or simply chose not to continue. In such cases, all data previously collected from the participant were excluded from analysis to protect their autonomy and privacy.

### **Instruments of the Study**

The instruments used in this study were designed to align with each phase of the Educational Design Research (EDR) framework and to support the systematic development and evaluation of the Pre-Laboratory Schema.

During the analysis and exploration phase, the teacher identified recurring issues in the conduct of Biology laboratory sessions, particularly the constraints posed by the

limited 1-hour period and the lack of student preparedness. To better understand these challenges within the actual classroom context, the teacher implemented preliminary trials of the Pre-Laboratory Schema during scheduled laboratory sessions. These initial applications served as a diagnostic tool, allowing the teacher to observe how students interacted with the schema, the difficulties encountered, and the extent to which it addressed the observed problems of time management and procedural clarity.

Following this, in the design and construction phase, the preliminary version of the Pre-Laboratory Schema was revised and improved based on the insights gathered during Phase 1. The editing of the prototype focused on enhancing its clarity, structure, and alignment with laboratory learning objectives to ensure it functioned as an effective preparatory tool. After these refinements, the revised schema was systematically developed into a more structured format and subjected to content validation by a panel of experts in science education. This process ensured that the tool was pedagogically sound, contextually appropriate, and aligned with curriculum standards before advancing to pilot testing and broader implementation. The experts evaluated the schema using a Likert-scale validation instrument focusing on its content validity, relevance, clarity, acceptability, and accuracy. Additionally, a pilot test was conducted to further refine the schema by assessing its clarity, usability, and instructional potential in a real classroom setting. Insights gained from this process provided the basis for revisions, ensuring that the final version of the Pre-Laboratory Schema was both pedagogically sound and contextually appropriate. In the evaluation phase, the effectiveness of the Pre-Laboratory Schema was quantitatively measured through a pre-test and post-test using the adopted Test of Integrated Science Process Skills (TISPS) developed by Okey, Wise, and Burns (1982). These tests were administered to both the experimental and control groups to compare students' acquisition of science process skills before and after the intervention. The results provided direct evidence of the schema's impact on students' laboratory performance and skill development.

To complement the quantitative findings, a follow-up focus group discussion with selected students was conducted using researcher-made interviews. This qualitative feedback captured students' perceptions, insights, and experiences with the Pre-Laboratory Schema, offering a deeper understanding of its effectiveness and informing further refinement for broader educational application.

The participants devote approximately one hour per week during regular laboratory sessions to complete tasks related to the study. Preparation of the Pre-Laboratory Schema typically requires one to two hours outside class time, depending on the complexity of the experiment. The pre-test and post-test each take about 45 minutes to administer, while the focus group discussion with selected participants lasts around 60–90 minutes. Overall, participation is integrated into their normal course requirements and does not require additional class periods beyond their existing schedule.

### **Procedure**

The data gathering procedure of this study followed the four phases of the Educational Design Research (EDR) framework: analysis and exploration, design and

construction, evaluation and reflection, and implementation and dissemination. This iterative process ensured that the development and implementation of the Pre-Laboratory Schema were systematically validated and grounded in context.

In the first phase, analysis and exploration, the researcher, who was also a biology teacher, had already identified persistent challenges in conducting laboratory sessions, particularly the limitation of the 1-hour schedule and the lack of student preparedness. To better understand these concerns in the actual classroom context, preliminary implementations of the Pre-Laboratory Schema were carried out during laboratory periods. These initial trials served as diagnostic tools, allowing the researcher to observe student engagement, identify challenges, and determine the extent to which the schema addressed recurring issues in time management, comprehension of procedures, and overall laboratory efficiency.

The second phase, design and construction, involved revising and refining the Pre-Laboratory Schema based on insights obtained in Phase 1. The revisions focused on improving structural organization, visual illustrations, and procedural clarity to strengthen its role as a preparatory tool. Following this, formal approval was secured from the IBED administration, specifically the Office of the Principal, to conduct the study. Informed consent forms were also distributed to students and their parents or guardians to ensure ethical compliance, as the participants were minors. After securing the necessary permissions, the revised schema was subjected to validation by a panel of science education experts using a Likert-scale instrument.

In the third phase, evaluation and reflection, the Pre-Laboratory Schema was revised again based on feedback from both expert validators and pilot test participants. Once finalized, the mixed-method design implementation commenced. A pre-test measuring science process skills was administered to both the experimental and control groups to establish baseline competencies. The experimental group employed the Pre-Laboratory Schema as part of their preparation, while the control group continued with conventional methods. After the intervention period, both groups took a post-test to measure gains in science process skills. To enrich the findings with student perspectives, a researcher-made semi-structured focus group discussion was conducted with purposively selected students from the experimental group. This qualitative component provided insights into their experiences, perceptions, and suggestions regarding the Pre-Laboratory Schema. All data were encoded, securely stored, and anonymized to maintain confidentiality. The interpreted results, combined with qualitative feedback, served as the basis for refining the instructional tool for broader application.

The fourth and final phase, implementation and dissemination, involved the full integration of the Pre-Laboratory Schema into laboratory sessions in the Grade 11 STEM strand, thereby demonstrating its applicability and potential as a sustainable instructional tool.

### **Ethical Considerations**

Prior to the commencement of the study, the researcher obtained formal approval from the Office of the Principal of Holy Name University-Integrated Basic Education Department to conduct the research involving incoming Grade 11 STEM-Medical students enrolled in General

Biology 1 for Academic Year 2025–2026. These students, who came from various junior high schools, were presumed to have had minimal to no prior Senior High School laboratory experience, making them appropriate participants for evaluating the effectiveness of the Pre-Laboratory Schema as a preparatory tool.

The study's objectives, scope, procedures, and data collection methods were clearly explained to the students and their respective parents or guardians. Participation in the study was entirely voluntary. To ensure informed participation, informed consent forms were obtained from both students and their parents or legal guardians prior to the collection of any data. The researcher upheld strict confidentiality and anonymity throughout the process. All data collected, whether survey responses, rubric scores, or observation records, were used exclusively for academic research purposes and reported only in aggregate form, without identifying individual participants.

Moreover, the study adhered to the highest ethical standards. Participants were informed that they had the right to withdraw from the study at any stage without penalty. The researcher also ensured that no psychological, academic, or physical harm was inflicted upon any participant. All protocols and ethical guidelines established by the Department of Education (DepEd), as well as the internal review policies of Holy Name University, were strictly adhered to throughout the research process.

This study poses minimal risk to participants, as all activities are aligned with their regular academic requirements in General Biology 1. The preparation of the Pre-Laboratory Schema and participation in laboratory experiments are consistent with existing curricular expectations. Possible minor risks include academic stress due to the additional preparation time required for completing the schema and discomfort during focus group discussions, as students may feel hesitant to share their opinions. These risks are mitigated by ensuring that participation in interviews or focus groups is voluntary, that students may withdraw at any point without penalty, and that their performance in the research activities does not affect their academic grades.

The study offers several direct benefits to the participants. Students who use the Pre-Laboratory Schema are expected to gain improved laboratory preparedness, enhanced comprehension of experimental procedures, and stronger development of science process skills. The tool provides them with structured guidance to foster confidence, engagement, and independence during laboratory work. Teachers also benefit from gaining access to a validated instructional tool that saves time for higher-order discussions and inquiries during laboratory sessions. On a broader level, the findings of this study may contribute to curriculum innovation in Senior High School Biology, offering a replicable model that can improve laboratory instruction in similar educational contexts.

In addition, the researcher acknowledged the use of Artificial Intelligence (AI) tools, such as ChatGPT by OpenAI, for academic writing support, grammar refinement, and content organization in drafting the research manuscript. However, all conceptual, analytical, and interpretative components of the study, including the design, data analysis, and conclusions, remained the original work of the researcher. The use of AI was limited to non-decision-making roles and did not replace scholarly judgment, ethical

considerations, or the researcher's accountability for the study's integrity.

**Pre-Laboratory Schema.** A student-completed worksheet that includes the name, grade and section, date, score, experiment title and number, and a drawn or illustrated step-by-step procedure of the experiment. It is completed prior to the laboratory session and serves as a visual instructional guide to help students mentally rehearse, internalize, and understand the experiment, thereby improving preparedness, procedural accuracy, and science process skills.

**Science Process Skills (SPS).** The cognitive and procedural abilities essential for scientific inquiry include both basic skills (e.g., observing, classifying, measuring) and integrated skills (e.g., hypothesizing, identifying variables, interpreting data, drawing conclusions). SPS are measured in this study using a validated observational checklist during laboratory sessions and pre-/post-test evaluations.

## Results

This chapter presents the quantitative and qualitative findings of the study through an integrated research approach. Quantitative data are organized and analyzed using descriptive and inferential statistics to highlight significant patterns related to students' performance and preparedness in Biology laboratory activities. These numerical results are supported by textual interpretations that link the findings to the objectives and hypotheses of the study. Complementing the statistical data, qualitative evidence from focus group discussions and open-ended responses provides deeper insight into students' experiences and perceptions, thereby contextualizing the measured outcomes of the intervention.

### Key Components of an Effective Pre-Laboratory Schema for Pre-Laboratory Experiments in Biology Classes

Prior to the development of the Pre-Laboratory Schema, Biology laboratory instruction in the Senior High School setting was characterized by persistent time-related and procedural challenges. In accordance with existing curricular guidelines, laboratory sessions were limited to approximately one hour per week. Within this restricted timeframe, teachers were required to conduct pre-laboratory briefings, oversee experimental procedures, and facilitate post-laboratory discussions. In practice, this structure constrained opportunities for meaningful scientific inquiry and limited students' engagement in higher-order laboratory tasks.

Narrative accounts revealed that a substantial portion of laboratory time was spent on preparatory activities, including explaining procedures, distributing materials, and clarifying instructions. Students commonly entered the laboratory without prior exposure to the experiment, resulting in frequent procedural questions and dependence on teacher guidance. Consequently, the time allotted for actual experimentation was often insufficient, leading to hurried execution of procedures, incomplete data collection, and minimal reflection on results. Post-laboratory discussions were frequently abbreviated or omitted due to time constraints.

Observations further indicated that students demonstrated low levels of initiative and active engagement during laboratory sessions. The absence of pre-laboratory preparation limited their ability to formulate hypotheses,

identify variables, and anticipate potential sources of error. As a result, laboratory activities tended to emphasize procedural completion rather than inquiry-based learning, thereby restricting the development of essential Science Process Skills such as observation, prediction, and analysis.

In response to these recurring challenges, the teacher-researcher conceptualized and implemented the Pre-Laboratory Schema as an instructional intervention. Designed as a structured preparatory tool, the schema required students to review, visualize, and diagram experimental procedures prior to laboratory sessions. This approach aimed to transfer initial cognitive processing outside the limited laboratory period, allowing students to enter the laboratory with a clearer understanding of the experimental flow and objectives.

Initial implementation of the Pre-Laboratory Schema yielded observable improvements in laboratory instruction and student behavior. Students appeared more prepared and confident, pre-laboratory briefings became more focused, and a greater portion of class time was devoted to experimentation and analysis. Additionally, students demonstrated increased autonomy, improved procedural accuracy, and a stronger ability to connect empirical observations with underlying biological concepts.

Through this classroom-based experience, the teacher-researcher identified the key components that define an effective laboratory schema: (1) visual representation of procedures for better comprehension and recall; (2) structured sequencing of steps to promote procedural accuracy; (3) integration of safety reminders to ensure proper laboratory conduct; (4) space for reflection to reinforce conceptual understanding; and (5) alignment with Science Process Skills, encouraging students to think critically before, during, and after the experiment.

The first key component is the visual representation of experimental procedures, which plays a critical role in enhancing student comprehension and recall. By requiring students to draw, diagram, or visually map out the experimental setup and flow of procedures, the schema supports dual coding of information, combining verbal and visual processing. This visual engagement enables students to better anticipate the sequence of actions in the laboratory, recognize apparatus arrangements, and mentally rehearse procedures before execution. As a result, students enter the laboratory with a clearer mental model of the experiment, reducing confusion and the need for repeated teacher explanations.

Closely related to visualization is the structured sequencing of steps, which ensures procedural accuracy and efficient time management. The schema organizes experimental tasks into logical, sequential stages, prompting students to follow a systematic approach rather than performing steps in a fragmented or trial-and-error manner. This structure minimizes procedural errors, promotes consistency across student groups, and supports learners in completing experiments within the limited laboratory period. Sequencing also reinforces the scientific method by emphasizing order, causality, and logical progression in experimental work.

Another essential component of the schema is the integration of laboratory safety reminders. Safety considerations are embedded directly within the pre-laboratory activity rather than treated as a separate or one-time orientation. By encountering safety reminders

alongside procedural steps, students are encouraged to associate correct techniques with responsible laboratory behavior. This integration promotes awareness of potential hazards, proper handling of materials, and adherence to laboratory rules, thereby fostering a culture of safety and accountability even before students physically enter the laboratory environment.

The schema also intentionally provides space for reflection, which serves to strengthen conceptual understanding and promote metacognitive engagement. Reflection prompts encourage students to consider the purpose of the experiment, expected outcomes, potential sources of error, and the connection between theory and practice. This component transforms the pre-laboratory activity from a purely procedural task into a cognitive exercise that prepares students to interpret results meaningfully. By reflecting before the experiment, students are better equipped to evaluate their observations during and after the laboratory session.

Central to the design of the Pre-Laboratory Schema is its explicit alignment with Science Process Skills (SPS). Each component encourages students to engage in essential scientific practices such as observing, predicting, hypothesizing, identifying variables, and analyzing potential outcomes. Rather than passively following instructions, students are guided to think critically before, during, and after experimentation. This alignment ensures that laboratory activities move beyond task completion toward inquiry-based learning and skill development.

The development of the Pre-Laboratory Schema thus emerged as a contextualized instructional response to the realities of Philippine Senior High School laboratory instruction. Grounded in authentic classroom observations and teacher reflection, the schema represents a practical and theory-informed intervention designed to maximize learning within a constrained one-hour laboratory period. It promotes student independence, efficient use of time, and deeper engagement with scientific processes.

However, these improvements cannot rely solely on the

teacher-researcher’s personal observations, as such accounts, while valuable, are not sufficient to establish the effectiveness of an instructional intervention. This is precisely why multiple data sources and multiple laboratory sessions are necessary. Conducting the Pre-Laboratory Schema across five laboratory sessions ensures that the observed improvements are consistent, replicable, and not the result of chance or isolated circumstances. In other words, repeated implementation strengthens the credibility of the findings and underscores the necessity of conducting laboratory sessions systematically rather than basing conclusions on a single experience.

Furthermore, expert validation provides external confirmation that the schema meets high standards of content validity, relevance, clarity, acceptability, and accuracy. This step ensures that the intervention is pedagogically sound and aligned with established principles in laboratory instruction. Focus group discussions (FGDs) with students offer another layer of evidence, confirming that learners themselves perceive the schema as helpful in improving their confidence, reducing confusion, and enhancing their understanding before entering the laboratory. Finally, pre-test and post-test results provide quantitative proof that students’ conceptual understanding and procedural knowledge improve after the implementation of the schema.

By integrating teacher observations with repeated laboratory trials, expert judgments, student feedback, and measurable learning gains, the study demonstrates that the Pre-Laboratory Schema could be an effective tool for improving laboratory preparedness. This triangulation of evidence underscores the importance of conducting structured laboratory sessions and confirms that reliable conclusions can only be drawn when multiple forms of data support the outcomes, rather than relying solely on observation. That is why, in the succeeding pages, the results and discussion are presented to systematically illustrate how these different sources of evidence establish the effectiveness of the intervention.

**Table 1:** Content Validity

	<b>Indicator</b>	<b>Weighted Mean</b>	<b>Interpretation</b>
1	Includes all essential parts of a laboratory experiment (e.g., experiment title, list of required materials, and the detailed procedure)	3.43	Strongly Evident
2	Promotes the development of science process skills (e.g., observing, measuring, classifying, inferring, predicting, experimenting, and communicating)	4.00	Strongly Evident
3	Balances procedural, conceptual, and safety aspects	3.00	Strongly Evident
4	Content is appropriate for the Grade 11 level	3.86	Strongly Evident
	<b>Overall Weighted Mean</b>	3.57	Strongly Evident

Table 1 presents content validity evaluates how well the material represents the essential components and intended scientific constructs of a laboratory activity. Results show that all indicators under this category were rated Strongly Evident, with weighted means ranging from 3.00 to 4.00.

The highest rating (WM = 4.00) was given to the indicator “promotes the development of science process skills,” showing unanimous agreement that the schema effectively supports core scientific abilities such as observation, prediction, inference, and experimentation. This finding is consistent with Padilla (1990) and Germann and Aram (1996)<sup>[21]</sup>, who highlight that structured and well-sequenced materials significantly enhance students’ science process skills. The high rating for fostering science process skills

supports the work of Padilla (1990) and Germann & Aram (1996)<sup>[21]</sup>, who argue that explicit scaffolds significantly strengthen students’ observing, hypothesizing, experimenting, and inferring skills. Moreover, the expert consensus reflects the expectations of DepEd’s K–12 Science Curriculum (2013)<sup>[13]</sup>, which emphasizes scientific inquiry, safety, and procedural fluency.

The lowest weighted mean of 3.00 for balance between procedural, conceptual, and safety aspects reflects strong integration of scientific dimensions necessary for inquiry-based laboratory instruction (Domin, 1999; Lazonder & Harmsen, 2016)<sup>[16, 27]</sup>. Additionally, the appropriateness of content for Grade 11 students earned a weighted mean of 3.86, supporting the developmental suitability of the schema

in line with the K–12 Science Curriculum and DepEd standards (DepEd, 2013) [13].

The Pre-Laboratory Schema obtained an overall weighted mean of 3.57, interpreted as Strongly Evident, indicating that experts consistently agreed that the material meets the essential standards of a valid laboratory instructional tool. The high ratings across the four indicators suggest that the schema effectively integrates the essential components of an experiment, promotes relevant science process skills, and aligns with the developmental level of Grade 11 learners. This supports McFarlane (2019) [30], who emphasizes that strong content validity reflects the tool’s alignment with instructional objectives and the needs of learners. The result also resonates with the work of Zamani and Ahmadi (2014) [54], who explain that expert validation ensures instructional materials are accurate, appropriate, and pedagogically sound.

Overall, the strong content validity rating confirms that the Pre-Laboratory Schema is instructionally robust, developmentally appropriate, and aligned with established frameworks in science education. This supports its use as an effective scaffold for enhancing students’ laboratory experiences.

**Table 2:** Degree of Relevance

	Indicator	Weighted Mean	Interpretation
1	Fits with actual lab activities and classroom implementation	3.86	Strongly Evident
2	Supports instructional goals and student engagement	3.86	Strongly Evident
3	Content and structure applicable to real lab settings	3.86	Strongly Evident
4	Aligns with STEM objectives for scientific investigation	3.71	Strongly Evident
5	Promotes student readiness and independence before the lab	4.00	Strongly Evident
	<b>Overall Weighted Mean</b>	3.86	Strongly Evident

Table 2 presents the Degree of Relevance pertains to the material’s usefulness, authenticity, and alignment with instructional goals. Weighted means ranged from 3.71 to 4.00, interpreted as Strongly Evident, indicating highly favorable evaluations from expert validators.

Student readiness and independence, which achieved the highest weighted mean (4.00), suggest that the schema effectively prepares students even before they enter the laboratory. This aligns with the retrieval- and schema-based learning work of Chen *et al.* (2023) and Fiorella & Mayer (2016) [20], which suggests that structured pre-lesson activities enhance both procedural fluency and conceptual understanding. The schema’s strong ability to promote readiness and independence echoes findings from retrieval-based and schema-based learning studies (Fiorella & Mayer, 2016 [20]; Chen *et al.*, 2023), which demonstrate that preparatory activities enhance conceptual retention and procedural efficiency. By prompting students to think about procedures, variables, and expected outcomes before entering the lab, your tool aligns with these established cognitive benefits.

The compatibility of the schema with actual laboratory conditions, with the lowest weighted mean of 3.71, demonstrates that it is feasible to implement within typical school laboratory environments, echoing Abrahams and Millar’s (2008) [1] assertion that practical work must be

closely connected to real laboratory constraints. Furthermore, the strong alignment with authentic laboratory conditions aligns with the work of Abrahams & Millar (2008) [1], who argue that effective laboratory instruction must reflect real constraints and genuine scientific inquiry. Because the schema fits within a one-hour DepEd laboratory period, it is both realistic and instructionally beneficial.

The experts rated the degree of relevance of the Pre-Laboratory Schema with an overall weighted mean of 3.86, interpreted as Strongly Evident. All indicators likewise obtained ratings within the “Strongly Evident” range, with scores from 3.71 to 4.00. The highest rating was for Item 5, “Promotes student readiness and independence before the lab” (WM = 4.00), while Item 4 received the lowest but still high rating (WM = 3.71).

The consistently high ratings indicate that the Pre-Laboratory Schema is highly relevant to senior high school laboratory instruction. First, experts found that the schema aligns with actual laboratory activities and classroom implementation, supporting Abrahams and Millar’s (2008) [1] argument that laboratory tools must directly support authentic scientific tasks to be instructionally meaningful. By structuring tasks in advance, the schema mirrors the recommended shift from passive, teacher-driven lab work toward more informed and student-centered engagement.

Overall, the high degree of relevance suggests that the Pre-Laboratory Schema is a well-aligned, contextually appropriate, and pedagogically strong tool for improving STEM laboratory preparation. The results affirm that the Schema addresses real instructional needs, fosters independent learning, and supports both curriculum standards and research-based strategies for effective science laboratory work.

**Table 3:** Degree of Clarity

	Indicator	Weighted Mean	Interpretation
1	Instructions are clearly written and easy to follow	3.71	Strongly Evident
2	The layout is organized and student-friendly	3.57	Strongly Evident
3	Terminology is age- and level-appropriate	3.86	Strongly Evident
4	Sections are distinct and non-confusing	3.86	Strongly Evident
5	Expectations are understandable without further clarification	3.86	Strongly Evident
	<b>Overall Weighted Mean</b>	3.77	Strongly Evident

Table 3 presents the Degree of Clarity of the Pre-Laboratory Schema obtained an overall weighted mean of 3.77, interpreted as Strongly Evident. All five indicators also received “Strongly Evident” ratings, ranging from 3.57 to 3.86.

The highest ratings were obtained by the indicators related to terminology being age- and level-appropriate, sections being distinct and non-confusing, and expectations being understandable without further clarification (WM = 3.86), all of which were interpreted as Strongly Evident. These findings align with Hofstein and Lunetta (2004) [25], who emphasize that clear, developmentally appropriate laboratory materials enhance students’ conceptual preparation and meaningful engagement in laboratory activities. When learners can easily interpret terminology

and procedural sections, their readiness and confidence improve, leading to more effective and safer laboratory implementation. Moreover, the clarity of expectations supports generative learning processes, as noted by Fiorella and Mayer (2016) [20] and Schwaborn *et al.* (2011), allowing students to focus cognitive resources on deeper processing such as planning, predicting outcomes, and summarizing procedures.

The lowest weighted mean, although still interpreted as "Strongly Evident," was recorded for the indicator of the layout being organized and student-friendly (WM = 3.57). Despite being the lowest among the indicators, this rating remains favorable and is consistent with Ainsworth's (2006) [2] DeFT framework, which highlights the importance of well-designed visual representations in supporting comprehension. An organized layout that visually guides learners promotes smoother navigation, reduces confusion, and supports generative processing, which is essential during pre-laboratory preparation.

Overall, Table 3 presents the Degree of Clarity of the Pre-Laboratory Schema, which obtained an overall weighted mean of 3.77, interpreted as Strongly Evident. All five indicators received Strongly Evident ratings, with weighted means ranging from 3.57 to 3.86, indicating a consistently high level of clarity across all evaluated aspects. The strong clarity ratings demonstrate that the Pre-Laboratory Schema effectively offers a well-structured, readable, and cognitively accessible tool for pre-lab preparation. Its clear language, organized sections, and student-friendly layout allow learners to enter laboratory sessions with confidence and comprehension, directly supporting the goals of the DepEd SHS Science Curriculum (2013) [13] to develop scientifically literate and inquiry-driven learners.

**Table 4: Degree of Acceptability**

	Indicator	Weighted Mean	Interpretation
1	Conforms to best instructional practices	3.86	Strongly Evident
2	Format and content suitable for science classes	3.86	Strongly Evident
3	Ethical, safe, and inclusive in design	3.86	Strongly Evident
4	The workload is reasonable for senior high school students	3.86	Strongly Evident
5	Encourages active student participation and responsibility	4.00	Strongly Evident
	<b>Overall Weighted Mean</b>	<b>3.89</b>	<b>Strongly Evident</b>

Table 4 shows the Degree of Acceptability of the Pre-Laboratory Schema as evaluated by experts. The highest rating was obtained by the indicator encouraging active student participation and responsibility (WM = 4.00), interpreted as Strongly Evident. This result indicates that experts strongly agree that the Pre-Laboratory Schema effectively motivates learners to take ownership of their laboratory learning. The process of reading, comprehending, and illustrating procedures prior to the actual experiment aligns with generative learning research (Fiorella & Mayer, 2016; Ainsworth, Prain, & Tytler, 2011) [20, 3], which emphasizes that active engagement strategies enhance conceptual understanding and scientific reasoning. This finding is further supported by inquiry-based learning studies (Lazonder & Harmsen, 2016) [27], highlighting the role of preparatory scaffolds in enabling students to

participate actively and meaningfully in scientific investigations.

The lowest weighted means, although still interpreted as Strongly Evident (WM = 3.86), were recorded for the indicators related to conformance to best instructional practices, suitability of format and content for science classes, ethical and inclusive design, and workload appropriateness for senior high school students. These results demonstrate that the Schema aligns well with research-based instructional strategies. Hofstein and Lunetta (2004) [25] emphasize that effective laboratory instruction requires structured preparation to promote meaningful engagement and reduce procedural confusion. Moreover, the ethical, safe, and inclusive design of the Schema is consistent with the recommendations of Talisayon (2012) [49] and DepEd safety policies, which stress the importance of clear and accessible pre-laboratory instructions to ensure safe and equitable participation for all learners. The appropriateness of the workload further reflects Sweller's (1988, 1994) Cognitive Load Theory, as the Schema organizes complex laboratory procedures into manageable steps, thereby preventing cognitive overload and supporting procedural fluency (Chen, Lin, & Huang, 2023) [10].

Overall, Table 4 shows that the Pre-Laboratory Schema obtained an overall weighted mean of 3.89, interpreted as Strongly Evident. All indicators received high acceptability ratings, with weighted means ranging from 3.86 to 4.00, indicating strong expert agreement regarding the instructional soundness, safety, inclusivity, workload appropriateness, and engagement potential of the tool.

The strong acceptability ratings indicate that the Pre-Laboratory Schema is a highly acceptable instructional support tool for senior high school science classes. Its alignment with research-based pedagogical practices, suitability for classroom use, ethical and inclusive design, manageable workload, and strong capacity to promote student engagement affirm its instructional value. Overall, the Schema supports inquiry-oriented and learner-centered laboratory instruction, reinforcing the goals of quality science education and meaningful student participation.

**Table 5: Degree of Accuracy**

	Indicator	Weighted Mean	Interpretation
1	Experiment steps lead to valid scientific results	3.14	Evident
2	Uses correct scientific terms and processes	3.29	Strongly Evident
3	Procedural illustrations reflect real lab practices	3.43	Strongly Evident
4	Accurately incorporates safety and measurement standards	2.86	Evident
5	Avoids conceptual and factual errors in scientific content	2.86	Evident
	<b>Overall Weighted Mean</b>	<b>3.12</b>	<b>Evident</b>

Table 5 shows the Degree of Accuracy of students' procedural illustrations in terms of scientific correctness, safety, and conceptual soundness. The table obtained an overall weighted mean of 3.12, interpreted as Evident, indicating that students generally demonstrated an acceptable level of accuracy in representing laboratory procedures, although some aspects still require improvement.

The highest ratings were recorded for indicators related to procedural illustrations reflecting real laboratory practices (WM = 3.43, Strongly Evident) and the use of correct scientific terms and processes (WM = 3.29, Strongly Evident). These results suggest that students were able to accurately depict laboratory sequences and employ appropriate scientific language in their illustrations. This finding is consistent with Ainsworth (2006)<sup>[2]</sup> and Fan and Lee (2022)<sup>[17]</sup>, who emphasize that student-generated representations support conceptual precision and metacognitive awareness when learners actively organize and externalize scientific information. Likewise, Quillin and Thomas (2015)<sup>[3]</sup> note that drawing activities promote model-based reasoning, which may explain why students perform better in representing procedural flow and laboratory practices.

Moderate performance was observed in the indicator assessing whether experiment steps lead to valid scientific results (WM = 3.14, Evident). This suggests that while students could illustrate procedures, some had difficulty fully conceptualizing how each step contributes to experimental validity. Abrahams and Millar (2008)<sup>[1]</sup> and Delen and Krajcik (2017)<sup>[15]</sup> explain that learners often require explicit scaffolding to understand the functional purpose of procedural steps, particularly in inquiry-based laboratory tasks.

The lowest ratings, although still interpreted as Evident, were found in indicators related to accurately incorporating safety and measurement standards and avoiding conceptual and factual errors in scientific content (both WM = 2.86). These findings align with Hofstein and Lunetta (2004)<sup>[25]</sup> and Domin (1999)<sup>[16]</sup>, who report that students commonly struggle with laboratory safety conventions and precise measurement unless these elements are repeatedly emphasized through guided instruction. From a cognitive perspective, Sweller's (1988)<sup>[46]</sup> Cognitive Load Theory and subsequent work by Leutner *et al.* (2009)<sup>[28]</sup> suggest that tasks requiring simultaneous drawing, reasoning, and recall may overload novice learners, increasing the likelihood of minor inaccuracies.

Overall, the results indicate that while students demonstrate strengths in visualizing laboratory procedures and using appropriate scientific terminology, persistent challenges remain in safety-related details and conceptual accuracy. These findings point to the need for targeted instructional supports, such as generative drawing activities (Fiorella & Mayer, 2016)<sup>[20]</sup>, retrieval-based drawing (Blunt & Karpicke, 2014)<sup>[9]</sup>, and guided inquiry worksheets (Rahmi *et al.*, 2018)<sup>[42]</sup>, to further enhance the precision and scientific correctness of students' procedural representations. Despite these areas for improvement, the results confirm that the Pre-Laboratory Schema provides a generally accurate and pedagogically sound foundation for supporting students' laboratory preparation in Senior High School science classes.

### Expert Validators' Qualitative Comments on the Pre-Laboratory Schema

The following paragraphs present that, beyond the quantitative validation ratings, the expert validators provided qualitative comments that offered deeper insight into the strengths and areas requiring refinement in the Pre-Laboratory Schema. A recurring theme across multiple participants was the need to incorporate an explicit section

on safety guidelines and hazard identification. Participants 1 and 3 emphasized that safety notes are indispensable components of laboratory preparation, aligning with Domin's (1999)<sup>[16]</sup> assertion that effective laboratory instruction prioritizes both procedural fluency and safety management. This recommendation also reflects Hofstein and Lunetta's (2004)<sup>[25]</sup> position that safety awareness is foundational to meaningful laboratory engagement, as it enables students to participate confidently and responsibly in hands-on investigations.

Another major theme centered on the completeness and accuracy of procedural components, specifically the listing of materials and equipment. Participants 2 and 5 noted that missing or incomplete equipment lists could impede students' ability to anticipate laboratory requirements and visualize the experimental flow. This feedback is consistent with Ainsworth's (2006)<sup>[2]</sup> DeFT framework, which emphasizes that clarity and completeness of representations are crucial for supporting learners' cognitive processing. Similarly, Mayer's (2009, 2014) Cognitive Theory of Multimedia Learning suggests that students are more likely to process laboratory procedures effectively when textual, visual, and procedural elements are well-integrated and complete.

Several validators also highlighted the need for improved documentation and structural clarity, including the inclusion of the subject, school year, IBED level, group members, and proper alignment of template fields. These recommendations align with Zamani and Ahmadi's (2014)<sup>[54]</sup> guidelines for expert panel validation, which stress the importance of structural coherence and user-friendly formatting in educational tools. Clear organization and well-defined sections also support cognitive load reduction (Sweller, 1988, 1994, 2012), enabling students to focus on essential scientific concepts rather than navigate structural ambiguities.

Despite these suggestions for improvement, validators also acknowledged the schema's existing strengths. Participants 1 and 4 affirmed that the schema was well-prepared, comprehensively organized, and pedagogically helpful in guiding learners through pre-laboratory preparation. Their observation resonates with the growing body of literature supporting learner-generated representations, such as diagrams and schema-based visuals, as tools that enhance conceptual understanding, reasoning, and procedural accuracy (Ainsworth *et al.*, 2011; Fan & Lee, 2022; Quillin & Thomas, 2015)<sup>[3, 17, 41]</sup>. The schema's emphasis on visualization also aligns with the generative learning principles articulated by Fiorella and Mayer (2016)<sup>[20]</sup>, wherein students who actively generate and organize information prior to laboratory work demonstrate improved comprehension and engagement.

Moreover, the validators' emphasis on strengthening the schema's clarity and completeness reflects findings by Chen *et al.* (2023), who reported that schema-based supports significantly enhance procedural fluency and scientific reasoning when the instructional materials are accurate, clear, and developmentally appropriate. The strong qualitative endorsement of the schema's instructional value also aligns with evidence from Wu and Rau (2019)<sup>[53]</sup>, who found that well-designed drawing-based modeling tasks promote higher-quality cognitive processing, especially when supported by structured templates.

Overall, the qualitative insights provided by the expert validators reinforced the schema's high content validity, while also guiding targeted revisions to further strengthen safety clarity, procedural completeness, and structural organization. These refinements echo the iterative nature of the Educational Design Research framework (McKenney & Reeves, 2012) <sup>[33]</sup>, which emphasizes continuous improvement informed by expert feedback and theoretical grounding. The integration of validator recommendations with established learning theories and empirical research confirms that the Pre-Laboratory Schema is not only pedagogically sound but also consistent with evidence-based practices in science education.

### Discussion

Key components of an effective pre-laboratory schema for Biology classes. The development process, along with expert and student feedback in Chapter 2, identified the essential components of an effective pre-laboratory schema. These include: (a) metadata such as subject, school year, IBED level, date submitted, score, grade, and section, experiment number and title, and members' names, (b) objectives and hypothesis, (c) a list of materials and equipment, and (d) safety reminders. These components emerged from classroom observations, validator comments, and thematic analysis, confirming that an effective schema must simultaneously support clarity, cognitive readiness, and procedural fluency. *Validity of the developed pre-laboratory schema in terms of content, relevance, clarity, acceptability, and accuracy.* Results show that the schema achieved strong content validity in terms of relevance, clarity, acceptability, and accuracy. Experts rated it as pedagogically sound, scientifically appropriate, and aligned with SHS Biology competencies. Qualitative feedback further emphasized the organization, clarity of visuals, age appropriateness, and completeness, while noting minor improvements needed in safety icons, terminology, and material listing.

### Conclusion

Overall, the pre-laboratory schema proved successful in promoting more organized, efficient, and conceptually grounded laboratory learning experiences. The schema's validity, its impact on students' science process skills, and the perceptions of both students and teachers regarding its classroom usability were highly effective.

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