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PROCESS-ORIENTED GUIDED INQUIRY LEARNING-BASED LABORATORY-AT-HOME IN BIOCHEMISTRY: EFFECTS ON STUDENT ATTITUDE, MOTIVATION, CONFIDENCE AND ACHIEVEMENT

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14 December 2022

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Acceptance Page:

This paper prepared by **JINKY MARIE T. CHUA** with the title: **"PROCESS-ORIENTED GUIDED INQUIRY LEARNING-BASED LABORATORY-AT-HOME IN BIOCHEMISTRY: EFFECTS ON STUDENT ATTITUDE, MOTIVATION, CONFIDENCE AND ACHIEVEMENT"** is hereby accepted by the Faculty of Education, U.P. Open University, in partial fulfillment of the requirements for the degree Course.

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14 December 2022

Biographical Sketch

Associate Professor Jinky Marie T. Chua is the Director of the Center for Natural and Applied Sciences at Cagayan State University (CSU). She has been teaching Chemistry and Research subjects at CSU since 2017. She has served as the College Research Coordinator for the College of Allied Health Sciences since 2018. Assoc. Prof. Chua has a Bachelor of Science in Industrial Pharmacy from the University of the Philippines in Manila and a Master of Public Health from Cagayan State University, where she received an Outstanding Thesis Award.

She co-authored a book on Biological Chemistry in 2019, which their University used at the peak of the pandemic and made available to other Philippine educational institutions through Lorimar Publishing in 2021. She has been a core member of funded research projects and published several journal articles. She won several presentation awards from local and international research conferences on public health, natural product development, and chemistry education. She has received an Award of Excellence for Research and Innovation and Best Mentor Award (Undergraduate Category) in 2022.

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The realization of this academic effort is greatly attributed to all persons involved in the conscientious attainment of this immense undertaking.

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I am indebted to all the UPOU FIC in the Chemistry Education program for sharing their knowledge and expertise that I was able to use in this study. The outputs and concept of this research were motivated by my sincere inspiration and moving experience with all the lessons. My sincere appreciation goes out to Ms. Rhonna Marie R. Verena for her motherly support, never-ending inspiration, and motivation from the beginning of my doctoral adventure till the completion of this dissertation.

A big thank you to my UPOU seniors, Sir Adrian D. Perdio and Sir Rex Jongel M. Lucino, for being my moral support system and being my big brothers throughout this journey.

Dedication

I dedicate my book to my son Niklaus, my inspiration, and my ever-supportive husband Richard for his unwavering love and encouragement to complete my dissertation.

I also dedicate this book to my devoted parents, siblings, and cousins for their unfailing support and encouragement along my journey.

Most significantly, this book is dedicated to our All-Powerful God, the center of this paper and the source of wisdom and fortitude for bestowing gifts on me via other people. All things are possible through Him.

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Abstract

This study involved developing and assessing a laboratory-at-home manual using the Process-Oriented Guided Inquiry Learning (POGIL) approach as an alternative laboratory component in the general biochemistry course of the second-year students of the Bachelor in Medical Laboratory Science. The first phase of the study covered designing, developing, pre-testing, and evaluating (validity and reliability) instruments: Instructional Material Evaluation Tool for Experts and Instructors, Biomolecules Achievement Test, and Instructional Material Evaluation Tool for Students, Attitude, Motivation, and Confidence in Laboratory Skills Questionnaire, and Perception Interview Guide Questions for Instructors and Students. The second phase involved designing, developing, and evaluating the POGIL-based Laboratory-at-Home (PLAH) and non-POGIL Laboratory-at-Home (nPLAH) Manuals on Biomolecules. The overall evaluation of experts, instructors, and students on PLAH and nPLAH manuals is high.

The effect of the PLAH on student achievement attitude, motivation, and confidence in laboratory skills was determined using a quasi-experimental pretest-posttest research design. The results were compared to other treatments using nPLAH and the Video (Traditional Manual with Video demonstrations) Manuals. Results showed that the students significantly increased their achievement scores after implementing the three different treatments. In addition, the students in the PLAH group gained more than those in the nPLAH and Video groups regarding achievement, attitude, motivation, and confidence in laboratory skills. Results showed that the gain before and after the treatments was significantly different except for the motivation level of the Video group. However, no significant difference was seen among the interventions except for confidence in laboratory skills, where Video is substantially different.

Further, students and instructors were interviewed to determine their perception of using the PLAH manual. In terms of perception of PLAH, the students had a fun, fulfilling, and challenging laboratory experience where teamwork, creativity, critical thinking, analysis, communication, and time management were enhanced. For the instructors, it made them more confident in teaching the Biochemistry laboratory in terms of knowledge, skills, and classroom management.

Keywords: Achievement; Attitude; Confidence; Biochemistry; Laboratory-at-home; Process-Oriented Guided Inquiry Learning (POGIL)

Chapter I

INTRODUCTION

Background of the Study

Chemistry and the other sciences in the Philippines are experimental subjects, and practical works are deemed necessary, but real practice falls short of this goal. Due to the socioeconomic conditions of our country, inadequate laboratory space and equipment, insufficient funding for chemicals and other supplies, huge classes and packed classrooms, and a lack of trained teachers all impede the growth of chemical education in the Philippines (De Guzman, 2001; SEI-DOST & UP NISMED, 2011; Garcia & Weiss, 2019). This was magnified by the COVID-19 pandemic, which drove most universities and institutions worldwide to move to a distant learning mode. Laboratory education was especially difficult since it is a hands-on experience for students and converting it to an online or modular format will inevitably modify what students do throughout their laboratory experience. Faced with this distance learning transition, various laboratory continuity options are considered, including hosting virtual computer-based laboratories, subscribing to simulations, watching videos related to experiments, having the instructors perform the experiments on videos, and the most common option- canceling laboratories entirely (Gamage *et al.,* 2020; Landicho, 2021; Soares *et al.,* 2020). None of these address how students may gain hands-on science experience in the absence of a fully equipped and supported teaching lab.

For college students, Biochemistry is broadly viewed as a challenging course because they examine life at the molecular level (Vanderlelie, 2013). "The chemistry of life" definition seems relatable, but following the chemistry underlying the processes is a challenge. Most students struggle to understand how this topic pertains to them because they have difficulty understanding abstract biological ideas that rely primarily on organic chemistry (Villafañe *et al.*, 2011). Most learners cannot understand the nature of or find the volume of the material overpowering (Bucholtz, 2012). The complex nature of chemistry can be attributed to the representation of matter at the symbolic level, where chemists can represent chemistry concepts by symbols, formulas, and equations. With this, most undergraduate students consider chemistry neither exciting nor important except the potential chemistry majors (Arnous & Ayoubi, 2018; Hofstein, Ben-Zvi, & Samuel, 1976; Hofstein & Mamlok-Naaman, 2017; Sneddon & Douglas, 2014). Many students are taking the course because it is required to further their understanding or appreciation of the subject. Most non-chemistry major students dislike the subject or exhibit fear of it. Without effective intervention, it is hard to connect the chemistry and the impact of the subject. Hence, the laboratory component is deemed sufficiently essential to the course's learning objectives.

The laboratory is an important part of learning because it improves mastery of science subject matter, scientific reasoning abilities, understanding of the complexity and ambiguity of empirical work, practical skills, scientific knowledge, interest in science and science learning, and teamwork abilities (Hofstein, 2004; Hofstein & Lunetta, 1982; Lunetta, 2016; Omiko, 2015; Williamson & Ruebush, 2014; Wood, 1996). As a result, despite being unable to perform the laboratories on-campus during a disaster or pandemic, students must gain extensive laboratory experience. Laboratory work in biochemistry was meant to offer students with familiarity with the relationship between theories and the actual world (Anwar *et al.,* 2017; Ottander & Grelsson, 2006). The capacity to analyze and discuss might also be developed through experimental studies (Hofstein *et al*., 2008).

Toward this purpose, this study aimed to develop and assess the laboratory-at-home manual adapting the Process Oriented Guided Inquiry Learning (POGIL) format that covers concepts in Biochemistry such as nucleic acids, proteins, enzymes, carbohydrates, and lipids, and its effect on student achievement attitude, motivation, and confidence in laboratory skills. POGIL adapts the guided inquiry technique, which consists of a learning cycle of exploration, idea creation, and learning application. Students actively participate in learning course material and developing critical skills while working in self-managed teams on guided inquiry activities in this research-based learning environment (Moog & Spencer, 2008). Several studies reported the effectiveness of POGIL-based laboratories on achievement, attitude, motivation, and confidence in laboratory (Barbara & Geliebter, 2020; Eberlein *et al*., 2008; Kim & Faseyitan, 2014; Schroeder & Greenbowe, 2007); however, there is no study to design and develop POGIL in laboratory-at-home activities. The activities were intended only to utilize safe household items, and no special equipment was needed. Inspired by "The Extraordinary Chemistry of Ordinary Things" book by Snyder (1997), the activities emphasize the experimental basis of Biochemistry, which can also be used at the beginning of chapters in lectures that students can perform for themselves. Hence, suitable for face-to-face or online classes. The manual is particularly for non-Chemistry majors with a Biochemistry subject which include questions that ask students to think critically about the connections between chemistry, society, and individual values. This work is intended to inspire and stimulate ideas about how one might fuse everyday events, people, and works into a pedagogical approach and provide students with a deeper understanding of the subject. It is intended to offer a new approach focused on a strategy that implements inquiry-based, student-centered laboratory activities that enhance learning skills while ensuring content mastery in the curriculum.

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5. What are the mean attitude, motivation, and confidence in laboratory skills scores of the students before and after using the
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Significance of the Study

The goal of this research was to create a pandemic and disaster-resilient POGIL-based Laboratory-at-home manual in Biochemistry. The results of this study would aid in the improvement of topic instruction. This will open up a new channel for students to gain laboratory experience in biochemistry. The manual might provide educators an alternate way to complete the laboratory portion of their courses. They can plan the laboratory activities in a new and engaging way even with insufficient laboratory rooms and equipment, inadequate chemicals and other materials, big classes, lack of time, and inadequate training. This would also help boost the instructor's morale and motivation in teaching the laboratory part of Biochemistry.

This Laboratory-at-home aspect of the manual could help instructors improve instruction by making chemistry concepts more meaningful and relevant to students by using ordinary things they see every day. In addition, the POGIL laboratory could help address some instructional challenges in terms of in-depth understanding of concepts, time constraints, large class size, motivation, collaboration, metacognition, and promotion of independent and life-long learning. Furthermore, it will encourage Chemistry teachers to begin making movements to depart from traditional laboratory teaching techniques by establishing tailor-made experiments relevant to the needs of the students, school resources, and accessible replacements that may be tapped.

The results of the study will likewise help curriculum developers and administrators enhance and develop chemistry curricula in the light of students' way on how they learn abstract concepts better through experiments using ordinary things at home. In addition, the findings of the study may be used as a basis for improving the Chemistry programs as regards its laboratory, instructional materials, methodologies and techniques, and evaluation measures. Administrators may also use the results of this study in planning and conducting training for instructors handling laboratory subjects, especially when face-to-face laboratory classroom is not possible.

The study findings will serve as a basis for CHED and DepEd to promote laboratory activities that can be done at home, even with our country's socioeconomic and geographic constraints. This study will be the first to develop a POGIL-based laboratory-at-home manual in Biochemistry and evaluate its effectiveness. The results can be a basis for funding programs to replicate the instructional material to other hard-to-understand subjects that needs laboratory to supplement a greater comprehension of abstract notions and theories obtained through experiencing and seeing them as genuine events. The validated research instruments can also be used to evaluate other instructional materials.

The Local Government Unit, particularly in far-flung areas, and Chemistry instructors' affiliations can use the study results to use their platforms for dissemination and training in designing and using POGIL-based manuals. These trainings will help prepare instructors and students to utilize the instructional material.

Furthermore, the findings of this study contribute to the limited empirical data on the benefits of using the POGIL approach and laboratory-at-home activities in improving the achievement, attitude, motivation, and confidence in laboratory skills of Biochemistry students in our country.

Scope and Delimitation of the Study

The first phase of the study covered the design and validation of the research instruments to be used in developing and assessing the effectiveness of the modules. Instruments are adapted to fit the evaluation of the laboratory instructional materials. Biochemistry content experts validated the content and constructs of all five (5) instruments. Further, instructional material experts validated the "Instructional Material Evaluation Tool for Experts and Instructors" and "Instructional Material Evaluation Tool for Students"; test experts validated the "Achievement Test in Biochemistry"; and a psychometrician for the non-cognitive instruments, "Attitude, Motivation, and Confidence in Laboratory Skills Questionnaire for students" and "Perception Interview Guide Questions." Pilot-testing of the instruments was done to check the reliability of the Achievement Test and Attitude, Motivation, and Confidence in Laboratory Skills Questionnaire.

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The third phase of the study involved determining the effectiveness of the manuals in terms of the results from pre and post (1) achievement test, (2) attitude, motivation, and confidence in laboratory skills survey, and (3) perception interviews. The second-year college students of Cagayan State University taking Biochemistry subject under Bachelor in Medical Laboratory Science during the first semester of the A.Y. 2021-2022 were the participants of the study. Seven classes were divided into three groups (PLAH, nPLAH, Video) through wherein the instructors are used as blocks or local control. All instructors are handling both PLAH and nPLAH groups wherein one instructor handles PLAH, nPLAH, and Video groups.

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Chapter II

REVIEW OF RELATED LITERATURE AND CONCEPTUAL FRAMEWORK

This chapter presents the review of literature and studies that supported and provided the foundation for the present study. The theoretical and conceptual framework of the present study was anchored on this literature review. This chapter also includes the conceptual framework, research hypotheses, and definition of terms.

Laboratory in Chemistry Education

The central role of laboratory classes in science courses is owed to the long list of benefits it gives students (Hofstein, 2004). Several studies that demonstrate the benefits of laboratories in scientific education are based on John Dewey's idea. He thought that humans learn via action and reflection. The basis for Dewey's perspective was the need for each learner to have meaningful experiences (Bilbao *et al.,* 2008). Thorndike, Jansen, and Bruner accord this theory. Thorndike stated that man learns by doing, which is reinforced by Jansen's belief that pupils may better assimilate knowledge if they are executed (Catuday, 2019). Bruner's Constructivism theory stresses the learner's active engagement in comprehending and synthesizing knowledge. Learning is a dynamic process in which students generate new ideas based on their prior and present knowledge. The learner chooses and changes knowledge, hypothesizes, takes decisions, and depends on their understanding. Cognitive framework (schema) gives meaning to experiences and enables individuals to move beyond the information provided (Vergara, 2017).

In the context of chemistry learning, appropriate laboratory activities can successfully enhance cognitive skills, metacognitive abilities, practical skills, and attitude and interest in chemistry, studying chemistry, and practical work. Furthermore, giving genuine and practical learning experiences to students might boost their enthusiasm to study chemistry (Hofstein, 2004). According to George Pimental, editor of the CHEMStudy (Merril & Ridgway, 1969), the laboratory was developed to help students better understand the nature of science and scientific inquiry by emphasizing the discovery approach. He also claimed that it enables students to monitor chemical systems and gather data that may be utilized to build theories that are subsequently presented in the textbook and class. Tobin (1990) proposed that meaningful learning in the laboratory is achievable if students are provided opportunities to use equipment and materials in an atmosphere conducive to building their understanding of phenomena and associated scientific ideas. Appropriate laboratory activities can be beneficial in assisting students in developing logical and inquiry-type skills, as well as problem-solving abilities (Tobin, 1990; Gunstone, 1991). They can also help with the development of psychomotor abilities (manipulative and observational skills). Furthermore, they have the ability to create positive attitudes and give pupils with opportunity to build collaboration and communication skills. Several studies done in the 1970s and early 1980s discovered that students enjoyed laboratory work in specific courses and that laboratory experiences resulted in positive and increased student attitudes and interest in science. According to Hofstein and Lunette (1982) and Lazarowitz and Tamir (1994), laboratory activities can increase constructive social interactions, positive attitudes, and cognitive advancement. Many laboratory activities need collaboration. The less formal atmosphere (compared to the classroom) and opportunities for more constructive interactions between students and teachers can promote social relationships, resulting in a better learning environment (Tobin, 1990). In this regard, the scientific laboratory is a one-of-a-kind learning environment. As a result, science teachers may be able to alter their educational strategies and prevent a repetitive classroom learning environment.

By giving a real, authentic scientific experience, a lab course may help a student become a better observer, a more thorough and precise thinker, and a more deliberate problem solver.

Purposes of Chemistry Laboratory

It is accepted that laboratory work should continue to have a role in undergraduate chemistry education. Still, changes will be necessary to bring benefits that justify the required outlay in time and resources. A key flaw in many laboratory courses is their lack of purpose, which frequently places too much focus on the experiments to be performed and too little on what the students should be learning.In addition, the tendency to provide detailed laboratory instructions could be more helpful as it tends to overload the students' working memory. This results in students needing help following the provided recipe searching for the correct answer or product without reflecting on the approach taken or the results' significance.

Reid and Shah (2007) found that the goals of laboratory work may be classified into four broad categories: (1) Learning chemistry-related skills. There is a potential to bring chemistry to life through illustrating ideas and concepts, subjecting theoretical notions to practical testing, and teaching new chemistry. (2) Practical abilities. There is an opportunity to work with equipment and chemicals, learn safety measures, master specialized methods, precisely measure, and observe. (3) Scientific abilities. There is a chance to acquire observation, deduction, and interpretation abilities. There is a chance to comprehend the empirical role as a source of evidence in investigation and to learn how to design experiments that provide true insights into chemical processes. (4) General abilities. There are various essential skills to learn, including teamwork, reporting, presenting and discussing, time management, and problem-solving techniques.

Chemistry Laboratory Instruction Styles

The constructivist theory suggests that learning outcomes are likely influenced by the style of laboratory instruction employed. As a result, Domin (1999) proposes a taxonomy of laboratory instruction styles and highlights the distinctive characteristics of each type. Four distinct laboratory styles are identified: expository, inquiry, discovery, and problem-based.

Expository instruction, or the traditional or verification approach, is the most common approach to laboratory teaching. In this style, the teacher sets the topic, providing links to previous work and providing detailed, specific instructions for students to follow to obtain the predetermined outcome known to both students and instructor. The approach is designed to enable activities to be performed simultaneously by a large group of students with minimal involvement by the teacher. It has evolved due to minimizing resources (time, space, equipment, and supervision). This method is often criticized as a 'cookbook' approach which places little emphasis on thinking, planning the experiment, or interpreting the results obtained, with the consequence that meaningful learning is unlikely to occur. It is suggested that no activities requiring students to operate at the higher levels of Bloom's Taxonomy are found in expository laboratories (Domin, 1999).

In inquiry instruction, outcomes are unknown, and students are required to generate their procedure. If done properly, this approach can allow students to engage in an authentic scientific investigation. In addition to experimentation, students are tasked with formulating, investigating, and identifying the purpose of the analysis and procedure used. The approach, therefore, gives students ownership over their laboratory activities. However, research suggests that while an inquiry-based approach promotes positive attitudes towards science and fosters critical thinking, it does not always lead to the hoped-for improvement in understanding of science concepts, possibly due to the tendency to overload the student's working memory.

Discovery instruction, also known as guided inquiry, might appear at first sight as similar to the inquiry approach. However, it differs because the teacher provides the procedure to guide the student toward discovering the desired outcome. The approach has been criticized because it is likely more time-consuming than expository learning. In addition, there is no guarantee that the students will discover the desired outcome unless the teacher closely supervises them.

Problem-based instruction is a deductive approach that asks students to use what they have already learned to answer questions the teacher sets. Students use their understanding of a concept to devise a pathway to solve the set problem. This requires them to think about what they are doing and why they are doing it. Then, students must decide how to proceed and what additional information may be needed. In the problem-based approach, the methods used to solve a problem are secondary to the problem itself; the important thing is to solve it.

The higher education sector has worked hard to transform traditional lecture-based instruction and laboratory exercises into more student-centered learning forms. As a result, innovative educational approaches such as student-centered, active learning, peer-led team learning, process-oriented-guided-inquiry-learning (POGIL), project-based learning (PBL), and others have received attention among educational communities (Kim & Faseyitan, 2014).

Challenges and Opportunities in Teaching Chemistry Laboratory

Education is a critical prerequisite for economic growth in knowledge-based economies. However, teaching and training a large population for preparation and in-service reasons is a large and costly undertaking (Woodfield, 2010), which is particularly challenging to handle in underdeveloped nations due to budgetary restrictions. This is exacerbated when education and training are required in scientific and technical fields.

Table 1

Shared themes between studies and challenges in teaching Chemistry

Themes	Content knowledge and connections	Laboratory and experiments	Learners	Planning and implementing teaching	General teacher qualifications
Yoon and Kim (2010)	√	√	√		
Feldman (1976)	√		√	√	√
Roehrig and Luft (2004)	√		√	√	√
Anderson (1996)	√	√		√	√
Johnson (2006)	√	√		√	
Lotter, Harwood, and Bonner (2006)	√	√		√	
Nivalainen et al. (2010)	√	√		√	
Kim and Tan (2011)		√	√	√	√
Harris and Rooks (2010)			√	√	√
Kagan (1992)			√		√
Heeralal (2014)		√		√	√
James and Crawley (1985)		√		√	√
Karataş (2016)		√			
Atav and Altunoglu (2010)				√	
Cheung (2008)				√	√
Eick and Reed (2002)				√	

Note. Several papers on the difficulties that chemistry professors experience when teaching in a laboratory setting were reviewed and they identified five common themes: topic knowledge and linkages, laboratories and experiments, students, instructional planning and implementation, and general teacher traits. Adapted from "Challenges faced by pre-service chemistry teachers teaching in a laboratory and their solution proposals" by A. Yalcin-Celik, H. Kadayifci, S. Uner, & N. Turan-Oluk, (2017), *European Journal of Teacher Education*, 40(2), p 212.

The content knowledge and linkages theme focuses on the issues associated with the teacher's chemical content knowledge. For example, there are gaps in their content knowledge and misinterpretations of the themes and phrases employed, which may have resulted in incorrect understanding by the students. Another category is linking topics that fail to connect with other chemistry subjects and other lessons—Also, not making connections between chemistry and everyday life, such as not making connections between lesson topics and everyday life or not being able to find examples from everyday life that relate to lesson topics.

The lab and experiments topic includes things like choosing or making up experiments, keeping an eye on the lab environment and how the experiments are done, and making sure the lab is safe. Problems can arise when choosing or making experiments if they don't give students a chance to be active or if it's hard to find or make experiments that fit the topic of the lesson. In this category, problems with controlling the lab environment and running the experiment included not being able to solve a problem right away when it came up during the experiment, not having the procedure for the experiment well organized, and not telling the students what their responsibilities were during the experiment. In the last category, laboratory safety, problems included teachers suggesting experiments that could be dangerous, not knowing how to handle problems that come up during the experiment, not telling students how to stay safe during the experiment and thinking that chemistry experiments are dangerous.

The issues connected to instructors' interactions with learners in the context of laboratory teaching were incorporated in the learners' topic. The most difficult category was student questions/explanations, which often featured students' queries and responses. During their lab teaching, the professors did not hear or pay attention to the students' questions, did not look at the students' answers, and did not correct the students when they used wrong phrases that showed they did not understand. Teachers have trouble getting students interested in a subject, figuring out what students already know, and explaining things, giving examples, and asking questions that are right for each student's level. All of these problems can be solved by knowing what students are interested in and how smart they are. Teachers' remarks on the difficulties of inspiring students were included in the student motivation category.

The issues that arose before to and throughout the teaching planning and implementation stages were included in the planning and execution of the teaching theme. An analysis of the obstacles in this area revealed that teachers had the most difficulty applying the teaching technique. Some of the problems were that the planned teaching method wasn't used, a simple story was told, which went against the planned method, students couldn't come up with hypotheses or focus on them, and they did things that didn't fit with the planned method. Also, it was hard for the teachers to know how to teach, either because they didn't know enough about the method they were using or because they came up with ideas for implementation in the lesson planning stage that didn't work with the method. The study found that teachers had trouble choosing goals that fit with the teaching method, deciding what to include in lesson plans, making a plan that fit with the topic and goals to be taught, and making sure that the lesson plan included the steps of the teaching method. The researchers also found that the pre-service teachers were not mentally ready for the subject before they started teaching practice, that the experiment objects were not ready ahead of time, and that they had trouble because they had never tried to experiment before the method. These difficulties were investigated in the context of conducting preliminary work for a class. The teachers reported that the necessary chemistry topic instruction was tough (subject teaching).

Personal qualities, experience, classroom management, asking effective questions, serving as a guide, public speaking, and employing technology are all part of the general teacher qualifications theme.

As laboratory instruction became more popular, overcoming these obstacles became increasingly vital. Despite their relevance, few research on this topic have been done. The remedies, mostly advocated by academics and scholars (Kim & Tan, 2011; Lotter *et al.,* 2007), focus on external resources available to instructors. Even fewer studies have been conducted in which pre- and in-service teachers together propose remedies. For example, in a survey conducted by Walan *et al.* (2016), in-service teachers were asked to identify solutions to the challenges they had identified. The teachers proposed facilitating teacher interaction, exchanging prepared teaching modules, and using resources and procedures previously.

Innovations in delivery systems must be part of the answer to the limits, necessitating more investigation. Hundreds of remote learning institutes have been established in both industrialized and developing nations throughout the last century. Several scholars have investigated the obstacles and potential for distant education in underdeveloped nations (Arger, 1993; Ramanujam, 2001; Fozdar *et al.,* 2006; Jung & Latchem, 2007). Educators have been worried about how to provide laboratory-based science and technology courses efficiently via distant mode. As education has shifted to online learning in the aftermath of the worldwide pandemic, one of the most challenging problems has been modifying laboratory lessons.

The COVID-19 crisis drastically altered primary educational activities, notably chemistry instruction. There has been an evolution to a new paradigm of distant education and comprehensive online educational technology choices. All of these are essential for chemistry learning and are mostly accomplished through expository approaches (partly depending on laboratory resources). Because of the autonomous teaching approaches developed by educational institutions, about 397,700 students were able to begin or continue studying chemistry classes. Soares *et al.* (2020) say that teachers of chemistry in Rio de Janeiro schools have to deal with real-life situations every day. They found that the following things were bad for the actions that were taken: the applied television broadcaster mostly only covered the heavily urbanized region, leaving out rural and poor areas; students didn't have enough technology (like smartphones, tablets, and laptops); teachers didn't have enough training to use online technologies; and video classes had their own problems.

The problem of delivering scientific laboratories from a distance date back to remote education (DE). Walter Perry (1979) stated how he was frequently questioned, "How are you going to be able to teach science and technology, when laboratory work is a large component of the whole course?" He mentioned that one method to cope with the difficulty is to employ multimedia, such as movies of investigations. This could be applied to the many interactive computer simulations that are available now. But the only ways to do hands-on experiments are with home lab kits or in specialized residential laboratories, where students spend several days in a lab session. In fact, these are the two main ways that students at Athabasca University do lab work in the sciences (Kennepohl & Last, 1997). There is no guide on how to set up a DE scientific laboratory program, which is a shame. Also, there is no way for scientists and teachers to share information that would help us make a curriculum that is very different from residential lab programs. Perry's response addressed the critical possibilities in the teaching laboratory when local lockdown and social separation were imposed. In light of the COVID-19 pandemic, recent research examine the following ways made by universities to offer Chemistry laboratory procedures remotely (Amsen, 2021; Shidiq *et al*., 2021; Gamage *et al*., 2020; Simon *et al*., 2020; Kolil *et al*., 2020).

Virtual labs/computer simulations offer alternatives to difficult experiments that may be too large, costly, unsafe for physical manipulation, or inaccessible to a large number of students. This lets people learn how to use and manage chemical equipment and instruments without actually having to use them. These can be easily made available to a distance learner with the right computer. They give the learner a "doing" experience that, while less direct than actual hands-on experiments, still gives the student some control over the experiment and may be just as educational as using the actual instrument. Even though virtual labs are a good way to teach, you can't use them to get hands-on experience with lab equipment and processes. Forinash and Wisman (2001) emphasized that they should not be used to completely substitute real laboratory testing. The transition from face-to-face to remote learning and the use of virtual laboratories has been criticized as putting too much strain on instructors and students. This is also available for free or for a price.

Experiment-related videos are used. It is extremely advised to create a video that can effectively clarify methodologies, detail equipment, and explain the experimental setting. As a result, the video serves as the demonstration. Furthermore, the film introduces the equipment, demonstrates practical approaches, and emphasizes the subject's theoretical material.

Lab kits, when paired with common household objects, allow you to perform experiments on a smaller scale at home without the need for expensive equipment. Creating and planning home lab kits can take anywhere from two to four years. Kit prototypes are given to a few students before mass production of the kits starts.

Logistics, like the availability of important supplies and the best results for the students, must be taken into account.

As an alternative to laboratory experiments, home experiments utilizing ordinary household materials and equipment (so-called kitchen chemistry) have been proposed. This strategy may be appropriate in beginning chemistry classes. However, "home chemistry experiments" are insufficient for people wishing to pursue a profession in chemistry or other fields requiring a high level of chemical exploration. These students require a good practical foundation in experimental chemical methods early in their studies in order to progress to more sophisticated and demanding processes later on.

With the Philippines' socioeconomic and geographic constraints with or without pandemics, home experiments that resemble commercial lab kits using domestic items are the ideal lab alternative. These tools require instructors to be creative and capitalize on students' interest. Creativity requires curiosity. But doing this brings us back to the challenges teachers have in teaching Chemistry laboratory: content knowledge and connections, laboratory and experiments, learners, planning and implementing teaching, and general teacher qualifications. Hence, a proposed solution of using a POGIL-based laboratory manual.

Importance of Laboratory Manual

Sibayan (2008) acknowledged that the failure of students to achieve academically is attributable to a number of problems afflicting education in the Philippines. Poorly trained instructors, insufficient facilities and equipment, and a lack of instructional resources in the preparation of the lesson for the students to have direct experience in learning are among the school-related reasons. Conducting a laboratory without a laboratory manual or worktext is difficult for the person in charge of the topic (Catuday, 2019). The necessary competencies and skills must be achieved effectively. Hence, a laboratory manual in Biochemistry could be beneficial to the teachers since this would solve challenges, they encounter in conducting laboratory classes, particularly on content knowledge, choosing/designing experiments, regulating the laboratory environment, managing the experiment process, planning, and implementing teaching. Furthermore, it benefits students by providing enough laboratory activities that will boost the development of the necessary skills and competences required by the course. This is not intended to replace the lessons produced by the teachers, but rather to augment and indicate uniformity of training.

According to Quiben's (2010) findings, the usage of instructional work text might assist both teachers and students in achieving laboratory work objectives and helping students improve their mastery of their manual abilities. The use of instructional materials contributes to a more successful teaching and learning process (Casiano, 2012). Teachers can offer the products to their pupils more effectively and efficiently. In turn, their clients may get insight and learn more effectively with care and precision. According to Onasanya and Omosewo (2011), a professionally educated teacher, no matter how well-trained, would be unable to put his or her ideas into practice if the educational environment lacked the resources and equipment needed to transform his or her expertise into reality.

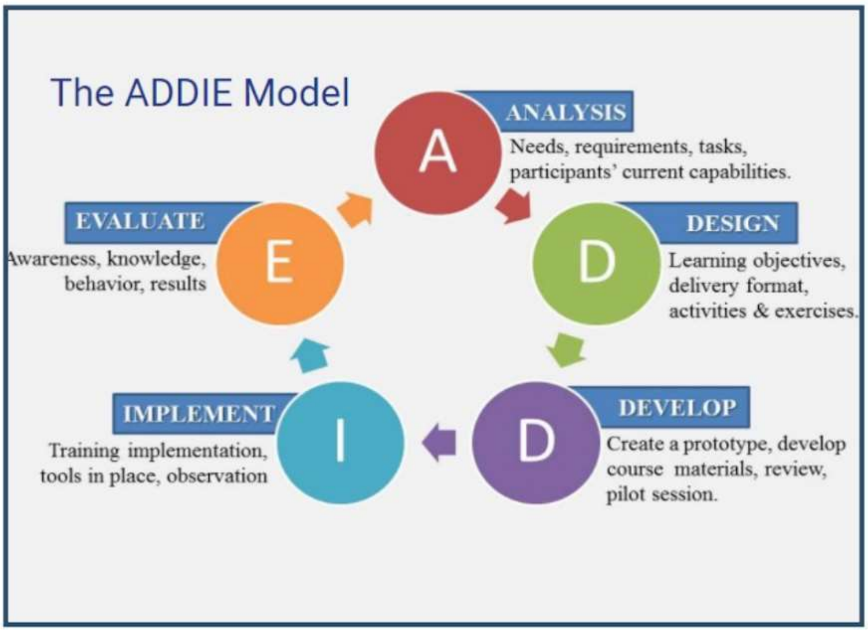
Section 3 of Chapter 3 of the Education Act of 1982 stated that the goal was to establish curricular designs, produce instructional materials, and plan and evaluate programs to improve teaching quality. Similarly, Section 5 of Presidential Decree No.6-A specifies that "one of the educational objectives is to create, use, and enhance instructional technology, as well as generate or manufacture textbooks and other instructional materials contributing to quality education." A well-developed instructional material will considerably improve student performance while also making learning easier and more permanent (Laroza, 2015). Similarly, as reviewed by students and teachers, the generated worktext, modules, and laboratory manual in Sciences and Mathematics disciplines are highly effective in boosting students' learning (Constantino, 2010; Cruz, 2006; Jimenez, 2008; Robles, 2004).

The ADDIE Model

The major technique of the study was based on Watson *et al.* (2013) ADDIE paradigm (Analyze, Design, Develop, Implement, and Evaluate). The following are determined during the Analysis phase: learners, formative evaluation, goals and objectives, limitations, strategy, and tools — What will keep the audience's interest, with different learning styles in mind? How will you deliver the material (e.g., written manual, presentation, face-to-face, online, one-on-one, or in a group)? Several features of high-quality educational materials were found by Articulo (2008). For example, they should 1) be written for a specific group of learners; 2) relate to the learners' own experiences; 3) help learners develop their learning skills as well as learn the content; and 4) make clear the specific learning goals and help learners set their own goals; (5) have a clear structure that guides learners through the material; (6) build on learners' existing skills or knowledge; (7) keep the learner interested in the text (by asking questions or giving interesting and useful activities or give feedback on activities and questions within the text); (9) give learners chances to develop their ideas or make choices (not all answers are right or wrong); and (10) give learners chances to practice, where appropriate.

Figure 1

The ADDIE Model



Note. From ADDIE Model in Safety Training how does yours measure up!, by T. Penney, 2016. (https://www.linkedin.com/pulse/addie-model-safety-training-how-does-yours-measure-up-terry-penney)

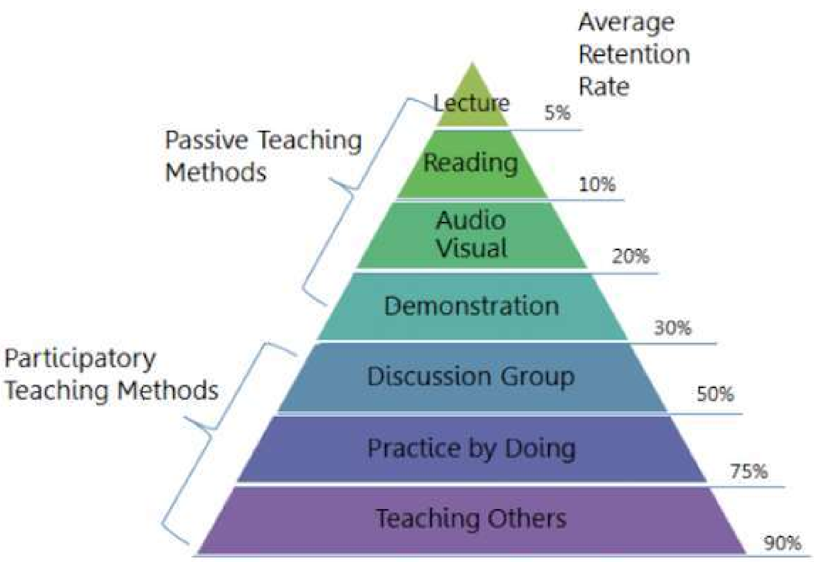
Because the rest of the ADDIE paradigm involves initial thinking and assessment-based research during the Analysis phase, this step can be time-consuming. This phase entails gathering information about the manual based on the five (5) aspects (Tan, 2019): (1) The content of learning materials: This includes the lessons and the skills and knowledge that the learner needs to know about the topic (Macarandang, 2009). Teachers should keep in mind the following things when choosing what to teach: (a) Does this content fit into the unit of study, learning experience, or problem-solving activity? (b) Do the learning instructional materials (IMs) offer useful information and a good way to learn? (c) How closely does the content of the learning material relate to the subject that needs to be learned? (d) Does the material have enough real-world examples to support a valid conclusion? (2)

Presentation and organization: This shows that the order of themes in the curriculum guide matches the issues in the module (Abolade, 2013). Salandanan (2011) says that presentation and organization are the logical and smooth flow of information that follows a pattern of experiences to give the learner more and more knowledge and skills. (3) Learning activities. Learning activities are the activities in the handbook that give students chances and experiences to learn how to do integrated science process skills or higher-order thinking skills. (4) Accuracy and timeliness of information: This refers to all conceptual, grammatical, factual, computational, typographical, and other minor errors (such as wrong or unclear illustrations, missing labels, wrong captions, and others) and out-of-date information. (5) Style: The following criteria are used to judge the format of the learning materials: a) the size of the letters and the space between them, b) the illustrations, c) the designs and layout, d) the paper and binding, and e) the manual's size and weight.

During the Design phase, or creating a storyboard, the learning objectives and goals into specific and measurable objectives are formalized. The methods to get the learners to retain content are considered. Figure 2 which is based on the National Training Laboratories Institute, helps determine methods. The types of resources to develop materials and the length of time to finish the manual are also considered. Like with the Analysis phase, a large amount of overall preparation time in the Design phase is spent.

Figure 2

Methods to retain the content



Note. From National Training Laboratories Institute's Learning Pyramid, by Northeastern University, 2009. (https://learning.northeastern.edu/introduction-to-experiential-learning/)

During the Development phase, you will check the manual against your design concept and make content for the people you want to read it. The methods for making instructional content depend on the type of content and the goals of the users. But some of the ways that all of these materials are put together are the same (Popham, 2010). Content validation is the first and most important step in making new materials or instruments. Content validation determines how quickly validity and reliability can be checked again in the future. At this stage, careful planning, setting goals, and a study of the literature are needed to give full information about the choice that will be judged by the material or instrument (Oriondo & Dallo, 2009). Catindig (2007) went on to say that the created ideas or items should be tested to see if they meet the goal of the material or instrument.

During the Implementation phase, you will use your manual and talk to your students and facilitators about it. In the last step, "Evaluation," learning goals and audience goals are checked to see if they were met. This can be done with a survey (qualitative or quantitative), a focus group, or debriefing sessions. Because the usefulness and effectiveness of teaching materials are indicators of how well they teach, they need to be evaluated all the time. Aquino (2010) said that the evaluation process includes the methods, techniques, and criteria for gathering and analyzing the evidence needed to make decisions and judgments. These decisions and reviews can be about the curriculum, teaching strategies, instructional media, students' progress, and other parts of an educational program. A good evaluation system does the following: 1) It makes it clear what the goals and objectives are, 2) It figures out how well the goals have been met, 3) It compares different ways of teaching, 4) It finds out what needs to be changed in the teaching programs, and 5) It gathers evidence that can be used to report on student progress.

Several related studies that used ADDIE Model were published during the peak of Covid-19 pandemic particularly using the online platform. Almmelhi (2021) looked into how well the ADDIE model works to improve creative writing in an e-learning setting.In Biochemistry topics, the research of Sari *et al.* (2022) of virtual laboratory of Biochemistry Practicum during the Covid-19 pandemic is a research with the ADDIE development model while with the ADDIE model, Day *et al.* (2022) made an innovative e-book with a learning video to help chemistry students learn more and be more interested in learning about metabolic biochemistry. Muliawati and Pathoni (2019) also made use of ADDIE model in the development of biochemical e-modules. Project-based innovative learning resources to guide students to study Organic Analytical Chemistry by Pakpahan *et al.* (2021) was conducted by following the ADDIE model to develop learning resource for undergraduate students. On the other hand, A POGIL-based e-module to empower students' critical thinking by Septianti *et al.* (2022) used research and development with research procedures using ADDIE model development.

Laboratory Work in the Philippines

The laboratory is critical to a student's growth since it allows each student to put theory into practice and involves many activities to learn difficult subjects. But students can not do lab experiments and activities because they were worried about the number of lab tools and equipment, the size of the class, the length of the experiment, the availability of a lab room, and their safety (Abas and Marasigan, 2020).

Chemistry experiments and hands-on activities are critical to fulfilling Science curriculum objectives. Duit and Tesch (2010) thought that hands-on demands included minds-on in their investigation. Not all experiments, even those that are elegantly conceived, produce the intended results; they must be arranged in such a manner that hands-on and mind-on occur. Millar (1987) also underlined the need of experimentation in scientific education. Furthermore, according to the American Chemical Society (2019), hands-on laboratories are crucial to the learning processes in all fields of study. According to the Society, research has shown that children who take part in well-designed laboratory activities improve their ability to solve problems and think critically. They also learn about reactions, materials, and lab equipment. Web-based and computer-simulated activities, on the other hand, may expand student exposure to chemistry while lowering expenses and eliminating hazardous waste and safety problems; but, these tools cannot replace hands-on laboratory experiences. Ornstein and Levine (2006) supported the hypothesis that students had more positive attitudes about science when they participate in hands-on laboratory activities and are exposed to greater levels of experimentation or inquiry on a regular basis. However, science laboratories are given less attention in the Philippines, particularly in public schools (De Borja & Marasigan, 2020).

Biochemistry Laboratory Work

Biochemistry is a scientific subject with diverse applications, including medicine, agriculture, nutrition, and industry (Nelson & Cox, 2008). It is available to students majoring in Chemistry as well as non-majors. It is a well-known fact that biochemistry is a hard subject for students in the higher education sector (Vella, 1990; Wood, 1996; Vanderlie, 2013; Varghese *et al.*, 2012; Anwar *et al.*, 2013; Broman *et al.*, 2011). By their very nature, the subjects have a lot of abstract ideas that are important for a deeper understanding of the subject and are usually taught through didactic methods (Meyer & Land, 2003). These ideas required high-level thinking in a short amount of time (Jidsejo *et al.*, 2009; Varghese *et al.,* 2012). So, students find it hard to learn biochemistry and find it hard to see why it's important (Wood, 1996). Even though the traditional lecture may be an important part of biochemical education, there is a lot of research that shows how other methods can be used to improve knowledge retention and keep students interested (Parsons & Taylor, 2011).

Biochemistry laboratory activity is meant to offer students with firsthand knowledge of the relationship between theories and the real world (Ottander & Greelson, 2006). However, the Biochemistry topic has issues with learning and instruction, particularly in laboratory work. Anwar *et al.* (2017) investigated the application of laboratory learning in the Biochemistry subject. They found that effective laboratory learning was affected by a number of factors, such as a pre-lab stage that could increase student motivation, a lab-work stage with complete tools and materials and better assistant skills, and a post-lab stage that could give feedback to the experiment report and give students a chance to present their investigation results.

In Biochemistry classes, students spend a lot of time in the lab doing hands-on work. Also, it costs a lot to run, has a lot of equipment, and takes up a lot of lab space. So, the goals of lab work must be clear, and there must be a way to keep track of whether or not these goals are being met. In his article from 1996, Wood tried to figure out what the goals of practical laboratory work are and how they can be met in terms of students' growth.

Table 2

Some Objectives of Practical Laboratory Work

To Illustrate Lectures
– Illustrate phenomena, equipment, by demonstration and personal handling – Experience handling biological materials – Learn standard (or historical) techniques, verify principles – Realise importance of biochemistry in medicine, industry, etc
Laboratory Skills
– To develop manipulative skills – To learn how to use a particular piece of apparatus – To learn how to follow a protocol [controls, safety] – To observe and record accurately – To process data, use statistical methods – To present data, results, conclusions
High Level Skills
– To learn how to plan experiments, validate assays, write protocols, be critical of data – To learn how to read the literature, find things in the literature, think of new experiments to answer interesting and worthwhile questions – To propose and test hypotheses, reason logically – To communicate results, etc, in oral and written form – To be able to function effectively as a member of a team

Note. Retrieved from "Problem-oriented learning, problem-based learning, problem-based synthesis, process-oriented guided inquiry learning, peer-led team learning, model-eliciting activities, and project-based learning: what is best for you?", by D.R. Wood, 2014, *Industrial & Engineering Chemistry Research, 53(13)*, 5337-5354.

Wood (2014) wrote down the following goals of practical laboratory work: (1) Illustrating what is being taught in class, (2) giving students the chance to learn technical skills and get hands-on experience, and (3) learning how to plan experiments and process data (Table 2).

He emphasized how important it is for students in biological science classes to see and handle biological materials and observe biological events. These things are important and exciting and lead new scientists to ask questions and begin problem-solving to explain the phenomena. He said that students could learn new skills, but they needed practice—the chance to do the same things over and over and learn from their mistakes—and a reason to try to get good data. Students might be busy following a "recipe" to get an answer quickly. They don't have much time to think. He emphasized that the knowledge of biological materials and phenomena and technical skills form the basis of scientific inquiry. Still, it's important to learn and understand how to ask questions. Many skills, like how to get along with other people and how to use and read scientific literature, are not taught or learned in a first-year course.

The POGIL Laboratory

In the 21st century, learning is all about developing skills like problem-solving, critical thinking, and constructive pedagogy. The trend in science and technology education around the world is to teach students how to do science (Akben, 2015). But the low performance of Filipino students in international and national tests makes it hard to see what each student has done well. Studies show that Filipino students don't remember ideas well, can't reason or analyze well, and can't talk to each other well. Also, a lot of high school graduates from certain schools aren't able to use what they've learned in real life or do scientific research (UP NISMED, 2005). One reason why students don't do well is that the teaching and learning process isn't very good (DOST-SEI, 2011). Traditional teaching methods that focus on the teacher are not enough to help students learn about science and technology (Akben, 2015). Modern education is hard because it is hard to combine and apply 21st-century skills so that students can learn more than just current topics. Several types of research and teaching methods have been used in Philippine classrooms to help students improve their grades, process skills, and critical thinking so they can deal with problems in the 21st century. Teachers in scientific education have utilized a variety of ways to help learners meet their learning objectives. The Process-Oriented Guided Inquiry Learning (POGIL) strategy is one of many that have a favorable influence on scientific learning (Wu & Hseih, 2006). POGIL's collaborative nature enables students to investigate topics while employing the scientific method. POGIL is a student-centered, research-based philosophy and science pedagogy. Students are divided into small groups for guided inquiry, which is conducted using carefully developed resources that steer and guide students as they build and rebuild their science knowledge (Boniface, 2009). Minderhout and Loertscher (2007) discovered that POGIL enabled students engaged in scientific courses to significantly improve their critical thinking skills.

The guided inquiry approach, which consists of a learning cycle of exploration, idea invention, and application in learning, is adapted in Process-Oriented-Guided Inquiry-Learning (POGIL). It is a student-centered technique in which students work in small groups with specific responsibilities allocated in order to be completely involved in the learning process. The lab tasks highlight essential principles and give a solid understanding of the subject topic while encouraging higher-order thinking skills. POGIL assists students in developing process skills such as critical thinking, problem solving, and communication via cooperation and reflection, allowing them to think critically and operate successfully in a team context. Any number of students can engage in a POGIL lab and work in small groups on specially prepared materials for guided inquiry. These resources, which are essentially a recapitulation of the scientific method, provide students with facts or information, followed by leading questions and activities that lead them to their own accurate conclusions. On a frequent basis, the instructor serves as a facilitator, recognizing and addressing individual and classroom-wide needs. Many studies have been reported on the usefulness of POGIL-based laboratories in chemical and bioscience instruction.

According to Hanson (2013), POGIL is both a philosophy and a teaching and learning method since it combines explicit assumptions about the nature of the learning process and the expected outcomes. He stated how POGIL learning activities use the learning cycle in guided inquiry activities to engage students, foster information and knowledge restructuring, and support students in acquiring understanding. He stated that the POGIL structure is great for helping children improve their problem-solving skills. Learning groups can assist students in improving their problem-solving abilities. POGIL activities are designed to be arranged around key concepts and their applications, allowing for a hierarchical knowledge structure. The assignments are designed to help students build critical understanding of the topics.

Boniface (2009) says that POGIL is a research-based, student-centered philosophy and science pedagogy in which students work in small groups to do guided inquiry using carefully designed materials that direct and guide students to build and rebuild their chemistry knowledge. This teaches both science facts and the basic steps of how science works at the same time. POGIL exercises focus on key scientific ideas and processes. This helps develop higher-order thinking skills while encouraging a full understanding of the subject.

Structure of the POGIL Laboratory

There is no one template for a POGIL activity. Every POGIL implementation is different, but the three most important things about POGIL materials are: 1) they are made for self-managed teams that use the instructor as a learning guide instead of a source of information; and 2) they are made for self-managed teams that use the instructor as a learning guide instead of a source of information. Activities lead students through explorations that help them build, deepen, refine, and integrate their understanding of disciplinary content; and (3) the application or development of at least one process skill is built into the structure of the activity and does not depend solely on activity facilitation in the classroom or laboratory.

The POGIL approach underpins PASCO Scientific's Advanced Chemistry via Inquiry laboratory investigations. Each lab is separated into models and experiments. A model/experiment is a representation or activity that students create and utilize while working through a series of questions aimed to help them comprehend chemical topics. These are in chronological order, with each revealing a different facet of the study. The procedure's guiding questions aid in the generation of understanding into the chemical process and theory. Students that choose the cognitive approach to completion actively think about and solve chemistry-related difficulties.

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the chemical process and theory. Students that choose the cognitive approach to completion actively think about and solve chemistry-related difficulties.

In POGIL exercises, the student begins by investigating a model or an experimental methodology. The following phase is concept creation. This is where students seek for patterns and correlations in the protocol data. The last phase is an application, in which the previously generated notions are applied to answer more questions and handle more complicated models or other exploration. This sequence of actions is known as a learning cycle. Willian (2019) has adapted these core techniques into guided inquiry "mini-experiments" in this set of experiments (exploration and concept invention). These mini-experiments are followed by practical laboratory experiences in which students conceive, set up, and conduct their experiments.

Many POGIL facilitation methodologies have the following characteristics: (1) Roles have been allocated to students within their groups. (2) The model is intended to serve as an introductory introduction to the topic or specialized material. (3) The pupils have completed any element of the task prior to the start of the class meeting. (4) Each group answers all of the Critical Thinking Questions. Every POGIL implementation is tailored to the purpose at hand. Some real POGIL implementations violate the extra properties (1-4) listed. However, this combination of characteristics works well in a variety of situations.

In contrast, the experiments in a standard undergraduate lab either validate a known experimental result (a measured value) or show or confirm a notion. The experiment is not unusual, and the conclusion is frequently predicted in advance. Students want to know if they gave "the correct answer." The experiment names convey exactly what will be done, leaving no space for exploration. The title of a guided-inquiry experiment based expressly on the POGIL technique is framed as a question, setting the stage for prediction and testing.

Each exercise begins with a question that serves as the foundation for the broader research. Each lab activity is related to one of the Learning Objectives. The time requirement portion includes two pieces of information: preparation time and lab activity length. The time estimate covers the time necessary to perform the experiment and analyze the results, as well as the time required for students to plan and carry out their investigations. The materials and equipment section provides all of the supplies and equipment required to conduct the experiments and the students' extended study. Although ready-made chemicals can be obtained for these activities, the Lab preparation section includes directions for preparing the solutions and assembling any materials that require additional preparation. The safety section describes the lab's safety practices. Instead of a standard Pre-Lab activity, the "Getting Your Brain in Gear" part is a series of questions that establish the foundation for the investigation's topics. Students must answer the pre-lab questions ahead of time. Building Model (where n is the model number; at least two models are produced and assessed in a lab activity), this is the approach for one portion of data collection in the lab, including integrated guiding questions or in-lab questions. In many situations, student groups perform comparable reactions with different substances or for varying amounts of time, then exchange their data to observe a broader range of findings. The data or symbolic representation gathered while developing the model is contained in the Model n section. Data may be arranged in a variety of ways, including graphs and tables. This data serves as the foundation for the analysis part. Analyzing model n is the part comprising guided inquiry analysis questions that help students through model-based discovery and concept development. Connecting to the theory part is a more detailed exposition of the theory that the students formed from the concepts established during the investigation's learning cycle activities. Finally, in the Applying Your Knowledge portion, students are given a topic or exercise in which they must apply the science skills and ideas learned during the research in a new or unusual situation.

Table 3

PASCO Scientific's Advanced Chemistry Laboratory Activity Components

TEACHER RESOURCES	STUDENT HANDOUT
Initial Question	Initial Question
Learning Objectives	
Time Requirements	
Materials and Equipment	Materials and Equipment
Prerequisites	
Lab Preparation	
Safety	Safety
Getting Your Brain in Gear	Getting Your Brain in Gear
Building Model 1*	Building Model 1*
Model 1*	Model 1*
Analyzing Model 1*	Analyzing Model 1*
Connecting to Theory	Connecting to Theory
Applying Your Knowledge	Applying Your Knowledge

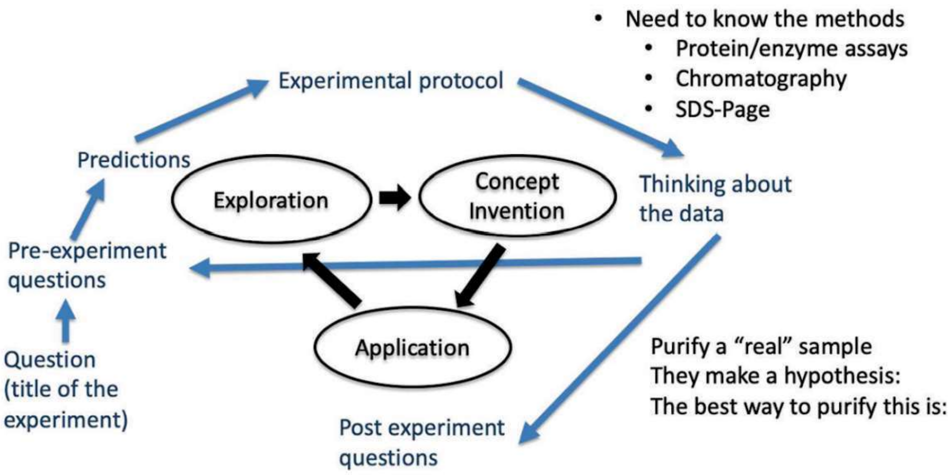
Note. Adapted from https://www.pasco.com/resources/lab-experiments/collection/32 Copyright 2021 by PASCO Scientific.

The POGIL method is used in the biochemistry labs at Auburn University. It is based on the model made by Hunnicut *et al. (*2015), which is shown in Figure 3. The POGIL Learning cycle is built on top of the methods used in the lab to make a guided inquiry, iterative learning method. The experiment is suggested in the form of a question, and the students then do some background reading to answer a set of "pre-lab" questions. At the end of these pre-lab questions, students should try to guess how the experiment will turn out. In other words, they've given an explanation. This is stressed throughout the semester. Then, the protocol is shown in its most basic form.

The students have to go through the process more than once before making a final version that can be tested (exploration and concept invention). Figure's cycle is done over and over until it can be used for a final inquiry (application).

Figure 3

POGIL Learning Cycle with the approach used in the Biochemistry laboratory at Auburn University



Note. From *Biochemistry Education from Theory to Practice*, by T. Bussey, K. Cortes, & R. Austin, 2019, ACS. Copyright 2019 by American Chemical Society.

There are two main types of POGIL activities: (1) Learning Cycle Activities, which help the student develop content knowledge through Exploration, Concept Invention, and Application, and (2) Application Activities, which deepen, refine, and connect the understanding of concepts already learned through the use of relevant process skills.

Online implementation of POGIL

Process-Oriented Guided Inquiry Learning (POGIL) is a proven technique for enhancing student learning and engagement in traditional classroom settings. However, with the rise of online learning technologies, there is a need to adapt POGIL techniques to suit the changing student demographic. The study of Trevathan and Myers (2013) presents a preliminary approach for adapting POGIL for use in tertiary courses delivered online. The authors first discussed the current technologies available for online teaching and compared their suitability for POGIL. They note that Web 2.0 technologies, such as wikis, blogs, and social networking, are particularly well-suited for POGIL, as they facilitate collaboration, interaction, and team building. They then described how they implemented POGIL techniques in an online third-year Information Technology course using Web 2.0 technologies. They used a wiki as a central platform for storing and sharing information, blogs for individual reflection and analysis, and social networking tools for group communication and collaboration. They also incorporated various online learning activities, such as online discussions, quizzes, and interactive simulations. They reported that the students in their course responded positively to the POGIL approach and the use of Web 2.0 technologies. They found that the online format allowed for more flexibility and convenience for both students and instructors, while still maintaining the benefits of POGIL, such as increased engagement, teamwork, and critical thinking.

Purkayastha (2019) particularly studied the implementation of POGIL in online courses. The study implemented POGIL in two online courses from the Health Information Management program and integrated POGIL practices into the course redesign by updating lecture slides and videos with POGIL activities and modifying the educational content. The results of the study showed that there is a statistically significant difference in the academic performance of students before and after the POGIL implementation, which suggests that POGIL can be effective in online courses. This study provides valuable insights into the potential of POGIL to improve student performance in online courses and highlights the importance of adapting instructional approaches to different learning contexts.

Another research, conducted by Rumain and Geliebter (2020), used a computerized experimental psychology laboratory that included POGIL. They created POGIL modules for the laboratories and held training for professors on how to adopt the method. The results showed that students who used the POGIL materials outperformed those who did not use them on both achievement assessments.

Benefits of the POGIL Laboratory

Because it contains the important traits of the other alternative atypical teaching approaches, the POGIL approach may be preferable to others. It has the following essential components: (1) a guided-inquiry structure for presenting activities; and (2) issue-based learning, with each activity beginning with a context-rich topic or model that students investigate. Structured exercises that direct students' thinking and reasoning are then used to guide them. Finally, inquiries, recommendations, and directions help them to consider various alternatives critically. (3) team-based active and collaborative learning (Hanson & Wolfskill, 2000). Students have a better comprehension and consolidation of the information by discussing it together. Finally, (4) the instructor serves as a facilitator, leading and assisting students in discovering information.

Hanson (2013) referenced multiple studies that showed that many students struggled with comprehending and applying concepts, determining importance, transferring skills within and between disciplines, and recognizing and improving the abilities required for success in specific courses, college, and professions. Poor performers retreat, and even the finest performers may withdraw if they are not stimulated. The lack of accomplishment discourages both students and educators.

To address this scenario and assist students in becoming better learners, it is critical to recognize that education consists of two components: content and process. Unfortunately, the process component is frequently overlooked. Education necessitates the structure of knowledge (content component) as well as abilities such as knowledge acquisition, utilization, and production (process component). As our knowledge base expands, society confronts more and more complicated challenges, and corporations seek technical improvements, the latter becomes increasingly vital. Those with well developed process skills will do best in these scenarios. Cognitive, social, and emotional domains can be used to characterize learning process skills. The most important for science education include information processing, critical and analytical thinking, problem solving, communication, teamwork, management, and assessment. A poll of industry managers and executives found that personnel with more substantial preparation in communication, team skills, associated usage of scientific sources, and problem-solving, without losing full preparation in core science ideas and practical abilities, performed better. As a result, these skills must be explicitly taught in tertiary-level courses to help students succeed in their studies, workplaces, and lives.

In POGIL, "process-oriented" refers to a focus on the process rather than the "content." The procedure assesses thinking and reasoning abilities, whereas the media used is content is content (the subject to be learnt). It has been suggested that the procedure is more important than the substance (Barbara & Geliebter, 2020). We aim to build and reinforce these reasoning abilities so that an individual with strong reasoning skills may apply them to any subject. Once students have developed these abilities, they will be able to apply them to the ever-changing information they will encounter. Students' process skills encompass cognitive and emotional processes for acquiring, interpreting, and applying information. The POGIL Project defined seven process skills as the emphasis of development in a POGIL classroom at the outset: teamwork, oral and written communication, management, problem-solving, information processing, assessment, and critical thinking.

In POGIL, on the other hand, "directed inquiry" indicates that we direct the learning process using well-thought-out and well-formulated questions. Today's curriculum promotes inquiry technique, and scientific instructors usually emphasize the relevance of learning processes like observation, categorization, and inference to science education (Basaga *et al.,* 1994). One may anticipate that exposing kids to inquiry experiences will cause certain changes in their cognitive behavior. According to Sund and Trowbridge (1973), the inquiry teaching technique allows students to engage in tasks such as observing, categorizing, recognizing issues, making hypotheses, creating experiments, and drawing conclusions. According to certain research, the inquiry technique has resulted in better science accomplishment. According to several researchers, the inquiry technique provided much higher accomplishment in science process skills than the traditional way. Traditional methodologies allow students to validate known results by providing extensive descriptions of the issues and equipment, as well as guiding students through the recognized protocols for carrying out experiments.

POGIL encourages critical and analytical thinking, problem-solving, reporting, metacognition, and individual accountability through learning teams, guided inquiry activities, and questions (Hanson, 2013). These are the tools you can use to improve your process skills and learn about the subject. In this POGIL structure, students work in learning teams to learn and understand more through guided inquiry. They do this by evaluating facts, models, or examples and answering critical-thinking questions.

They use what they've learned in exercises and problems, present their results to the class, think about what they've learned, and evaluate how well they did and where they could improve. Students must do more exercises and problems and read relevant parts of a textbook or other reference material to help them remember what they have already learned and to encourage them to take responsibility for their own learning.

POGIL and achievement

Research to date shows that when POGIL is used, students demonstrate better than with traditional instruction in terms of learning and retention (Farrell *et al.*, 1999; Hanson & Wolfskill, 2000; Moog & Spencer, 2008; Moog *et al.*, 2006; Villagonzalo, 2014; Bug-os & Caro, 2019). Another research examined the course grades of Franklin and Marshall College General Chemistry students before and after applying the POGIL instructional style. The findings indicated that using POGIL reduces the amount of students who obtain a D or F or quit from the course.The findings are the same for studies done on POGIL laboratory in different courses. In the Green Plastics POGIL Laboratory, Kim's (2014) study revealed positive responses to the POGIL lab environment. Students could effectively acquire a conceptual understanding of the subjects, obtain some of the benefits, and realize the significance of preparedness and assistance of their team members during the activities. In the organic chemistry POGIL laboratory by Schroeder & Greenbowe (2008), students' performance improved compared with students in past traditional classes.

In a recent research that used a POGIL-based curriculum for the experimental psychology laboratory, students who used the POGIL outperformed students who did not use it on achievement exams (Rumain & Geliebter, 2020). These findings are comparable with prior POGIL findings in the chemistry sector for the study of organic chemistry work taught utilizing POGIL (De Gale & Boisselle, 2015). Idul and Caro

(2021) evaluated the effect of POGIL on increasing student academic performance in the Philippines and discovered a substantial difference between the POGIL (satisfactory) and non-POGIL groups (fairly satisfactory).

However, there are findings that students that are exposed to POGIL marginally affect student achievement (Walker & Warfa, 2017). And in a study made by Eaton (2006) in an introductory college chemistry course using POGIL, students performed below those in the control group on the exam. This suggests that care should be taken when implementing student-centered cooperative learning in introductory college chemistry courses. Also, Ahmad's (2007) study showed that the quantitative data about achievement showed no significant difference between groups; students who used POGIL were not different from those who didn't.

POGIL and attitude

Several studies have found that when POGIL is employed, students' attitudes are much higher than in non-POGIL courses (Bug-os & Caro, 2019). Fitria and Hidayah (2021) found that the POGIL learning paradigm had a favorable influence on students' observation abilities and scientific attitudes.

Vishnumolakala *et al.* (2017) discovered that post-POGIL views of undergraduate chemistry students' attitudes, self-efficacy, and experiences were statistically substantially higher. In contrast, data from a general chemistry and an organic chemistry course on students' attitudes toward chemistry show little to no influence, despite positive trends favoring POGIL students (Chase *et al.,* 2013).

POGIL and motivation

According to Aristiyarini *et al.* (2022), the POGIL model is effective in increasing learning motivation and mastery of the concept of buffer solutions for students. Similar results were concluded by several studies that chemistry students who were taught using POGIL compared to those taught using traditional learning (Yuliastani *et al.*, 2018; Purnama & Rahayu, 2023). Walker and Warfa (2017) found that using POGIL at these different school levels improves students' academic achievement, critical thinking skills, problem-solving, attitudes, self-efficacy, scientific literacy, self-regulation skills, students' performance, mathematical connection ability, mathematical reasoning capabilities, argumentation, students' chemistry learning motivation, and scientific explanation.

POGIL and confidence

Students exhibited increased interest and confidence in learning chemistry, scored significantly higher in the POGIL method than in traditional methods, and improved process skills throughout the course. When the POGIL technique was initially used at Stony Brook in the fall of 1994, these findings were acknowledged, where course assessment revealed that: most students reported that interest and confidence in chemistry increased, instructors received positive student ratings, revealing positive student attitudes, examinations improved, and process skills are improved throughout the semester.

Several studies showed that the tests of significance made students feel better about their academic abilities (De Gale & Boisselle, 2015). Some studies found that there was no significant difference between how confident students were in their ability to understand and use organic chemistry before and after taking part in the POGIL activities (Ahmad, 2007).

Real-Life Chemistry Laboratory Experience

Chemistry's most valuable contribution is to prepare students to deal coherently with global concerns. Chemistry can assist individuals better understand their issues by providing facts and ideas that describe the issue, quantify its severity, and explain its causes. They may then use this knowledge to teach new procedures and materials and to aid in issue solutions. Reports and ideas for upgrading the chemistry curriculum have resulted from discussions in the chemical education community. The proposals are about teaching chemistry in the context of real-life occurrences. This is offered as a method of increasing student motivation. Furthermore, it is suggested that real-world events stress the multidisciplinary aspect of chemistry and its relevance to the students' life.

One of the most significant challenges in chemistry education is motivating pupils when they are learning chemical topics (Zoller & Pushkin, 2007; Marks & Eilks, 2010; Parchmann *et al.,* 2006). Furthermore, several studies have shown that if students can identify how learning activities apply to real life, they are more likely to be motivated and thrive in the science topic they are researching (Hofstein & Kesner, 2006; Hofstein & Lunetta, 2004). Chemistry and technology situations in everyday life should be real and relevant. It is anticipated that a context-based curriculum can increase students' interest in and attitudes toward science, particularly chemistry (Erdogan, 2007; Millar, 2006). These stages are critical for learning to take place (Osborne & Dillon, 2008).

These ideas were included into chemistry through teaching analytical chemistry and environmental chemistry. A curriculum was created in which students learned about environmental concerns such as drinking water quality and the greenhouse effect (Mandler *et al.,* 2012). The results demonstrate that the kids' awareness of environmental concerns increased significantly. The unit, according to all of the students, transformed their everyday perspectives of environmental concerns and boosted their comprehension. Furthermore, more students stated that it inspired them to learn chemistry in particular; they liked the idea of being able to discover things on their own. According to the researchers, such a program might encourage education for sustainable growth. Students learnt chemistry concepts through experimenting with real-world environmental challenges utilizing cutting-edge technology. Furthermore, multiple instructional modalities (group activities, collaborative learning, role-playing, and solo projects) were blended. Students said that they gained a more thorough understanding of the nature of scientific processes and were more skeptical of evidence obtained through scientific approaches, particularly in laboratory activities.

The results match the study that Andrews and his colleagues (2020) did at home during the COVID-19 pandemic as part of their General Chemistry Laboratories. Most of the class had a good experience with the labs: 74% thought they learned more from the labs than they would have otherwise; most thought the labs helped them understand what they had learned in class; 62% said they enjoyed this unusual lab experience; most preferred these labs to the more routine ones they were used to on campus; and 53% thought they learned more from the labs than they would have otherwise. But half of the people who answered said that these experiments took longer than on-campus labs. Students who were still in dorms or who lived in small spaces said that the experiments needed a lot of counter space, which they did not have. Students also found it hard to balance the time needed for at-home labs with their other classes. Mandler and his colleagues' (2012) Green Plastics Laboratory, on the other hand, only used safe household items and no special equipment. In the lab, you learned about things like pH, acid-base titrations, buffers, solubility, phase equilibria, and thermodynamics.

Theoretical Framework

This study was influenced by two evaluation theories: Formative Evaluation and Developmental Evaluation Theory. Scriven (1967) developed the first hypothesis, which consists of the following steps: 1) enhancing, 2) standardizing, and 3) enhancing. Flagg (1990) defined four stages of formative evaluation: phase one (planning), phase two (design), phase three (production), and phase four (implementation). A requirements assessment in Planning looks at how people think, what they do, what they know, what they can do, and what they expect. The design gives options for the specific content, goals, and ways of teaching. The production is made up of decisions about the appeal, understandability, user-friendliness, pace, and iconography. Lastly, the Implementation phase is finished to help improve support materials like print materials or to let designers know that changes need to be made. Patton (2011), on the other hand, underlined that one of the ways for measuring the efficacy of a program is to produce feedback and learning. As a type of evaluation, Hattie and Timperley (2007) emphasized that feedback is one of the most effective influencers on learning and accomplishment. However, the influence might be either favorable or bad. Feedback from teachers or professionals in the subject is frequently utilized to enhance instructional materials. Race (2000) says that feedback is one of the most important things to look at when evaluating educational materials.

POGIL-based Laboratory-at-home provides support that ensures that learning is not just reading alone but also an active process of learning. This is based on Brunner's (2015) Scaffolding theory, which says this is important to give students enough help when they're just starting to learn a subject. It is also based on Vygotsky's theory of social development, which says that a child's social interactions can affect and guide his or her cognitive growth and ability to learn (Gowrie Marketing, 2022).

Since the POGIL Laboratory-at-Home includes group work, this theory also says that children take in and learn from the beliefs and attitudes they see around them.

Piaget's theory of cognitive development and Johnstone's theory of cognitive load were used to explain why some students did better on tests when they were taught with POGIL than when they were not. This study was based on two theories: the Cognitive Development Theory and the Information Processing Model. The Cognitive Development Theory (CDT) looks at how the mind changes as it goes through the different stages of cognitive development. This theory was created by Jean Piaget in 1973. It says that a learner builds on what he or she already knows to increase cognitive development and complexity growth with more interactions. This leads to more complex understandings, cyclical growth, and maturity (Piaget, 1973). Using POGIL pedagogy to improve students' higher-level reasoning skills would support the Cognitive Development Theory, which says that learning is hierarchical and depends on what was learned before. This would help students learn their subjects better.

The Information Processing Model (IPM) was created as a result of Johnstone's (1997) research and the improvement of the Cognitive Load Theory (Chandler & Sweller, 1991), which investigates short- and long-term memory. Johnstone (1997) looked into how the Cognitive Load Theory (CLT) applies to learning about chemistry. He saw that when students tried to take in too much information at once, which often happens in traditional teacher-centered lecture teaching, they came up with an alternative idea (AC) about the chemical issue at hand. The IPM points out how ineffective traditional, teacher-centered teaching methods are. This makes me wonder if a student-centered method might be better for teaching certain chemical-related topics (Johnstone, 1997). Using POGIL pedagogy to improve Biochemistry results would support the IPM that student-centered pedagogies, like POGIL, are better at helping students understand concepts than traditional, teacher-centered pedagogies.

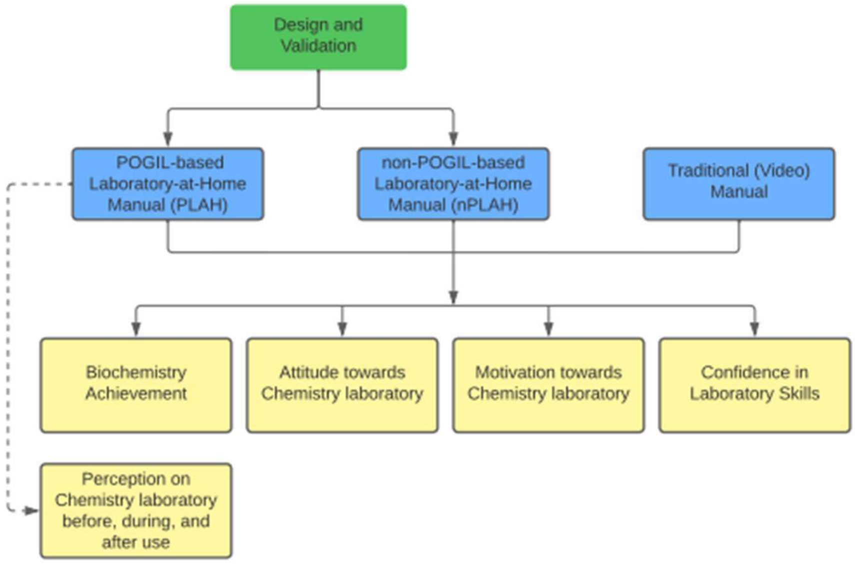
Conceptual Framework

The schematic paradigm of the conceptual framework for this study is shown in Figure 4. This study is founded on the assumption that when a laboratory manual is used, students perform better in class, and their attitude, motivation, and confidence in laboratory skills improve. In particular, the effect of the PLAH manual is compared to nPLAH and Video manuals.

The study used the Input Process-Output Model. This study used the Analysis, Design, Development, Implement, Evaluate (ADDIE) approach in formulating research tools and manuals in Biochemistry (Phase 1 and 2), as shown in Figure 1. For Phase 1, input includes analysis which requires frameworks as the basis for the content domains of the instruments. The process includes design, development, implementation, and evaluation. Designing involves breaking down the required domains into factors, making a table of specifications, deciding on the response format, and writing the items. Developing is creating a prototype of the instrument. Implementation involves pilot testing. Evaluation involves the assessment of validity and reliability. The output would be valid and reliable research instruments: Instructional Material Evaluation Tool for Experts and Instructors, Achievement Test, Instructional Material Evaluation Tool for Students, Attitude, Motivation, and Confidence in Laboratory Skills Questionnaire, and Perception Questionnaire and Perception Interview Guide Questions.

Figure 4

The conceptual framework



Note. The schematic paradigm of the conceptual framework for this study.

For Phase 2, analysis requires mapping out the competencies needed in General Biochemistry, specifically on biomolecules. Designing involves creating content outlines, choosing activities, mapping out time frames for each activity, creating assessment questions, and adapting the POGIL format. Developing is creating a prototype of the manual. Implementation involves pilot testing. An evaluation involves the validation of experts and students using instructional material evaluation tools. The output would be evaluated Laboratory-at-home manuals, one POGIL-based and the other non-POGIL.

Input for Phase 3 is the characteristics of students. The process includes a pre-achievement test, attitude, motivation, and confidence in laboratory skills survey before utilizing the developed PLAH, nPLAH, and Video manuals, and post-achievement test, and attitude, motivation, and confidence in laboratory skills survey. Analysis of the pre-and post- results of the different groups was compared. Further, the perception of students and instructors in the laboratory before, during, and after the utilization of the PLAH manual were gathered through interviews. The output of the study is the effect of the manual on students' achievement, attitude, motivation, confidence in laboratory skills, and perception of the use of the PLAH manual.

Hypotheses of the Study

The following hypotheses were formulated based on the research questions:

1. There is a significant difference on the mean achievement scores of students before and after using the PLAH, nPLAH, and Video manual.
2. There is a significant difference on the mean attitude scores of students before and after using the PLAH, nPLAH, and Video manual.
3. There is a significant difference on the mean motivation scores of students before and after using the PLAH, nPLAH, and Video manual.
4. There is a significant difference on the mean confidence in laboratory skills scores of students before and after using the PLAH, nPLAH, and Video manual.
5. There is a significant difference on the mean achievement scores of students among PLAH, nPLAH, and Video groups.
6. There is a significant difference on the mean attitude scores of students among PLAH, nPLAH, and Video groups after exposure.
7. There is a significant difference on the mean motivation scores of students among PLAH, nPLAH, and Video groups after exposure.
8. There is a significant difference on the mean confidence in laboratory skills scores of students among PLAH, nPLAH, and Video groups after exposure.
9. There is a significant relationship between the achievement of the students and their attitude.

10. There is a significant relationship between the achievement of the students and their motivation.
11. There is a significant relationship between the achievement of the students and their confidence in laboratory skills.

Definition of Terms

To facilitate the reader's understanding, the following terms were defined based on how they were used in the study.

Achievement – This refers to the Biochemistry topics or concepts that the student learns during the implementation of the study. This is measured using the students' pre- and post-tests amongst the three groups.

Attitude – This refers to the students' favorable or unfavorable reactions or responses to the items in attitude survey based from Chemistry Laboratory Work Questionnaire. The students' attitudes are quantified by means of their total score.

Confidence in laboratory skills – This refers to the student's confidence level for a general or particular laboratory skill on a 5-point scale. This is measured using the students' pre- and post-scores amongst the three groups (PLAH, nPLAH, Video).

Education profile – This refers to the learning platforms used, internet sources, and prerequisite grades of students.

Expert – For content experts, this refers to a faculty member who specializes in Chemistry or science education and has a rank of a professor or been in the academe for more than ten years and has a master's or doctoral degree in the field of science or chemistry education. Instructional materials (IM) experts, test experts, and psychometricians are the other consultants.

Instructor – An individual who handles or teaches Biochemistry during the implementation of the study.

Laboratory-at-home manual – This is the work-text to be developed in this study, and it refers to a material to assist the instructor in handling the Biochemistry laboratory. It includes experiments using materials that can be easily found at home.

Motivation – This is defined as the forces that account for the arousal, selection, direction, and continuation of behavior. This refers to the students' favorable or unfavorable reactions or responses to the items in motivation survey based from Chemistry-specific version of the academic motivation scale (AMS) and Chemistry Motivation Questionnaire. This is measured using the students' pre- and post-scores amongst the three groups.

Non-POGIL Laboratory-at-home manual (nPLAH) – This refers to the developed laboratory-at-home manual wherein the format is a conventional laboratory manual without the elements of POGIL.

Perception – This refers to the beliefs of the students and instructors of the chemistry laboratory before, during, and after the use of the POGIL-based laboratory-at-home manual.

POGIL – This refers to Process Oriented Guided Inquiry Learning, a process-oriented and research-based pedagogic strategy. Its fundamental components are active engagement, guided inquiry questions, and process skills.

POGIL-based Laboratory-at-home manual (PLAH) – This refers to the developed laboratory-at-home manual where the format is based on the POGIL laboratory. It consists of pre-laboratory exercises, laboratory tasks, and post-laboratory applications. The Learning cycle exploration, concept invention, and application are incorporated.

Video manual – This refers to the traditional Biochemistry manual used by the University with links to the video recordings of past students doing the experiments.

Chapter III

METHODOLOGY

This chapter presents the research design, the participants, instrumentation, description of the intervention, data collection, and data analysis procedure.

Research Design

A quasi-experimental pre-test post-test control group design was employed in this study. For Phase 3 (Evaluation), the pre- and post- design was used in determining the achievement, attitude, motivation, and confidence in laboratory skills of students. This is to compare the effects on students exposed to the following manuals: PLAH (X1), nPLAH (X2), and Video (X3).

Table 4

The research design

Groups	Pre-test/ survey	Intervention	Post-test/ survey
PLAH	O_1 O_7	X_1	O_2 O_8
nPLAH	O_3 O_9	X_2	O_4 O_{10}
Video	O_5 O_{11}	X_3	O_6 O_{12}

Note. The first group (PLAH) was exposed to X1 while the second group (nPLAH) was exposed to X2, and the third group (Video) acted as a control, X3.

All groups were pre-tested using validated Biochemistry achievement test (O1, O3, and O5, respectively) and attitude, motivation, and confidence in laboratory skills questionnaire (O7, O9, and O11, respectively) at the start of the semester before implementing the interventions. After the utilization of the manuals, post-tests and surveys were administered. The research design is illustrated in Table 4.

Students and instructors' interviews before, during, and after using the PLAH manual were done to validate and complement findings in Phase 2. This aspect helped the researcher to discuss, interpret, and analyze the data collected and triangulate.

Meanwhile, qualitative and quantitative approaches were employed in developing the module.

The Sample

For the evaluation of the manuals (Phase 3), the second-year college students at Cagayan State University taking Biochemistry subject under Bachelor of Science in Medical Laboratory Science (BSMLS) during the first semester of the AY 2021-2022 are the study participants. The University was selected for ease of observation and monitoring of the progress of the study. Instructors included are those who (a) are teaching BSMLS Biochemistry for 1st semester of the academic year 2021-2022, (b) are teaching non-Chemistry majors, and (c) are teaching at least two classes of Biochemistry with laboratory. Students included are those (a) enrolled in Biochemistry for 1st semester of the AY 2021-2022, (b) non-Chemistry majors, and (c) enrolled in Biochemistry for the first time. Excluded students are Chemistry majors, course repeater, and those in modular learning mode.

Table 5

Assignment of interventions

Groups	Instructor 1	Instructor 2	Instructor 3	TOTAL
PLAH	C1 (46)	C4 (50)	C6 (42)	138
nPLAH	C2 (46)	C5 (47)	C7 (42)	135
Video	C3 (44)			44
TOTAL	136	97	84	317

Note. The first instructor has three classes, while the second and third instructors have two classes each.

All instructors and students of the seven (7) Biochemistry classes available for the semester were included. Multi-stage sampling was used in assigning the interventions used. The primary unit is the instructors, and the secondary units are the classes. The PLAH and nPLAH interventions were randomly assigned for instructors handling two classes, while PLAH, nPLAH, and video interventions were assigned for the instructor handling three (3) classes.

Apart from the CSU-CAT exam used to establish the homogeneity of the participants, the profile of students from each group was done to describe the groups and further establish the equivalence of the groups. The demographic, economic, and educational baseline characteristics of the participants are collected before receiving any treatment. Equivalency was established using the Chi-square test to compare the baseline characteristics of the three (3) groups.

Data Gathering Instruments

The validity of the questions in the research instruments was checked by ten (10) experts: Biochemistry content experts (5), Instructional Material experts (2), test experts (2), and a psychometrician. Experts, instructors, and students evaluated the proposed manuals. Four (4) experts were those (a) teaching Chemistry subjects for at least five years, (b) with at least ten years of teaching experience and (c) have MS or Ph.D. in Science Education, and (d) has written laboratory manuals.

Biochemistry content experts validated the content and constructs of all five (5) instruments. Further, instructional material experts validated the “Instructional Material Evaluation Tool for Experts and Instructors” and “Instructional Material Evaluation Tool for Students”; test experts validated the “Achievement Test in Biochemistry”; and a psychometrician for the non-cognitive instruments, “Student Profile Questionnaire,” "Attitude, Motivation, and Confidence in Laboratory Skills Questionnaire for students" and "Perception Interview Guide Questions."

Student Profile Questionnaire

A student profile survey was administered to the students before the interventions were given. This survey is composed of three parts. The first part is related to the demographics of the students, such as age, sex, and address. The next part is on the economic profile, particularly the parents' major source of income, monthly household income, and living situation. The last part is related to their education, questions including learning platforms used, source of internet used for learning, and pre-requisite grade. Their ability to edit videos was also included. The results of the student profile survey were used in groupings of the students for PLAH and nPLAH groups. Equivalency was established using the Chi-square test to compare the baseline characteristics of the three (3) groups: PLAH, nPLAH, and Video.

Instructional Material Evaluation Tool for Expert-Instructors

In order to have a basis for determining the acceptability of the developed manuals, an instructional material evaluation tool for experts and instructors was designed and developed by the researcher. It comprises a series of questions that assess the manual's attainment of objectives, content, format and language, presentation, usefulness, originality, clarity, and appeal. It made use of a structured questionnaire using the Likert format based on Laroza (2015), POGIL (2021), and Catuday (2019). In this survey type, five choices were provided for every question or statement. The choices represented the degree of agreement each respondent had on the given question. Some modifications to the items were made to better align them with the purpose of the study. This tool was content validated by five Biochemistry experts (Content validity ratio= 1.00) and two IM experts further the checked structure.

Biochemistry Achievement Test

Participating students took a 90-item multiple choice type test in Biochemistry to determine the effectiveness of the intervention. A copy of the achievement test is presented in Appendix L. The achievement test was administered as a pre-test to gather baseline information on what the students knew prior to their exposure to the instructional manual and as a post-test to measure the students' achievement after utilizing the manuals. Most of these questions were problems requiring an understanding of basic definitions, concepts, and applications in Biochemistry. The test covered the topics of General Biochemistry on nucleic acids, proteins, enzymes, carbohydrates, and lipids. The achievement test was designed and developed by the researcher. In developing the achievement test, the researcher adhered to the standard procedures for developing and validating a test, beginning with the developing test specifications (see Appendix K). The instrument was content validated by Biochemistry content experts (CVR=1.00) and format validated by test construction experts (2) from Cagayan State University. It was pilot tested on a small group of students with similar characteristics as the respondents to test for reliability. From 100 items, only 90 items with alpha >0.70 were included in the final instrument. The reliability coefficient of the researcher-made achievement test was estimated at 0.742 using Cronbach alpha. Statistical Package for the Social Science (SPSS) software was used to aid in the item analysis.

Attitude, Motivation, Confidence in Laboratory Skills Questionnaire

For attitude, motivation, and confidence in laboratory skills, the study adapted questionnaires. The questionnaire consists of three parts. Part 1 on attitude is adapted from the Attitude and Interest to Chemistry Laboratory Work Questionnaire by Hofstein *et al*. (1976). Part 2 on motivation is based on the questionnaires of Liu *et al*. (2016) on the Chemistry-specific version of the academic motivation scale (AMS) and Salta & Kouglougliotis' (2015) Chemistry Motivation Questionnaire. Part 3 on confidence in laboratory skills is adapted from Arnous & Ayoubi (2018) on Chemistry Laboratory Anxiety Instrument (CLAI) and Kennepohl & Shaw's (2010) Confidence in Laboratory Skills Survey. This was given before and after the interventions to determine if there was a change brought about by the utilization of the manuals. For each question, students were asked to rate their attitude, motivation, or confidence level on a five-point scale. The instrument was content validated by Biochemistry content experts (CVR=1.00) and further validated by a psychometrician from Cagayan State University. It was pilot tested on a small group of students with similar characteristics as the respondents to test for reliability. Only items with alpha >0.70 were included in the instrument. The reliability coefficient of the questionnaire was estimated at 0.702 using Cronbach alpha using SPSS.

Instructional Material Evaluation Tool for Students

Unlike the IM Evaluation tool for experts and instructors, the Instructional material evaluation tool for students focuses only on content, format and language, clarity, and appeal. It made use of a structured questionnaire using the Likert format based on Laroza (2015) and Catuday (2019). In this survey type, five choices were provided for every question or statement. The choices represented the degree of agreement each respondent had on the given question. Some modifications to the items were made to better align them with the purpose of the study and be suitable for the evaluating the students. This tool was also validated by five Biochemistry and two IM experts. This tool was also pilot tested on a small group of students with similar characteristics as the respondents to test for reliability. Only items with alpha >0.70 were included in the instrument. The reliability coefficient was estimated at 0.704 using Cronbach alpha. This tool also includes a qualitative part where students were asked to list unclear words, figures, tables, and suggestions.

Perception Interview Guide

The student perceptions of the laboratory guide questions are adapted from Berger (2015). It consists of three parts: before using the manual, after doing three (3) modules, and after using it. The first part consists of 10 open-ended questions where students describe their previous Chemistry laboratory experience, and this is conducted at the beginning of the course. The second part consisted of nine (9) open-ended questions and was conducted six weeks after the start of the course, while the third part consisted of eight (8) questions and was conducted after ten weeks. Students for the 2nd and 3rd parts describe their Chemistry laboratory experience using the PLAH manual.

The instructor's perception of the laboratory guide questions is adapted from Bautista and Boone (2015). It consists of three parts, wherein each part included 3-7 open-ended questions which reflect specifically on their Chemistry laboratory experiences and the perceived effect on their confidence regarding teaching Chemistry laboratory. The interviews are conducted similarly to that of the students: before using the manual, after three (3) experiments, and after using the manual.

In the qualitative analysis, the interviews of both students and instructors were used to determine the difficulties, progress, and effectiveness of the using the manual used in this study.

The Intervention

Biochemistry manuals are the interventions that were utilized in this study from September to December 2021. The first group of students used the POGIL-based laboratory-at-home (PLAH) manual, while the second group used the non-POGIL laboratory-at-home (nPLAH) manual. The third group used the traditional laboratory manual with video demonstrations. The manuals were given through the CSU Learning Management System (LMS) at the start of the semester so that the researcher could monitor the student and instructor activities.

On the first day of the semester, the manual/s and instructions were presented to the instructors and the students. The learners exposed to the interventions had undergone an orientation on how the manuals are used. In this phase, the researcher discussed the roles of the instructor and the students, the timeline, and the outputs. Another pre-implementation step is the assignment of groups and roles. Students were divided into groups of at most five (5) students each in all interventions.

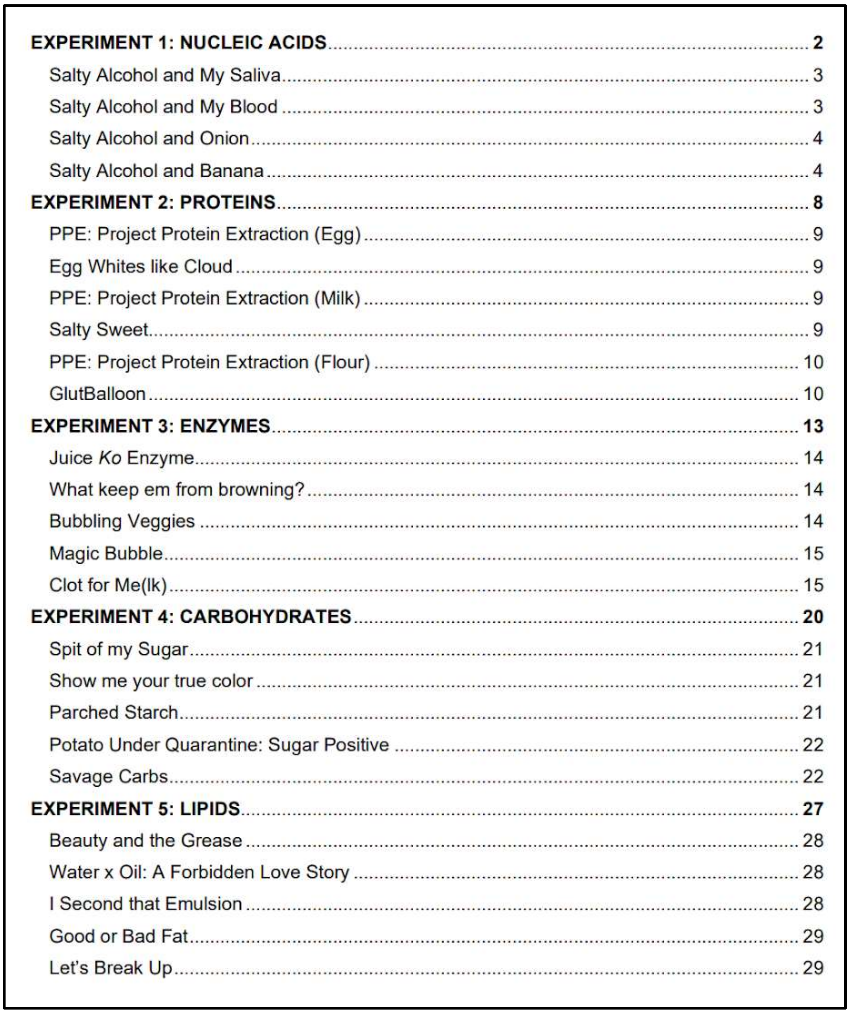
Each laboratory module should be completed by each group two weeks after the lecture on the specific biomolecule has been discussed. For instance, if the instructor finished her lecture discussion on nucleic acids on September 1, the students shall do all activities under Module 1 and submit their reports by September 14.

Non-POGIL Laboratory-at-home (nPLAH) Manual

The existing course syllabus in General Biochemistry served as the basis for developing the instructional materials. Each experiment consists of short activities, as shown in the table of contents of the manual (Figure 5).

Figure 5

Non-POGIL Laboratory-at-home Manual Table of Contents



Note. The laboratory-at-home manual consists of five experiments on five topics: nucleic acids, proteins, enzymes, carbohydrates, and lipids.

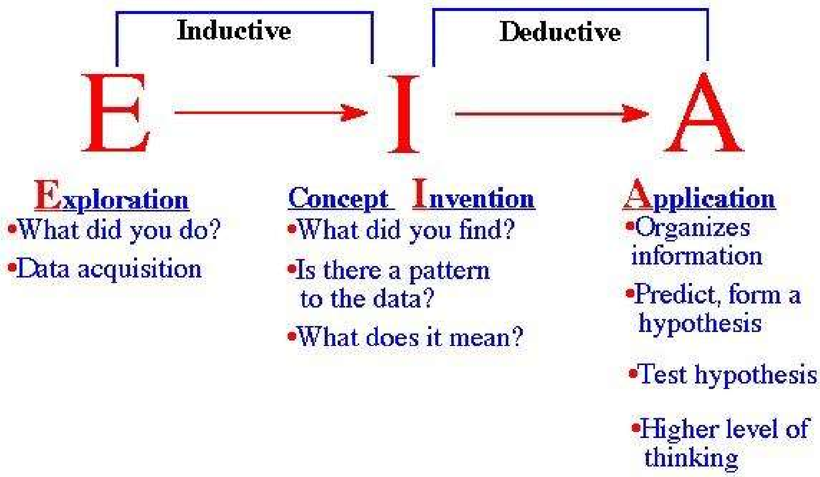
The conventional parts of a laboratory manual: are objectives, background, materials, procedures, and conclusion. However, the experiments are designed only to utilize safe household items, and no special equipment is needed (see Appendix D).

POGIL-based Laboratory-at-home (PLAH) Manual

PLAH manual is similar to the nPLAH manual but uses the POGIL laboratory format (see Appendix C). This format follows a three-stage (E, I, A) Learning Cycle Approach, as seen in the figure below.

Figure 6

POGIL Laboratory Learning Cycle



Note. From *What is Process-Oriented Guided Inquiry Learning*, by Project Kaleidoscope, n.d. https://serc.carleton.edu/sp/pkal/pogil/what.html

The worksheets are thoughtfully designed to adhere to the learning cycle paradigm. There is a focal question and a collection of questions where students submit preliminary solutions during the pre-lab session. For instance, in the first module on "How are you able to extract DNA?", there are four pre-laboratory questions as shown in Appendix C (page 6 of the PLAH Manual). Students perform reactions and/or gather data to test these hypotheses, which are subsequently aggregated and assessed using post-laboratory guided-inquiry questions. The POGIL laboratory focuses on experimentation rather than verification. There might be distinct substrates, reagents, circumstances, or reactions that work and those that do not. The scientific approach is paralleled in this learning experience. During the experiment, five-person groups work on an assigned Model. This might be done remotely since each group member has a role, with typical functions specified by Farrell *et al.* (1999). The manager ensures that tasks are completed, the scribe records the replies of the groups, the reflector watches and notes group dynamics, and the presenter presents group responses with the class via online platforms. Finally, the presenters would summarize the activity by presenting their groups' work in a 15-minute movie uploaded asynchronously by the video editor. The experiment itself serves as background material, while the critical thinking questions are intended to lead students through the process of unlocking and understanding the core principles represented in the experiment.

Table 6.1

PLAH Manual and the corresponding POGIL learning cycle aspect

Manual Experiment Component	POGIL Learning Cycle Aspect	Process Skill of the PLAH Manual
Title	Motivation	
Pre-lab session	Motivation	
	Exploration	Critical Thinking
Experiment	Exploration	Teamwork
Guided Inquiry-Directed Questions (In-lab questions)	Exploration *(What did you do?)*	Information Processing
Post-lab session	Exploration *(Data Acquisition)*	Oral and Written Communication Management
Guided Inquiry-Convergent Questions	Concept Invention *(What did you find? Is there a pattern to the data? What does it mean?*	Assessment Problem-Solving

Guided Inquiry-Divergent Questions	Application (Organization information) (Predict and form a hypothesis) (Test hypothesis)	Critical Thinking

Note. The components of each module of PLAH emphasizing the POGIL Learning Cycle Aspect and Process Skills Involved.

The difference between PLAH, nPLAH, and Video Manuals

For the PLAH manual, as seen in Table 6, the title of each worksheet is a focus question. For instance, in the PLAH manual the title of the first module is ""How are you able to extract DNA?", while for nPLAH and Video manuals the title is "Experiment 1: Nucleic Acids". In the experiments, observation or data collection develop theoretical construction rather than confirming a concept. These involve minimal instructor output. The experiments are designed for the students to get reliable data. The questions in the post-lab session guide students to appropriate conclusion and reinforces the developed concept through the application (Divergent questions). It also guides the student in recognizing what has and has not been learned from the experiment through appropriate questions.

There are three sorts of questions in each module. Directed questions concentrate on the students' recognition of certain parts of the experiment, with the response acquired directly from the experiment. Convergent questions help students put the facts together to get a general conclusion or comprehension of the ideas, whereas divergent questions are open-ended questions that challenge students to build on their new knowledge by contemplating, further researching, and generalizing (Haryati, 2018). Most importantly, the methods used to perform the experiment adhere to the constructivist learning cycle while utilizing a range of process skills. The presenters would share their groups' work through a 15-minute video and data sheet asynchronously through the LMS discussion forum a week before the submission of their reports.

Each experiment for the PLAH Manual promotes several process skills. As seen in tables 6.1 and 6.2, only the PLAH manuals has pre-lab questions and divergent questions which involves critical thinking skills. For the conduct of the experiment, the PLAH Manual variation of experiments in a class, and variation of roles within a group. The convergent questions involves information processing while convergent questions involves assessment and problem-solving skills.

Table 6.2

Difference between PLAH, nPLAH, and Video Manuals

Manual Experiment Component	PLAH	nPLAH	Video
Title	In focus question form	Not in question form	Not in question form
Pre-lab session	Background with focus question Pre-lab questions	Background	Background
Experiment	Each group is assigned a variation/ experiment (different groups have different experiments) Every group member has a role (manager, video editor, scribe, presenter, and reflector)	All groups will conduct all the experiments	All groups will watch all the experiments uploaded
Guided Inquiry-Directed Questions (In-lab questions)	Questions that direct students to specific aspects of the experimentt	NA	NA
Post-lab session	Pool data from all groups Group presentation Discussions with other groups	Reflection/ Conclusion	Reflection/ Conclusion
Guided Inquiry-Convergent Questions	Questions that guide students to develop a concept similar to the scientist.	NA	NA

Guided Inquiry-Divergent Questions	Questions that have students expand the concept in new ways.	NA	NA

Note. The difference between PLAH, nPLAH, and Video manuals emphasizing the manual experiment components.

For the nPLAH Manual, each module contains almost all that the PLAH Manual has except for all groups having similar experiments to do and that it only has two to four questions as post-lab reflection or conclusion. The Video manual is the traditional Biochemistry laboratory manual with YouTube links to demonstrations done by past students. For all manuals, the expected results are not explicitly written. However, these are tackled during feedback and post-laboratory discussion with their instructors.

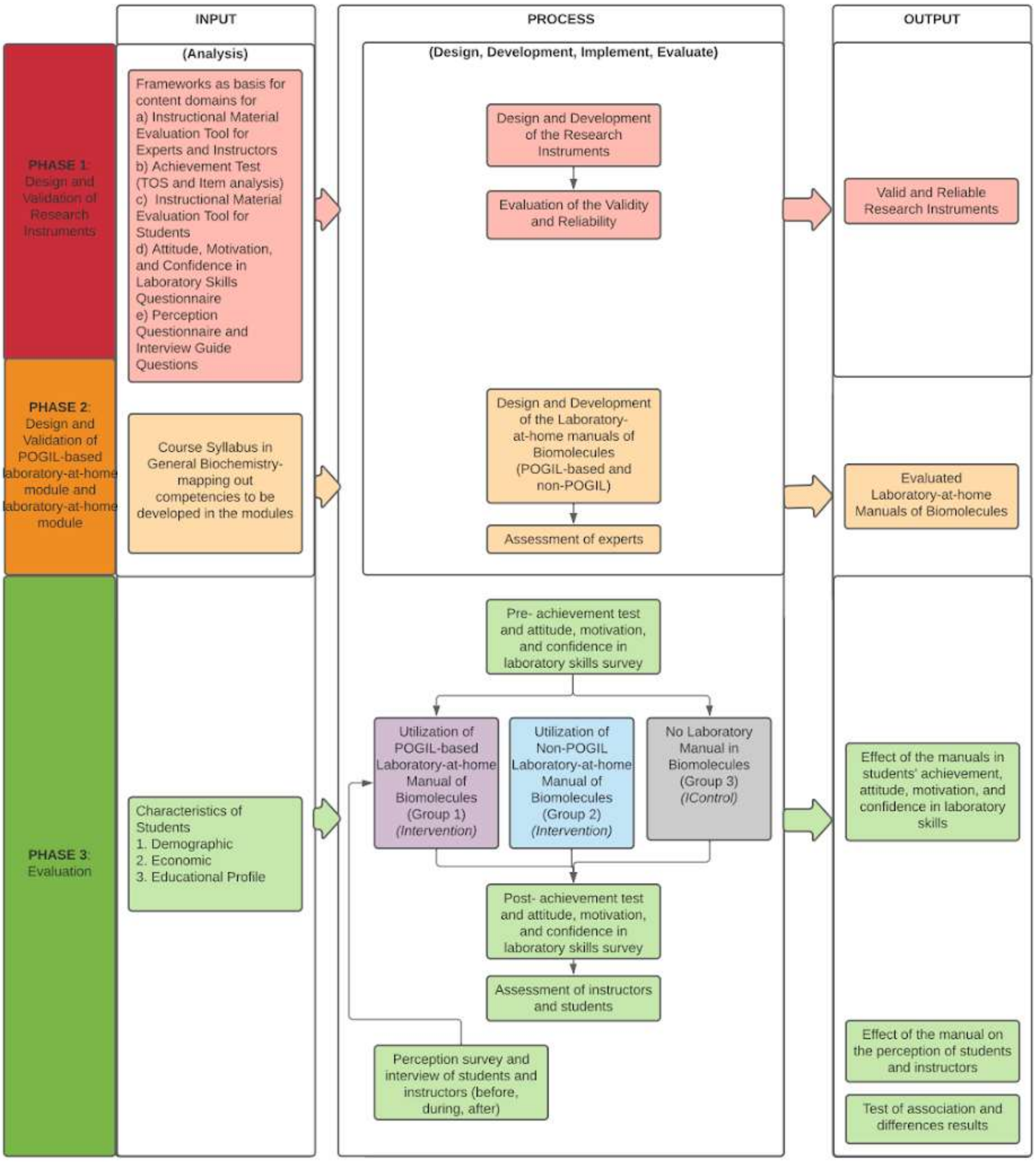
Data Collection Procedure

Permission to conduct the research was sought from the University President, Campus Executive Officer, and College of Allied Health Science Dean of Cagayan State University. Ethics clearance application was directed at the Research Ethics Board of the Region 2 Trauma Medical Center (REB-R2TMC).

The first phase of the study covers the design and validation of the research instruments to be used in developing and assessing the effectiveness of the module. The design was based on several questionnaires. Data for the validity of the questionnaires and interview guide were obtained from experts. Experts were given hardcopy of the instruments with “essential,” “useful but not essential,” and “not necessary” choices in each item. The content validity ratio (CVR) was used to determine the validity of the instruments. The Achievement Test, Attitude, Motivation, and Confidence in Laboratory Skills Questionnaire, and IM Evaluation Tools were pilot tested to those with similar characteristics as the respondents. The test of the reliability of the questionnaires was done using Cronbach's alpha.

Figure 7

The Research Paradigm of the Study



Note. The research paradigm of this study using the IPO model.

The second phase of the study covers the design and validation of the PLAH and nPLAH manuals. Experts (6) and instructors (3) were given hard copies of the manuals for validation. The manuals are assessed by the experts and instructors (Phase 2) before the start of the semester and by students (Phase 3) at the end of the semester. The results were then analyzed.

The third phase of the study is the evaluation part, wherein the effectiveness of the manuals is evaluated. The pre-achievement test and pre-survey of attitude, motivation, and confidence in laboratory skills were conducted online through the CSU-LMS at the start of the semester. The first group with three classes used the PLAH manual, while the second group with three classes used the nPLAH manual, and the third group with only one class used the traditional manual with video demonstrations. The manuals were given through CSU-LMS with a corresponding set of instructions to instructors and students on how to use them. Students were asked to write down comments, words that were hard to understand, and difficult activities after the experiment. The interview was done at the start of the semester, after three experiments, and after using the manual to instructors and students using the PLAH manual. After all experiments are done, the researcher administered the post-achievement test and post-survey of attitude, motivation, and confidence in laboratory skills through the LMS. The students were asked to evaluate the manuals through an online survey, and the comments written by the students throughout the semester were uploaded through CSU-LMS.

Data Analysis Procedure

Frequency, percentage, and weighted mean were used to analyze and identify the level of acceptability of the instructional materials using the corresponding verbal interpretation. To justify the expert rating, inter-rater agreement was computed across the various parts of the manuals. The extent to which evaluators agreed on the absolute level of performance (the numerical score) assessments on the various parts of the manuals was measured using inter-rater agreement. This made use of the number of ratings in agreement (rating of 5, 4, 3) and the number of raters to determine the inter-rater agreement.

Frequency and percentages are used to analyze data describing the student profile. Equivalency was established using the Chi-square test to compare the baseline characteristics of the three (3) groups at a 0.05 level of significance using STATA software.

The data collected from the pre- and post-test and surveys and scores were analyzed using R software. Normality tests are done to determine the more appropriate statistical analyses to be used. Paired t-test was used to determine the significant differences between the pre- and post-scores. At the same time, the Kruskal-Wallis test was used to determine the significant differences among the different groups at a 0.05 level of significance. On the other hand, Spearman's correlation was used to determine the significant relationship between the variables.

Finally, a thematic analysis of the interviews was done to determine the main themes of the perception of the use of the PLAH Manual.

Chapter IV

RESULTS AND DISCUSSIONS

This chapter presents the research findings from the evaluation of manuals, analysis of the test scores, non-cognitive surveys (attitude, motivation, and confidence in laboratory skills), and perception interviews.

Student Profile

Demographic Profile

Apart from the CSU-CAT exam that is used to establish homogeneity of the participants, the profile of students from each group was done to describe the groups and further establish the equivalence of the groups. The demographic, economic, and educational baseline characteristics of the participants are collected before receiving any treatment that is going to be compared in a treatment comparison.

Demographic data of the students were gathered using a survey questionnaire which the students filled out using CSU-LMS. The demographic data included in the survey were age, sex, and address. Since the nature of the intervention of this study involves the use of laboratory manuals that are made available online, it is important to profile and determine the capability of the students in using and accessing the manual. The results are summarized in Table 7. Results showed that the majority of the respondents across the three treatment groups are 19 years old. This is mainly because the participants are BSMLS second-year students who had two years of senior high school. Among 317 participants, only 70 (22.1%) are male. Allied health courses, for one, attract more women than men by about 4 to 1. CSU's BSMLS program follows the national trend of being a female-dominated field. Davis (2016) said that the gender disparity is partial because male students going into healthcare want to become physicians or physician assistants without being knowledgeable of other existing healthcare programs. Most (35.96%) of the participants across the treatments are from the Province of Cagayan, followed closely by those residing in Tuguegarao City (29.97%).

Statistical tests showed that there is no significant difference among the participants' demographic profile (age, sex, and address) among PLAH, nPLAH, and Video groups.

Table 7

Demographic Profile of students in the treatments used

	PLAH		**nPLAH**		**Video**		**Total**		**p-value**
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**	
Age									**0.997a**
18	8	5.80	8	5.93	3	6.41	19	5.99	
19	99	71.74	95	70.37	32	72.21	226	71.29	
20	30	21.74	31	22.96	9	21.38	70	22.08	
21	1	0.72	1	0.74	0	0.00	2	0.63	
Sex									**0.380b**
Male	27	19.57	30	22.22	13	29.55	70	22.08	
Female	111	80.43	105	77.78	31	70.45	247	77.92	
Address									**0.531b**
Tuguegarao	45	32.61	34	25.19	16	36.36	95	29.97	
Cagayan	50	36.23	50	37.04	14	31.82	114	35.96	
Others	43	31.16	51	37.77	14	31.82	108	34.07	

Note. a=Fisher's exact test

b=Chi-squared test

Data collected by the author in September 2021.

Economic Profile

The economic profile included the parents' major source of income, monthly household income, and living status (owned, rented, or living with relatives). Since the respondents using PLAH and nPLAH have to do laboratory within their residences, which involves the use and purchase of some materials in a certain area in the house, it is important to determine the financial and living capability of the student's parents to be able to conduct the experiments. According to Moneva *et al.* (2020), there is a significant association between parental financial support and students' motivation in learning. The results are summarized in Table 8. Results showed that the majority of the parents' source of income is from government salaries (30.91%), followed by farming (23.66%).

Table 8

Economic Profile of students in the treatments used

	PLAH		**nPLAH**		**Video**		**Total**		**p-value**
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**	
Parents' Major Source of Income									**0.690a**
Employed-Government	46	33.33	42	31.11	10	22.73	98	30.91	
Employed-Private	24	17.39	29	21.48	15	34.09	68	21.45	
Self-employed	8	5.80	9	6.67	3	6.82	20	6.31	
Business	24	17.39	20	14.81	4	9.09	48	15.14	
Farming	33	23.91	31	22.96	11	25.00	75	23.66	
Others	3	2.17	4	2.96	1	2.27	8	2.52	
Household Monthly Income									**0.133b**
Below10000	46	33.33	57	42.22	14	31.82	117	36.90	
10001-20000	44	31.88	36	26.67	16	36.36	96	30.28	
20001-40000	21	15.22	29	21.48	6	13.64	56	17.67	
40001-60000	13	9.42	11	8.15	3	6.82	27	8.52	
above 40000	**27**	19.56	13	**9.63**	8	18.18	48	15.14	
Living status									**0.427b**
Owned	119	86.23	115	85.19	34	77.27	268	84.54	
Rented	11	7.97	8	5.93	6	13.64	25	7.89	
Living with relatives	8	5.80	12	8.89	4	9.09	24	7.57	

Note. a=Fisher's exact test

b=Chi-squared test

Data collected by the author in September 2021.

Not all families have both parents working. A large number of agricultural farms is attributed to the characteristics of the region as its economy relies heavily on agriculture. Some of the students' parent/s are working under a private company, from managers to service and sales workers category. Only a small portion of the parents fell under the self-employed category at 6.3%. The specific jobs reported under these categories were pastors, tricycle drivers, laborers, construction workers, vegetable dealers, delivery, and vendor. From the declared family income of the students, the majority of the students were found to belong to families earning below Php240,000 annually, which is aligned with the income of the types of occupations discussed above.

Most (84.54%) of the participants own the houses they stay in. They described that they have an average house with separate kitchens, rooms, living areas, and backyards. The backyard is an ideal area to do laboratory-at-home experiments for those are using the PLAH and nPLAH Manuals. However, there are those who do not have this area and are limited to doing the experiments in their rooms.

Education Profile

Since the nature of the intervention of this study involves the use of technology, it is of utmost importance to determine the familiarity and capability of the students in using a digital device. In terms of the digital devices used by the students for online learning, survey results showed that almost half of the participants owned both cell phones and laptops (44.16%). Most of the students use their smartphones to access the LMS but do their activities using their laptops. This profile is consistent with prior research (Kalogiannakis *et al*., 2011; Bahian *et al*., 2020; Basha & Daoud, 2010) that the majority of students use smartphones to access LMS because it is more convenient and user-friendly. This belief is substantiated by Kalogiannakis *et al*. (2011), as they revealed in their study that students preferred carrying out easy and low-stake Moodle tasks on their mobile phones, such as accessing learning materials.

The majority (47.00%) of the participants have a Wi-Fi connection which is aligned with the number of those who have multiple devices used for online learning. These students only use prepaid mobile data when there are problems with the Wi-Fi connection, which rarely happens. Although today's generation of students is labeled as “millennials" and “digital natives,” the demographics show that there are still students who do not know how to edit videos. This skill is significant in the study since individual outputs/videos of a group under PLAH intervention needs to be merged into a single video. This means that there is a need to assist the students with how to do the video editing before the intervention. Also, each PLAH group must have a member that knows already how to edit videos to assist better those groupmates who slightly/do not know how to edit videos.

Table 9

Education Profile of students in the treatments used

	PLAH		**nPLAH**		**Video**		**Total**		**p-value**
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**	
Digital Device/s used for Online Learning									**>0.001b***
Cellphone	41	29.71	47	34.81	8	18.18	96	30.28	
Laptop	36	26.09	42	31.11	3	6.82	81	25.55	
Cellphone and Laptop	61	44.20	46	34.07	33	75.00	140	44.16	
Source of Internet									**>0.001b***
Data	16	11.59	31	22.96	6	13.64	53	16.72	
Wifi	53	38.41	72	53.33	24	54.55	149	47.00	
Data and Wifi	69	50.00	32	23.70	14	31.82	115	36.28	
Ability to edit videos									**0.189b**
No	62	44.93	64	47.41	14	31.82	140	44.16	
Slight to Yes	76	55.07	71	**52.59**	30	68.18	177	55.84	
Yes	25	18.12	36	26.67	18	40.91	79	24.92	
Chemistry prerequisite grade									**0.213a**
below 86	19	1.45	23	0.74	4	0.00	46	0.95	
81-85	17	12.32	22	16.30	4	9.09	43	13.56	
86-90	76	55.07	64	47.41	30	68.18	170	53.63	
above 90	43	31.16	48	35.56	10	22.73	101	31.86	

Note. a=Fisher's exact test/b=Chi-squared test

*significant at 0.05

Data collected by the author in September 2021.

Most of the students have a grade on their prerequisite Chemistry subject (Inorganic and Organic Chemistry) 86-90. It can be observed that only a small portion (0.95%) have a grade below 80. The groups are similar at baseline; hence, the researcher is more confident that observed differences in outcomes between the groups are related to the intervention rather than confounding factors.

Evaluation of Experts and Instructors on the Developed Laboratory-at-Home Manuals (PLAH and nPLAH)

Evaluation of the PLAH Manual Based on Experts and Instructors' Judgments

As presented in Table 10, the experts' and instructors' overall average rating on the developed PLAH manual is 4.57 (strongly agree) with a corresponding interpretation of "excellent" evaluation of its acceptability. The same holds true with the expert's evaluation of the average ratings on the different aspects of the manual, ranging from 4.47 (clarity) to 4.75 (appeal).

Table 10

Evaluators' PLAH Manual Rating

Aspect of the Instructional Manual	Items	Means*
1. Objectives	The objectives are specific, measurable, attainable, and realistic.	4.67
	The objectives guide the students to know what they are expected to do after completing each activity.	4.22
	The objectives are aligned with the mission, vision, goal, and objectives of the University.	4.67
	Overall	**4.52**
2. Content	The content is aligned with the topics on Biomolecules.	4.22
	The contents of the laboratory manual are appropriate for college students.	4.78

	The contents of the laboratory manual are doable.	4.44
	The laboratory manual adequately covers the necessary topics under Biomolecules within a semester.	4.33
	The content of the laboratory manual caters to the different learning needs of students.	4.22
	The activities are relevant to the concepts being developed using the laboratory manual.	4.56
	There are evaluation items in each activity that deepen the understanding of concepts.	5.00
	Overall	**4.51**
3. Format and Language	The language used in the laboratory manual is within college students' level of understanding.	4.67
	The structures of the sentence used in the laboratory manual varied and understandable.	4.56
	The activities indicated in the laboratory manual are clearly explained.	4.44
	The procedures of the different activities are easy to follow and apply.	4.22
	The sentences are free of grammatical errors.	4.78
	Overall	**4.53**
4. Presentation	The sequence of topics covered is logically presented.	4.78
	Exercises contain useful introductions that facilitate a smooth transition from one activity to another.	4.22
	Organization of the laboratory material allows the use of various types of teaching and learning strategies to meet individual differences.	4.78
	Overall	**4.59**
5. Usefulness	The activities enable students to apply information acquired in real-life situations.	4.89
	The activities are engaging, beneficial to students' learning, and supportive of higher-level thinking skills.	4.78
	Laboratory manual uses strategies that allow for fuller development of social skills such as striving for excellence, being responsible, and working harmoniously with others.	4.67
	The information provided is relevant and up-to-date.	4.67
	Laboratory manual encourages the integration of positive values and appreciation of the health and safety of learners.	4.44
	Overall	**4.69**

6. Appropriateness	Material is free of controversial and sensitive issues which may be difficult to discuss in and outside the classroom.	5.00
	The color, print size, spacing, quantity, and type of visuals are suitable for the abilities and needs of intended students.	4.00
	Overall	**4.50**
7. Clarity	The language and writing style is suited to the ability of the students.	4.67
	The presentation of topics follows a logical sequence.	4.78
	Structure and format follow a logical sequence.	4.44
	Directions are clear and complete for students to perform the required tasks.	4.00
	Overall	**4.47**
8. Appeal	The activities are laid out in a motivating and interesting manner.	4.67
	The activities are presented in a way that catches students' attention and interest.	4.89
	The activities require learners to become actively engaged to ensure learning.	4.78
	The laboratory manual is interactive and provides high-quality sensory experiences to all users.	4.67
	Overall	**4.75**
9. POGIL	The key concepts as learning objectives are stated clearly and appropriately.	4.44
	Activities lead students to achieve the content learning objectives.	4.56
	Questions for each activity assess students' achievement of content learning objectives.	4.44
	Activities focus on process skill goals which are stated clearly.	4.67
	Process skill goals are appropriate for each of the activities and course levels.	4.89
	Activities and questions lead students to accurate content understanding.	4.78
	Activities and questions help students to avoid misconceptions.	4.44
	Guide questions and procedures instruct students to work cooperatively.	4.22
	Each activity is clearly presented and has an appropriate set of data that provides information to achieve intended content objectives.	4.56
	Guide questions in each activity allow for the assessment of students' process skills goals.	4.67
	Guide questions are sequenced toward the achievement of target learning objectives	4.56

	Application questions extend ideas in a meaningful and useful manner.	4.67
	Students are prompted to assess what they have learned in terms of content.	4.44
	Students are prompted to assess what they have learned in terms of targeted process skills.	4.67
	Exploration questions require students to engage with the activities.	4.78
	Invention questions are sequenced to require critical thinking that leads to concept development	4.67
	Questions are designed to develop targeted process skills.	4.78
	Each activity promotes the development of targeted process skills.	4.44
	Activities promote inclusion by choosing language and graphics which are appropriate and accessible to diverse student populations.	4.22
	Questions promote inclusion by choosing language that is appropriate and understandable to diverse student populations.	4.56
	Questions are clearly stated to elicit the intended response from students.	4.67
	The sequence of questions for each of the activities flows logically to avoid conceptual leaps, unnecessary repetition, or content unrelated to learning objectives.	4.56
	Overall	**4.58**
10. Overall evaluators' responses on the PLAH Manual	Objectives	4.52
	Content	4.51
	Format and Language	4.53
	Presentation	4.59
	Usefulness	4.69
	Appropriateness	4.50
	Clarity	4.47
	Appeal	4.75
	POGIL	4.58
	Overall	**4.57**

Note.

Mean Rating	**Interpretations**	
4.50-5.00	Strongly agree	Excellent
3.50-4.49	Agree	Very Good
2.50-3.49	Undecided	Good
1.50-2.49	Disagree	Fair
1.00-1.49	Strongly Disagree	Poor

In detail, all evaluators agreed that the PLAH Manual has objectives that are clearly stated in the behavioral form, specific, measurable, attainable, and realistic. Also, they strongly agreed that the objectives guide the students to know what they are expected to do after completing each activity and are aligned with the mission, vision, goal, and objectives of the University. The objectives of laboratory manuals provide the specific target that should be attained after performing the experiment (Mercado, 2018). This implies that the objectives of the developed PLAH manual as evaluated by experts and instructors, are of great assistance to the students in knowing what they are expected to learn.

Content validation is the most crucial and preliminary step toward material or instrument development (Tan, 2019). The results of the content aspect validation have a qualitative interpretation of “excellent” because the contents of the developed manual have met the assessment indicators (Putri, 2021). The evaluators’ responses showed that they strongly agreed that the content of each activity is aligned with the topics on Biomolecules and is appropriate for college students. Furthermore, they strongly agreed that the activities are doable and cover the necessary topics on Biomolecules within a semester. Also, they strongly agree that the manual caters to the different learning needs of students and that activities are relevant to the concepts being developed, and that there are evaluation items in each activity to deepen understanding of concepts. Yalcin-Celik *et al.* (2017) examined many studies related to the challenges chemistry teachers face in teaching in a laboratory, and one of the shared themes is content knowledge. The results of the content validation may have solved this challenge since interviews with the instructors revealed that after utilization of the PLAH manual their content knowledge in laboratory chemistry improved largely.

Regarding the format and language of the module, the evaluators agreed that the format and language are within college students' level of understanding. Likewise, the format and language used are clear, easy to understand, and free of grammatical errors. This can be seen in the instructions given in the laboratory manual, which are clearly presented and straightforward. According to Petersen and McLaughlin (2017), formatting is one aspect that received several suggestions during their development of a laboratory manual. The evaluators also strongly agreed that the topics are presented in a logical and sequential order. They further agreed that the activities are presented to facilitate a smooth transition and that the organization allows the use of various teaching and learning strategies to meet individual differences. In the PLAH Manual, the POGIL laboratory format is crucial since it follows a three-stage learning cycle approach- exploration, concept invention, and application. Instructors shared their thoughts and opinions on the manual's POGIL structure when they were interviewed after using one module of the PLAH Manual. They were able to explain the benefits of utilizing the manual, its general content and organization, and how it helped them as educators. One said, ***"Actually, this type of design promotes independent learning in a way that you do not micromanage because everything is provided, even the process."*** Another also added, ***"In the POGIL format, they have different tasks, and everyone has their own assignments, which means they cannot copy from anyone and that each of them really has to work. POGIL is more interactive and engaging, that is why it is also more effective for the students."*** According to recent research, instructors believe that POGIL is an effective teaching strategy since they have seen greater student participation, active engagement, and comprehension of science (Mamombe *et al.,* 2021). Instructors mentioned how POGIL helped students improve their abilities, such as resourcefulness.

Looking at the evaluators' responses on the usefulness of the PLAH manual, they strongly agree that it will enable students to apply the concepts acquired in real-life situations and that it will engage students. Furthermore, they strongly agreed that this manual would help the students develop their social skills and encourage positive values and appreciation of health and safety. Also, they strongly believed that the manual was relevant and up to date. Several studies highlight the usefulness of developed laboratory manuals in enhancing students' learning as evaluated by students and instructors (Constantino, 2010; Cruz, 2006; Jimenez, 2008; Robles, 2004). In terms of topic comprehension, pedagogical expertise, and laboratory abilities, instructors recounted their experiences teaching Chemistry laboratory using the PLAH Manual. ***As for the laboratory skills of students, I am amazed that as simple as measuring at eye level, they incorporate and show this in their outputs."*** On the other hand, in terms of strategies, one of them said, **"*Nothing compares to the examples given to students that were taken from real-life scenarios because, with this, the students were able to retain and grasp the concept, especially because they execute it."*** Student feedback on the use of ordinary things they see everyday, they were able to incorporate their understanding to other similar scenarios just like in the divergent questions (application) in their PLAH Manual.

Likewise, the evaluators' responses showed that they strongly agreed that the manual is appropriate that is free of controversial and sensitive issues. They agreed that the color, print size, spacing, quantity, and type of visuals were suitable for the students. According to Rello *et al.* (2016), readability increases significantly with font size. The selected pictures correspond to the biomolecule to be experimented on. For example, in the module on 'How do you know which foods are high in starch?', a picture of starchy food is presented. This piques the interest of the reader that a usual food that he/she is eating has starch. The colors are also attractive so that students become interested in them. However, as recommended by some evaluators, additional pictures can be added since there is only one picture per experiment.

With regard to the clarity of the manual, the evaluators agreed that the language and writing are suitable for college students. Likewise, the presentation, structure, and format follow a logical sequence. Further, the directions are clear and complete for students to perform the required tasks. According to the instructor-participants, the PLAH manual makes all supplies for experiments easily available to students, and the directions are simple to follow, which discourages students from asking questions. One said, ***"the material is well-crafted, and it is easy to follow; it actually can help to manage."***

Regarding the appeal of the PLAH Manual, which ranked highest amongst the components evaluated, the evaluators strongly agreed that the activities are motivating and interesting enough to catch students' attention and interest. This may be attributed to the materials in each activity using ordinary things students see every day, which makes learning relevant and meaningful which is also present in the nPLAH Manual. They further agreed that the activities require learners to become actively engaged and interactive with all users. Aside from having hands-on activity and role of each member of the group, each group has a different experiment to do and share with other groups. After utilizing the first module of the PLAH manual, all instructors were pleased to find that their students were enjoying and applying what they had covered because the experiment could be done at home, and materials were easily accessible to them. One instructor said, ***"Actually, compared to last year, where we only depended on videos, it's already a big help for this time that they are able to do some experiments at home. For me, I can see that they are learning, so my confidence as a teacher is also improving."*** Another participant also explained how the first module using PLAH is beneficial to her students. She said, ***"There is really a development since they are the ones who are actually doing it. They can incorporate their skills and their knowledge as well because they also need to do some readings before performing the experiment; they will see to it what is it they are doing, that's why they're improving."*** POGIL educators believe that their students were more engaged and active, had better communication and collaboration skills, and had higher learning results while utilizing the POGIL technique (Hu *et al*., 2016). The interviews revealed that the instructors valued the usage of the PLAH Manual because it helped them reduce misunderstandings, increase student engagement, increase knowledge and accomplishment, and engage their students. This suggests that using the PLAH Manual boosted students' attention, involvement, and active learning.

Looking at the evaluators' responses on the POGIL aspect of the manual, they strongly agree that the activities lead students to achieve objectives, focus on process skill goals, and are clearly presented. Likewise, activities and questions enable them to achieve the objectives, lead students to accurate content understanding, and avoid misconceptions. They strongly agreed that the questions allow for the assessment of students' process skills goals and are sequenced toward achieving objectives. Furthermore, exploration questions require students to engage with the activities; invention questions require critical thinking that leads to concept development, and application questions extend ideas in a meaningful and useful manner. Also, questions are appropriate to diverse student populations, clear, logically sequenced, and designed to develop targeted process skills. The PLAH Manual provides support that ensures that learning is not just reading alone but also an active process of learning. This is anchored on the Scaffolding theory by Brunner (2015) which identifies the importance of providing students with enough support in the initial stages of learning a subject. It is also anchored on Vygotsky's social development theory which asserts that a child's cognitive development and learning ability can be guided and mediated by their social interactions (Gowrie Marketing, 2022). Since the PLAH Manual incorporates group work, this theory also suggests that children internalize and learn from the beliefs and attitudes that they witness around them.

To support the expert evaluation, inter-rater agreement was determined across the various components of the PLAH Manual. Unlike inter-rater reliability, which takes into account the ordering or relative standing of performance ratings, the researcher utilized inter-rater agreement to assess how well evaluators agreed on the absolute level of performance (the numerical score) ratings on the various components of the manual. In this approach, the assessment findings offered input on the manual's strengths and faults. Because the experts' evaluation ratings range from 3 to 5, the precise and adjacent agreement is offered as a more realistic indicator of rating consistency. According to Table 11, the mean inter-rater agreement varied from 50% (on clarity) to 75%. (appeal). The experts and instructors were consistent in their evaluation ratings of strongly agreeing that there are evaluation items in each activity that deepen the understanding of concepts (2.7) and material is free of controversial and sensitive issues that may be difficult to discuss in and outside the classroom (6.1).

Table 11

Inter-rater agreement among the nine (9) experts and instructors

Aspect of the PLAH Manual/Item		% Agreement		
		Rating of 5 (Strongly agree)	**Rating of 4 (Agree)**	**Rating of 3 (Undecided)**
1. Objectives	1.1	67	33	0
	1.2	22	78	0
	1.3	67	33	0
	Average	**52**	**48**	**0**
2. Content	2.1	44	33	22
	2.2	78	22	0
	2.3	67	11	22
	2.4	56	22	22
	2.5	22	78	0
	2.6	56	44	0
	2.7	100	0	0
	Average	**60.43**	**30**	**9.43**
3. Format and Language	3.1	67	33	0
	3.2	56	44	0
	3.3	44	56	0
	3.4	22	78	0
	3.5	78	22	0
	Average	**53.40**	**46.60**	**0**
4. Presentation	4.1	78	22	0
	4.2	44	33	22
	4.3	78	22	0
	Average	**66.67**	**25.67**	**7.33**
5. Usefulness	5.1	89	11	0
	5.2	78	22	0
	5.3	67	33	0
	5.4	67	33	0
	5.5	44	56	0
	Average	**69**	**31**	**0**
6. Appropriateness	6.1	100	0	0
	6.2	22	56	22
	Average	**61**	**28**	**11**
7. Clarity	7.1	56	44	0
	7.2	78	22	0
	7.3	44	56	0
	7.4	22	56	22
	Average	**50**	**44.50**	**5.50**
8. Appeal	8.1	67	33	0
	8.2	89	11	0
	8.3.	78	22	0
	8.4	67	33	0
	Average	**75.25**	**24.75**	**0**
9. POGIL	9.1	44	56	0
	9.2	56	44	0

	9.3	44	56	0
	9.4	67	33	0
	9.5	89	11	0
	9.6	78	22	0
	9.7	44	56	0
	9.8	33	44	0
	9.9	56	44	0
	9.10	67	33	0
	9.11	56	44	0
	9.12	67	33	0
	9.13	44	56	0
	9.14	67	33	0
	9.15	78	22	0
	9.16	67	33	0
	9.17	78	22	0
	9.18	56	44	0
	9.19	22	78	0
	9.20	56	44	0
	9.21	67	33	0
	9.22	56	44	0
	Average	**58.73**	**40.22**	**0**

Note. The experts' evaluation ratings range from 3 to 5.

In summary, the evaluators unanimously agreed that the nine features of the created PLAH Manual (objectives, content, format and language, presentation, usefulness, appropriateness, clarity, appeal, and POGIL) were outstanding, with an overall mean of 4.57 and a standard deviation of 0.46. Meanwhile, the inter-rating agreement indicates that the nine (9) experts consistently (above 50%) provided a respectable grade to the different sections of the manual, adding proof to the module's overall acceptance.

The nPLAH and Video manuals were not evaluated using the questions on POGIL characteristics since they lack the components that the items under this component evaluates. Further, the evaluators of the PLAH manual are users of POGIL approach.

Evaluation of the nPLAH Manual Based on Experts and Instructors' Judgments

As presented in Table 12, the experts' and instructors' overall average rating on the developed nPLAH manual is 4.53, signifying an "excellent" evaluation of its acceptability. The same holds true with the expert's evaluation of the average ratings on the different aspects of the manual, ranging from 4.44 (appropriateness) to 4.67 (appeal).

Table 12

Evaluators' nPLAH Manual Rating

Aspect of the Instructional Manual	Items	Means*
1. Objectives	The objectives are specific, measurable, attainable, and realistic.	4.67
	The objectives guide the students to know what they are expected to do after completing each activity.	4.22
	The objectives are aligned with the mission, vision, goal, and objectives of the University.	4.78
	Overall	**4.56**
2. Content	The content is aligned with the topics on Biomolecules.	4.22
	The contents of the laboratory manual are appropriate for college students.	4.78
	The contents of the laboratory manual are doable.	4.56
	The laboratory manual adequately covers the necessary topics under Biomolecules within a semester.	4.22
	The content of the laboratory manual caters to the different learning needs of students.	4.44
	The activities are relevant to the concepts being developed using the laboratory manual.	4.56
	There are evaluation items in each activity that deepen the understanding of concepts.	4.89
	Overall	**4.52**
3. Format and Language	The language used in the laboratory manual is within college students' level of understanding.	4.78

	The structures of the sentence used in the laboratory manual varied and understandable.	4.56
	The activities indicated in the laboratory manual are clearly explained.	4.44
	The procedures of the different activities are easy to follow and apply.	4.22
	The sentences are free of grammatical errors.	4.56
	Overall	**4.51**
4. Presentation	The sequence of topics covered is logically presented.	4.67
	Exercises contain useful introductions that facilitate a smooth transition from one activity to another.	4.11
	Organization of the laboratory material allows the use of various types of teaching and learning strategies to meet individual differences.	4.67
	Overall	**4.48**
5. Usefulness	The activities enable students to apply information acquired in real-life situations.	4.67
	The activities are engaging, beneficial to students' learning, and supportive of higher-level thinking skills.	4.56
	Laboratory manual uses strategies that allow for fuller development of social skills such as striving for excellence, being responsible, and working harmoniously with others.	4.67
	The information provided is relevant and up-to-date.	4.56
	Laboratory manual encourages the integration of positive values and appreciation of the health and safety of learners.	4.44
	Overall	**4.58**
6. Appropriateness	Material is free of controversial and sensitive issues which may be difficult to discuss in and outside the classroom.	4.78
	The color, print size, spacing, quantity, and type of visuals are suitable for the abilities and needs of intended students.	4.11
	Overall	**4.44**
7. Clarity	The language and writing style is suited to the ability of the students.	4.67
	The presentation of topics follows a logical sequence.	4.78

	Structure and format follow a logical sequence.	4.44
	Directions are clear and complete for students to perform the required tasks.	4.00
	Overall	**4.47**
8. Appeal	The activities are laid out in a motivating and interesting manner.	4.67
	The activities are presented in a way that catches students' attention and interest.	4.78
	The activities require learners to become actively engaged to ensure learning.	4.67
	The laboratory manual is interactive and provides high-quality sensory experiences to all users.	4.56
	Overall	**4.67**
10. Overall evaluators' responses on the nPLAH Manual	Objectives	4.56
	Content	4.52
	Format and Language	4.51
	Presentation	4.48
	Usefulness	4.58
	Appropriateness	4.44
	Clarity	4.47
	Appeal	4.67
	Overall	**4.53**

Note.

Mean Rating	Interpretations	
4.50-5.00	Strongly agree	Excellent
3.50-4.49	Agree	Very Good
2.50-3.49	Undecided	Good
1.50-2.49	Disagree	Fair
1.00-1.49	Strongly Disagree	Poor

In detail, the experts and instructors evaluated the nPLAH manual almost the same as the PLAH manual (difference of below 0.06) in terms of objectives, content, format and language, appropriateness, and clarity. This is as expected since these aspects are the same for the PLAH and nPLAH. However, in terms of presentation, usefulness, and appeal, nPLAH Manual's mean evaluation is noticeably lower (difference between 0.08-0.11).

Regarding the presentation of the nPLAH Manual, the evaluators strongly agreed that the topics are presented in a logical and sequential order. They further agreed that the activities are presented to facilitate a smooth transition and that the organization allows the use of various teaching and learning strategies to meet individual differences. However, compared to the PLAH Manual, the title of each worksheet already reveal the concept to be discovered, and each worksheet does not begin with a focus question. Typically, behavioral strategies are associated with lower levels of learning, such as recall and are delivered mathematically rather than generatively, where the learner generates relationships between his or her own existing knowledge and the newly introduced information (Magliaro *et al.,* 2005).

Looking at the evaluators' responses on the usefulness of the nPLAH manual, they strongly agree that it will enable students to apply the concepts acquired in real-life situations and that it will engage students. Furthermore, they strongly agreed that this manual would help the students develop their social skills and encourage positive values and appreciation of health and safety. Also, they strongly believed that the manual was relevant and up to date. However, compared to the PLAH Manual, the questions in the post-lab session in the nPLAH Manual are limited and do not reinforce the developed concept through application. Each module in the PLAH Manual comprises three types of questions: directed, convergent, and divergent questions. Directed questions concentrate on the students' recognition of certain parts of the experiment, with the response acquired directly from the experiment. Convergent questions help students put the facts together to get a general conclusion or comprehension of the ideas, whereas divergent questions are open-ended questions that challenge students to build on their new knowledge by contemplating, further researching, and generalizing (Haryati, 2018). Furthermore, as shown in Table 6, each experiment for the nPLAH Manual does not enhance numerous process skills. When compared to the PLAH Manual, the methods necessary to complete the experiment do not follow the constructivist learning cycle while accessing a number of process skills.

Regarding the appeal of the nPLAH Manual, the evaluators strongly agreed that the activities are motivating and interesting enough to catch students' attention and interest. One of the instructors stated that the manual demonstrated that chemistry is everywhere and that it can be done at home and outside of the four walls of a laboratory. The laboratory-at-home aspect of the manual helped students feel less anxious about performing the experiments, which promotes active learning. One instructor said, ***"The activities that can be done at home reduced the fear of my students to do experiments since they are handling simply only things found at home and fruits that are not expensive."*** Further, according to the instructors, the laboratory-at-home aspect promotes resourcefulness and preparedness and improves the laboratory skills of students. ***"Most of the materials can be found at home, but those that have none, look at alternatives that can be used and have them approved first. They even take good videos of how they prepared themselves and their workplaces before conducting the experiment and even how they carefully did the experiment. That is actually a laboratory skill that they need to develop."*** However, compared to the PLAH Manual, the groups have similar activities to do which may make other groups dependent on the results of another group. Also, they only interact with their groupmates and not with other groups in their class.

To justify the aforementioned expert rating, inter-rater agreement was determined across the various components of the nPLAH Manual. Unlike inter-rater reliability, which takes into account the ordering or relative standing of performance ratings, the researcher utilized inter-rater agreement to assess how well assessors agreed on the absolute level of performance (the numerical score) ratings on the various components of the manual. In this approach, the assessment findings offered input on the manual's strengths and faults. The mean inter-rater agreement varied from 51.20% (on format and language) to 69.75% (appeal) as indicated in Table 13.

Table 13

Inter-rater agreement among the ten (10) experts and instructors

Aspect of the nPLAH Manual/Item		**% Agreement**		
		Rating of 5 (Strongly agree)	**Rating of 4 (Agree)**	**Rating of 3 (Undecided)**
1. Objectives	1.1	67	33	0
	1.2	22	78	0
	1.3	78	22	0
	Average	**55.67**	**44.33**	**0**
2. Content	2.1	44	33	22
	2.2	78	22	0
	2.3	67	22	11
	2.4	44	33	22
	2.5	44	56	0
	2.6	56	44	0
	2.7	89	11	0
	Average	**60.29**	**31.57**	**7.86**
3. Format and Language	3.1	78	22	0
	3.2	56	44	0
	3.3	44	56	0
	3.4	22	78	0
	3.5	56	44	0
	Average	**51.20**	**48.80**	**0**
4. Presentation	4.1	67	33	0
	4.2	22	56	22
	4.3	78	11	11
	Average	**55.67**	**33.33**	**11**
5. Usefulness	5.1	67	33	0
	5.2	56	44	0
	5.3	67	33	0
	5.4	56	44	0
	5.5	44	56	0
	Average	**58**	**42**	**0**
6. Appropriateness	6.1	78	22	0
	6.2	33	44	22
	Average	**55.50**	**33**	**11**
7. Clarity	7.1	67	33	0

	7.2	78	22	0
	7.3	44	56	0
	7.4	33	33	33
	Average	**55.50**	**36**	**8.25**
8. Appeal	8.1	67	33	0
	8.2	78	22	0
	8.3.	67	33	0
	8.4	67	22	11
	Average	**69.75**	**27.50**	**2.75**

Note. The experts' evaluation ratings range from 3 to 5.

In summary, the evaluators unanimously agreed that the nine features of the created nPLAH Manual (objectives, substance, format and language, presentation, usefulness, appropriateness, clarity, and appeal) were good, with an overall mean of 4.53 and a standard deviation of 0.56. Meanwhile, the inter-rating agreement indicates that the nine (9) experts consistently assigned a respectable grade to the different sections of the handbook, adding proof to the manual's overall acceptance.

Evaluation of Students on the Developed Laboratory-at-Home Manuals (PLAH and nPLAH)

Evaluation of the PLAH Manual Based on Students' Judgments

Students have also evaluated the developed instructional manuals in terms of their content, format and language, clarity, and appeal. The responses of 138 respondents were tallied per indicator/characteristic. A similar trend of findings emerged as to how the experts evaluated the PLAH manual. As shown in Table 14, the student participants generally perceived excellent acceptability of the PLAH manual with an average rating of 4.54.

In terms of the content of the PLAH manual, the student participants strongly agreed that the content is aligned with the topics on Biomolecules and that the contents of the laboratory manual are appropriate to them and are doable. Also, they strongly agree that the evaluation items in each activity deepen their understanding of the concept. Most students said that they learned the concepts better, such as the factors affecting and functions of biomolecules. The first experiment on extracting DNA from saliva and other samples gave them an application and more profound knowledge that is seemingly impossible given the situation. ***"This laboratory class allowed us to practically apply what we learned. In other words, it allowed us to put the theoretical concepts we learned in the lecture portion of this subject into practice,"*** one student said. Another stated, ***"The biological fluids we had encountered in some experiments helped me to understand more the action was taking place between them."*** These experiments helped them explore deeper the properties and the capability of those biological fluids to execute or show results when exposed to an environment or when different parameters were introduced. According to Shearer (2018), individualized learning methodologies, as well as experiments and practical activities, can contribute to the development of multiple intelligences. The importance of content knowledge and its connection to student learning (Magnusson *et al.,* 1992).

Table 14

Student Participants' PLAH Manual Rating

Aspect of the Instructional Manual	Items	Means*
1. Content	The content is aligned with the topics on Biomolecules.	4.88
	The contents of the laboratory manual are doable.	4.67
	The lecture concepts can be understood better with the guide questions of the laboratory manual.	4.77
	Overall	**4.77**
2. Format and Language	The language used in the laboratory in the manual is within college students' level of understanding.	4.76

	The structures of the sentence used in the laboratory manual varied and understandable.	4.50
	The activities indicated in the laboratory manual are clearly explained.	4.27
	The procedures of the different activities are easy to follow and apply.	4.40
	The sentences are free of grammatical errors.	4.15
	Overall	**4.42**
3. Clarity	The language and writing style is suited to the ability of the students.	4.65
	The presentation of topics follows a logical sequence.	4.58
	Structure and format follow a logical sequence.	4.57
	Directions are clear and complete for students to perform the required tasks.	4.14
	Overall	**4.49**
4. Appeal	The activities are laid out in a motivating and interesting manner.	4.45
	The activities are presented in a way that catches students' attention and interest.	4.41
	The activities require learners to become actively engaged to ensure learning.	4.59
	The laboratory manual is interactive and provides high-quality sensory experiences to all users.	4.63
	Overall	**4.52**
5. Overall students' responses on the PLAH Manual	Content	4.77
	Format and Language	4.42
	Clarity	4.49
	Appeal	4.52
	Overall	**4.54**

Note.

Mean Rating	**Interpretations**	
4.50-5.00	Strongly agree	Excellent
3.50-4.49	Agree	Very Good
2.50-3.49	Undecided	Good
1.50-2.49	Disagree	Fair
1.00-1.49	Strongly Disagree	Poor

They agreed that the language used in the PLAH manual is within their understanding and that sentences are free of grammatical errors. Moreover, they agreed that the activities are clearly explained, the procedures are easy to follow, and the directions are clear and complete. They further agreed that the topics were logically presented. Most students said they were confident with their ability to perform experiments because the experiments prepared them since they were easy to follow. In addition, they have suitable materials to be used. The majority of the responses are the same as a student's: ***“I am confident in doing the experiments now since the instructions in the manual are very clear, and it is easy to follow." "Very comprehensive and structured," "objectives clearly defined," and "review questions truly make you think"*** are mostly the remarks from students. Students also expressed satisfaction with the quantity of information, indicating that it was neither too brief nor comprehensive, as well as the quality of the images.

They strongly agreed that the activities were motivating and engaging enough to ensure learning. Further, the laboratory manual is interactive and provides high-quality sensory experiences to all users. The majority of the students found that their laboratory experience was way different from the laboratory class using the PLAH Manual. One of the respondents mentioned that ***"The chemistry laboratory class this semester is more engaging than my previous experiences because we did not do any experiments like this. Besides, last semester we just had modules and tasks to do."*** This semester is more exciting for most respondents because they can do some experiments and see activities related to their topic. One of the respondents said, ***"It was good. I learned a lot, and there are so many differences. One is that I could perform different experiments even if I was at home. Because of it, I understood the topic better and was able to apply the different ideas."*** According to Chan (2012), organizing laboratory learning for students is primarily about developing practical competency, typically within their field of specialization. Students can use laboratory learning to relate to and reinforce theoretical concepts taught in class. It also focuses on a variety of learning outcomes, such as experiential learning. They extracted different biomolecules, such as proteins, gained a lot of knowledge, and were allowed to interact with their respective groupmates virtually. One of the respondents said, ***"To be honest, it's a lot of fun. I'm learning and will undoubtedly learn more throughout the upcoming laboratory activities. Completing laboratory activities at home is entertaining."*** According to Doren *et al*. (1997), this curriculum teaches students about experimental design, careful observation, analytical thinking, and fun. By actively immersing students in experimental research, ignite their interest in science and boost their self-confidence. Most of the respondents say that what they like performing laboratory even if they are only at home is it enhances their skills, especially because when acting in groups, they are in different places, which makes it more challenging to communicate with their groupmates makes them think of a strategy and techniques to still work efficiently as a group which can, later, help them. One respondent said, ***" My laboratory experiences in Biochemistry are fantastic this semester. I learn to engage a lot by doing different roles like being the manager, reflector, presenter, and scribe… My groupmates and I worked hard on every experiment and enjoyed it. Wearing personal protective equipment also motivates and inspires me, as I already envision myself as a true professional. I hope to enjoy all the remaining experiments and acquire more knowledge in Biochemistry."*** Another respondent explained, ***"We can comprehend it more easily… if we watch a video of an experiment without performing it, we can't describe what happened. I find performing the laboratory activities exciting and interesting because it is amusing to see the result after all the things that we did."***

High-quality teaching materials should encourage students to participate more deeply and profoundly in their studies. As Loyens (2008) emphasizes, in a self-directed learning environment, students have more freedom to design and follow their own goals, as well as conduct critical evaluations of the resources they choose. According to the findings, the activities included into the manual were able to produce an environment comparable to laboratory classroom activity, as perceived by the student participants.

Evaluation of the nPLAH Manual Based on Students' Judgments

Students have evaluated the developed nPLAH manual in terms of its content, format and language, clarity, and appeal. The responses of one hundred thirty-five (135) respondents were tallied per indicator/characteristic. As shown in Table 15, the student participants generally perceived a very good acceptability of the nPLAH manual with average rating of 4.46. Compared to the PLAH manual rating, student rating for format and language, and clarity are almost the same (difference of less than 0.06). However, rating for content and appeal for PLAH manual is higher.

Table 15

Student Participants' nPLAH Manual Rating

Aspect of the Instructional Manual	Items	Mean*
1. Content	The content is aligned with the topics on Biomolecules.	4.79
	The contents of the laboratory manual are doable.	4.55
	The lecture concepts can be understood better with the guide questions of the laboratory manual.	4.61
	Overall	**4.65**
2. Format and Language	The language used in the laboratory manual is within college students' level of understanding.	4.71
	The structures of the sentence used in the laboratory manual varied and were understandable.	4.51

	The activities indicate4.27d in the laboratory manual are clearly explained	4.14
	The procedures of the different activities are easy to follow and apply.	4.27
	The sentences are free of grammatical errors.	4.21
	Overall	**4.37**
3. Clarity	The language and writing style is suited to the ability of the students.	4.64
	The presentation of topics follows a logical sequence.	4.53
	Structure and format follow a logical sequence.	4.55
	Directions are clear and complete for students to perform the required tasks.	4.13
	Overall	**4.46**
4. Appeal	The activities are laid out in a motivating and interesting manner.	4.38
	The activities are presented in a way that catches students' attention and interest.	4.39
	The activities require learners to become actively engaged to ensure learning.	4.51
	The laboratory manual is interactive and provides high-quality sensory experiences to all users.	4.36
	Overall	**4.41**
5. Overall students' responses on the PLAH Manual	Content	4.58
	Format and Language	4.37
	Clarity	4.46
	Appeal	4.41
	Overall	**4.46**

Note.

Mean Rating	**Interpretations**	
4.50-5.00	Strongly agree	Excellent
3.50-4.49	Agree	Very Good
2.50-3.49	Undecided	Good
1.50-2.49	Disagree	Fair
1.00-1.49	Strongly Disagree	Poor

In terms of the content of the nPLAH manual, the student participants strongly agreed that the content is aligned with the topics on Biomolecules and that the contents of the laboratory manual are appropriate to them and are doable. Also, they strongly agree that the evaluation items in each activity deepen their understanding of the concept. There are only three post-laboratory questions compared to the PLAH manual which has several guide questions (directed, divergent, and convergent questions). This is consistent with the findings of Nengsi (2016), which found that the use of guided inquiry-based guides can increase students' engagement and conceptual understanding. A guided inquiry-based laboratory manual can assist in developing scientific inquiry techniques (Lubis *et al.,* 2016).

The students agreed that the activities are motivating and engaging enough to ensure learning. Further, the laboratory manual is interactive and provides high-quality sensory experiences to all users. Compared to the PLAH manual, different groups have the same experiments for nPLAH and they do not have set roles in their own groups. Although there is still collaborative learning for nPLAH manual and use of at-home materials, most students enjoyed exchanging outputs with other teams and learning as a class through the difference in results of their experiments. According to Science "comes alive" as a consequence of laboratory experiences, and students become interested in learning more about science and its application in everyday life (Singer *et al*., 2006) ***"Throughout the whole semester, my laboratory experiences were all fulfilling despite not being in an actual laboratory setup and the experiments conducted within our house. Apart from completing the tasks designated to me, one of the most fulfilling moments during the semester was interacting with my group members whenever we exchanged inputs for the datasheet of the team. And interacting with other groups and discover the differences in our results."*** Discoveries have helped students participate more in experiments and acquire knowledge that would fill their curiosity and bring satisfaction.

Mean achievement scores of the students before and after the intervention

Using mean and standard deviation, the researcher compared the achievement scores of the students before and after the utilization of the interventions (PLAH, nPLAH, and Video Manual).

Mean achievement scores of the students before and after using PLAH Manual

Table 16.1 represents the mean scores before and after using the PLAH manual. It can be shown in the table that before using PLAH, the overall mean achievement score was 44.34, with an SD of 9.51. After using the PLAH manual, students' overall mean achievement score increased to 62.60 with an SD of 9.28. This implies that there is an overall gain of 18.26.

Table 16.1

Mean scores before and after using PLAH Manual

		Mean	Std. Deviation
PLAH	Post-test	62.60	9.28
	Pre-test	44.34	9.51
	Diff	18.26	8.31

It could be said that the students who used POGIL have accumulated a great understanding, as evidenced by an increase in the mean achievement scores. This is supported by the study of Wright *et al.* (2017), offering an excerpt from a laboratory manual in which students will assist in the development of experimental protocols, the execution of experiments, and the analysis of results. Several studies showed that when POGIL is incorporated into teaching, students' performance is better than with traditional instruction (Farrell *et al.*, 1999; Hanson & Wolfskill, 2000; Moog & Spencer, 2008; Moog *et al.,* 2006; Villagonzalo, 2014; Bug-os & Caro, 2019). Similarly, several studies found that compared to typical laboratory sessions, POGIL was more effective in terms of the conceptual understanding of students (Hanson, 2013; Tobin *et al.,* 2012; Gaddis, 2007). Student interviews revealed that their chemistry laboratory using

PLAH Manual is helpful in the current semester because they performed different experiments, which made them understand the lessons better. ***"The current chemistry laboratory is useful because it represents our lessons this semester. For example, it helps me understand how enzymes work on different materials"***, one student said. According to several studies, the addition of POGIL improved students' understanding of significant ideas by teaching them not only how to absorb existing knowledge but also how to create it for themselves by asking the right questions and discovering the correct answers, and then using that information to develop a model or concept; POGIL aims to help students become self-directed and autonomous learners (Woods, 2014).

Mean achievement scores of the students before and after using nPLAH Manual

Table 16.2, on the other hand, presents the mean scores before and after using the nPLAH manual. It has been shown in the table that before utilizing the nPLAH, the overall mean score was 42.79, with an SD of 9.46. It can also be seen in the table that after using the nPLAH, there is an increase of 17.73 in the mean achievement scores of students, with an overall mean score after using nPLAH of 60.52 with an SD of 11.29. Therefore, we can say that nPLAH is also effective as an instructional material, as evident by the increasing mean score compared with the data yielded before using the nPLAH.

Table 16.2

Mean scores before and after using nPLAH Manual

		Mean	Std. Deviation
nPLAH	Post-test	60.52	11.29
	Pre-test	42.79	9.46
	Diff	17.73	10.47

According to the study of Shatila (2007), laboratory-at-home activities have been examined in several types of research, all of which have yielded good outcomes. This is similar to the findings of Nj and Obi (2021), where a study showed a gain in the Chemistry Achievement Test when students are taught using home materials. Many educational tools are available to students to help them gain a better knowledge of the issue under study. To avoid becoming stationary in a changing world, one would discover that improvised materials have, at most, the same effects as conventional materials (Shafquat *et al*., 2010; Anam & Nanjwan, 2016; Arikpo & Nanjwan, 2002). This could be a reason for the increase in the achievement scores for both nPLAH and PLAH. However, it could be seen that the increase in the group which utilized the PLAH manual is higher than that of the nPLAH manual. This could be due to the incorporation of POGIL where there are different experiments for each group in a class.

The constant response of students in the PLAH group when it comes to learning is the enhancement of conceptual understanding of lessons from their lectures through different experiments across groups. Students in the PLAH group appreciated the differences in groups' results as they had other or added reagents in their experiments compared to another group. One student said, ***"The laboratory experiments helped me better understand how biomolecules work and how it is affected by different factors. It amazed me how the reactions regarding biomolecules can be seen using materials and substances in our households."***

Mean achievement scores of the students before and after using Video Manual

Table 16.3 compares the mean achievement scores of students before and after using the Video manual. The results show that there is an increase of 17.83 in the mean achievement scores of the students after using the Video manual. The findings suggest that this intervention helped students understand the concepts, as seen by their post-test achievement scores.

Table 16.3

Mean scores before and after using Video Manual

		Mean	Std. Deviation
Video	Post-test	62.24	8.20
	Pre-test	44.41	9.26
	Diff	17.83	7.90

As stated by Jordan *et al*. (2016), "multimedia training has been proven to be a helpful learning aid." By employing video in the classroom, students may develop high-quality mental models and cognitive abilities such as interpretation, critical thinking, and problem-solving (Pekdag, 2017). It has been shown that instructional tools that integrate visual and auditory components allow more effective learning than either strategy alone. These studies, which were established to improve the teaching environment of information and communication technologies, raise student motivation and, as a result, academic accomplishment. According to the studies, there are two areas of advantage that videos bring in educational settings. One of these is how films improve students' attentiveness and motivation throughout the educational process. The potential of films to help pupils grasp and absorb complex and abstract ideas is the second area of value.

It could be seen that the increase in achievement scores in the group which utilized the PLAH manual was higher than that of the Video manual. This could be due to the incorporation of POGIL and the laboratory-at-home aspect. Some students admitted that they are not fast learners and with the mere fact that it is hard for them to grasp most things by merely just reading. One student in the PLAH group said, ***"It is advantageous. Doing experiments on our own enabled us to try new things and remember topics more than just watching people conduct experiments."***

Mean attitude level of the students before and after intervention

Using mean and standard deviation, the researcher compared the attitude of the students before and after the utilization of the interventions (PLAH, nPLAH, and Video Manual).

Mean attitude level of the students before and after using PLAH Manual

Table 17.1 represents the mean attitude level before and after using the PLAH manual. It can be shown in the table that before using PLAH, the overall mean attitude level was 3.01, with an SD of 0.24. After using the PLAH manual, students' overall mean attitude level increased to 3.23 with an SD of 0.28. Although their overall response of "partially agree" did not change, the 0.22 difference revealed that the mean attitude improved.

Table 17.1

Mean attitude of the students before and after using the PLAH Manual

		Mean	Std. Deviation
PLAH	Post-survey	3.23	0.28
	Pre-survey	3.01	0.24
	Diff	0.22	0.40

This is similar to the findings of several studies wherein the quantitative findings of the study displayed that guided inquiry laboratory experiments developed (Farrell *et al*.,1999; Ural, 2016). A study by Shatila (2007) revealed that POGIL-based learning greatly improves a student's attitude. Students had an increased interest in chemistry. These positive attitudes toward learning are reflected in the effectiveness of learning in various laboratory activities. One of the students said, ***"To be honest, it's a lot of fun. I'm learning and will undoubtedly learn more throughout the upcoming laboratory activities. Completing POGIL laboratory activities at home is entertaining."*** According to Doren *et al*. (1997), this curriculum teaches students about experimental design, careful observation, analytical thinking, and fun. By actively immersing students in experimental research, ignite their interest in science and boost their self-confidence.

Aside from increased interest, their positive attitudes toward doing experiments are evident. Some students also said that their experience in the laboratory was thrilling. For example, one said, ***"The laboratory experience I had this semester with my biochemistry subject was challenging, exciting, and fun. It is challenging because it is hard to find all the materials needed in every experiment and how to document it, and exciting thus fun because I get to experience experimenting even though it was not inside the laboratory, and I get to observe how things react first hand."***

The students felt fulfilled whenever they were on the task of conducting experiments. Most students find the experiments time-consuming; however, they always feel fulfilled after each task. According to Singer *et al.* (2006), laboratory experiences "bring science to life," thus students are eager in learning more about science and its application in everyday life. ***"Throughout the whole semester, my laboratory experiences were all fulfilling despite not being in an actual laboratory setup and the experiments conducted within our house. Apart from completing the tasks designated to me, one of the most fulfilling moments during the semester was interacting with my group members whenever we exchanged inputs for the datasheet of the team. And interacting with other groups and discover the differences in our results."*** Discoveries, specifically with the help of the POGIL format, have helped students participate more in experiments and acquire knowledge that would fill their curiosity and bring satisfaction.

Mean attitude level of the students before and after using nPLAH Manual

Table 17.2, on the other hand, presents the mean attitude level before and after using the nPLAH manual. It has been shown in the table that before utilizing the nPLAH, the overall mean score was 3.15, with an SD of 0.22. It can also be seen in the table that after using the nPLAH, there is an increase in the mean attitude levels of students with an overall mean score after using nPLAH of 3.24 with an SD of 0.33. Although their overall response of "partially agree" did not change, the 0.09 difference revealed that the mean attitude improved.

Table 17.2

Mean attitude of the students before and after using the nPLAH Manual

		Mean	Std. Deviation
nPLAH	Post-survey	3.24	0.33
	Pre-survey	3.15	0.22
	Diff	0.09	0.40

We can say that nPLAH is also effective as an instructional material, as evident by the increasing mean score compared with the data yielded before using the nPLAH. However, using the PLAH Manual (0.22) had a greater increase in attitude level compared to nPLAH (0.09). According to several studies, students' attitudes are noticeably better in classes that employ POGIL than they are in ones that do not (Bug-os & Caro, 2019). The POGIL learning approach has been shown to have good benefits on students' scientific attitudes, according to Fitria & Hidayah (2021).

Compared to nPLAH, in PLAH, there is an improvement in the mean attitude with Factor 1, which appears to indicate that students consider laboratory work as specifically part of the chemistry learning experience; Factor 2, which includes items that are connected to the desire for more practical work in the laboratory as compared to teachers' lectures; and Factor 7, consists of items dealing with the immediate and future benefits a student gains from experimentation. Most of the respondents answered that performing these laboratory activities let them teach the real-life application of the subject. Skills developed will be useful, especially when working in laboratories someday. They also stated that it equips them to be competent enough in the laboratory based on their laboratory experience. One said, ***"I believe that the semester's chemistry laboratory is very useful for my course and helps me improve my ability and capability… It taught me about laboratory settings and what we expect to do at laboratories."*** Another said, ***"I am fulfilled and amazed that we can still perform many experiments this semester despite the pandemic using easy-to-find materials at home."***

Mean attitude level of the students before and after using Video Manual

The mean attitude levels of students before and after utilizing the typical manual with video demonstrations are compared in Table 17.3. The data suggest that after using the manual, the students' average attitude level decreased by 0.55.

Table 17.3

Mean attitude of the students before and after using the Video Manual

		Mean	Std. Deviation
Video	Post-survey	3.15	0.25
	Pre-survey	3.70	0.45
	Diff	-0.55	0.56

The overall mean score before using the manual is 3.70, with an SD of 0.45, as indicated in the table. The overall mean score after using the manual is 3.15, with a standard deviation of 0.25. "Fully agree" became "somewhat agree" in the overall response.

Videos have long been acknowledged as a valuable tool for communicating laboratory expertise. In contrast to the findings of this study, some studies have found that videos are superior to written instruction in the teaching of manipulative laboratory skills to students (Kempa & Palmer, 1974). In their study, Mojica and Upmacis (2021) found that using videos assisted students in visualizing what was happening while reading the experimental protocol in the manual. Factors 2,3,6,7 and 8 are, however, responsible for the drop in attitude level. Factor 2 denotes the "quantity" of practical labor. This category includes issues related to a desire for more hands-on laboratory work rather than teacher lectures. Factor 3 represents the "importance" of laboratory activity in classroom learning. It shows how effective laboratory work is as a teaching method. There was also a decrease in the mean attitude of students on Factor 6, which represents a student's assessment of his own experimentation versus teacher demonstrations; Factor 7, which contains items dealing with the immediate and future benefits a student gains from experimentation; and finally, Factor 8, which contains items describing the benefits of laboratory work (experiments and experimentation). This contrasts with a study by Carmichael (2016), which found that learning laboratory manuals through videos benefits learners, boosts their performance, and improves students' attitudes.

Mean motivation of the students before and after the intervention

The researcher analyzed the students' motivation before and after using the interventions using mean and standard deviation (PLAH, nPLAH, and Video Manual).

Mean motivation level of the students before and after using PLAH Manual

Learner motivation has long been acknowledged as an important aspect in influencing how quickly and successfully people learn. Students in the PLAH learning style have a mean motivation level of 3.37 with a standard deviation of 0.30 for the pre-survey and 3.58 with a standard deviation of 0.30 for the post-survey. The initial result of "partially agree" changed to "fully agree" after utilizing the manual. Table 18.1.1 demonstrates a 0.21 rise in motivation as a result of PLAH exposure, indicating that the student's motivation has improved. The majority of the changes are related to student self-efficacy and self-determination. The grade, career, and intrinsic motivation remained unchanged.

Table 18.1.1

Mean motivation of the students before and after using PLAH Manual

		Mean	Std. Deviation
PLAH	Post-survey	3.58	0.30
	Pre-survey	3.37	0.30
	Diff	0.21	0.42

POGIL, according to Yalcinkaya (2012), helps students develop their problem-solving skills and knowledge, which leads to enhanced self-efficacy and motivation. Students are engaged in the concepts of innovation, invention, and creativity in POGIL-based learning, which significantly aids in their understanding (Sanders *et al*., 2005). During the POGIL teaching process, the interactive character of students' past cognitive and emotional attributes may result in both meaningful cognitive learning results and affective consequences (Bloom, 1976; McCoach *et al*., 2013). Students' future feelings about course content and interests are shaped by these emotional consequences. The findings back up Giff's (2016) premise that active learning techniques are linked to increased engagement, motivation, and perseverance, as well as confidence, all of which are linked to self-efficacy.

According to studies, students' motivation was boosted when they attempted to tackle real-world problems while communicating with their peers (Yalcinkaya *et al.,* 2012). POGIL is primarily reliant on this kind of engagement. Most of the students in the PLAH group say that what they like performing laboratory even if they are only at home is it enhances their skills, especially because when acting in groups, they are in different places, which makes it more challenging to communicate with their groupmates makes them think of a strategy and techniques to still work efficiently as a group which can, later, help them. One respondent said, ***"My laboratory***

experiences in Biochemistry are fantastic this semester. I learn to engage a lot by doing different roles like being the manager, reflector, presenter, and scribe… My groupmates and I worked hard on every experiment and enjoyed it. Wearing personal protective equipment also motivates and inspires me, as I already envision myself as a true professional. I hope to enjoy all the remaining experiments and acquire more knowledge in Biochemistry."

Table 18.1.2

Mean Motivation Factors before and after PLAH Manual

Motivation factors	**Before**	**After**	**PLAH Motivation difference**
Grade Motivation	3.18	3.39	0.21
Self-Efficacy	2.96	3.44	0.48
Self-determination	3.17	3.47	0.3
Career Motivation	3.82	3.84	0.02
Intrinsic Motivation	3.66	3.75	0.09

Table 18.1.2 shows the mean average pre- and post-survey scores on grade motivation, self-efficacy, self-determination, career motivation, and intrinsic motivation. Everything has improved, least improvement can be seen with career motivation. According to their pre- and post-survey results, the majority of respondents believe that professional desire is the most effective motivational element that affects students' propensity to study well. This is similar to other studies (Firat, 2018; Frick *et al*., 2011), that discovered that students are more likely to embrace learning materials that are targeted to their interests or key study goals, such as their future employment. Students ranked Self-Efficacy as the least compelling reason for studying before using PLAH, which contradicts Noor *et al*. (2020), who discovered that students believe self-efficacy has a major influence on their motivation to study. When comparing before

and after ratings, the PLAH Manual had the biggest impact on self-efficacy. As a result, using the PLAH Manual has a bigger impact on this motivating factor than the others. Students ranked Grade Motivation as the least effective motivational factor before and after using PLAH, which is consistent with the findings of Frick *et al*. (2011), who found that students are more productive when they are less worried about grades.

Mean motivation level of the students before and after using nPLAH Manual

The mean Motivation level of the students in the nPLAH learning mode is 3.37 with an SD of 0.29 for the pre-survey and 3.51 with an SD of 0.31 for the post-survey. Table 18.2.1 shows the students' average motivation in laboratory skills before and after utilizing the nPLAH. Because the mean post-survey scores are higher than the mean post-survey scores, there is sufficient evidence to suggest that students' motivation in the chemistry lab increased after utilizing the nPLAH Manual, notwithstanding the students' overall response of "fully agree."

Table 18.2.1

Mean motivation of the students before and after using nPLAH Manual

		Mean	Std. Deviation
nPLAH	Post-survey	3.51	0.29
	Pre-survey	3.37	0.31
	Diff	0.14	0.42

Compared to nPLAH (0.14), employing the PLAH Manual (0.21) resulted in a higher rise in motivation. Even after using the nPLAH laboratory manual, the student's grade motivation, self-efficacy, and self-determination statements remained linear, indicating that they only partially agreed.

The majority of respondents agree that Career Motivation is the most effective motivational element that affects students' motivation to study efficiently before and after utilizing nPLAH, according to the motivation score. This is comparable to the findings of other studies (Firat, 2018; Frick *et al*., 2011), who found that students are more likely to accept learning materials when they are tailored to their interests or key goals in studying, such as their future career.

Table 18.2.2

Mean Motivation Factors before and after nPLAH Manual

Motivation factors	Before	After	nPLAH Motivation difference	PLAH Motivation difference
Grade Motivation	3.14	3.19	0.05	0.21
Self-Efficacy	3.13	3.33	0.20	0.48
Self-determination	3.09	3.34	0.25	0.30
Career Motivation	3.87	3.88	0.01	0.02
Intrinsic Motivation	3.71	3.77	0.06	0.09

Prior to utilizing nPLAH, students ranked Self-Efficacy as the least motivating element for studying, in contrast to Noor *et al*. (2020), who found that students believe Self-Efficacy has a strong influence on their motivation to study. Students presented Grade Motivation as the least effective motivational factor noticed after utilizing nPLAH, which is similar to the findings (Frick *et al*., 2011), in which students appear to be more productive when they are not stressed by grades. After using the nPLAH Manual, the most significant improvement is in Self-Efficacy.

Mean motivation level of the students before and after using Video Manual

Table 18.3.1 shows the students' average motivation in laboratory skills before and after utilizing the Video Manual. Students' mean motivation level for the pre-survey in this learning mode is 3.41, with a standard deviation of 0.41. The students' mean motivation level for the post-survey, on the other hand, is 3.51, with a standard deviation of 0.38. Although the total response of "fully agree" did not alter after using the manual, the mean motivation of the students afterward was higher than the mean motivation of the students before using the video. It implies that this method of studying boosts a student's motivation.

Table 18.3.1

Mean motivation of the students before and after using Video Manual

		Mean	Std. Deviation
Video	Post-survey	3.51	0.38
	Pre-survey	3.41	0.41
	Diff	0.10	0.56

The increase (0.10) is less when compared to PLAH (0.21) and nPLAH Manual (0.14). After using the instructions, the responses for each component remained unchanged. A student in the PLAH group explained, ***"We can comprehend it more easily… if we watch a video of an experiment without performing it, we can't describe what happened. I find performing the laboratory activities exciting and interesting because it is amusing to see the result after all the things that we did."***

In terms of grade motivation, self-efficacy, and self-determination, students "partially agree," while in terms of career and intrinsic motivation, they "fully agree." The majority of respondents say that the most effective motivational factor that affects students' motivation to study effectively before and after using the traditional manual is career motivation. This is similar to the findings of Firat (2018), who found that students are more likely to accept learning materials when they are tailored to their interests or key goals in studying, such as their future job goals. The speaker showed that Grade Motivation is the least effective motivating factor observed before and after using the traditional manual with video demonstrations. This is similar to the findings (Frick *et al*., 2011), where students appear to be more productive when they are not pressured through grades. Self-efficacy was the most improved motivation aspect, followed by self-determination.

Table 18.3.2

Mean Motivation Factors before and after Traditional Video Manual

Motivation factors	**Before**	**After**	**Video Motivation difference**	**PLAH Motivation difference**
Grade Motivation	3.17	3.23	0.06	0.21
Self-Efficacy	3.18	3.33	0.15	0.48
Self-determination	3.22	3.43	0.21	0.30
Career Motivation	3.83	3.84	0.01	0.02
Intrinsic Motivation	3.67	3.71	0.04	0.09

Kempa and Palmer (1974) demonstrated that when it came to teaching students manipulative laboratory skills, videos outperformed written instruction. According to Donkin *et al*., in 2019, the outcomes of their study reveal that when students are taught in a blended learning format, they are more engaged and motivated, and they respond favorably to the use of video recordings for the initial acquisition of hands-on skills. Seeing videos of real-life scenarios to which learners can relate, according to Dwivedi in Riyana (2008), creates meaning, enriches the learning experience, and increases motivation to study. Participants in this study explained the importance of watching actual laboratory classroom scenarios with students who were not actors and with no scripted material.

Mean confidence in laboratory skills of the students before and after intervention

The researcher used mean and standard deviation to compare the students' confidence in laboratory skills before and after the interventions - PLAH, nPLAH, and Video Manual.

Mean confidence in laboratory skills level of the students before and after using PLAH manual

Table 19.1 shows the students' mean confidence in laboratory skills before and after utilizing the PLAH Manual. Prior to using the manual, the students had a high level of confidence in their laboratory skills (2.81 with an SD of 0.45). The students had very high confidence after utilizing it (3.39 with an SD of 0.43). According to Straumanis (2010), POGIL has demonstrated the capacity to boost student academic confidence. Furthermore, according to the findings of a study, students' academic confidence increased after using POGIL (De Gale *et al*., 2015). According to Schroeder and Greenbowe, it is considered to have directly resulted in students attaining a greater success rate on what they previously regarded to be tough questions (2008).

Students who study utilizing the POGIL method, according to Hein (2012), develop process skills that help them evolve in communication, written expression, and problem-solving, all of which are highly desirable attributes in the profession. Additionally, Hu & Shepherd (2013) back up the premise that this active learning technique encourages students to develop critical thinking, problem-solving, teamwork, and leadership skills (the process-oriented focus of POGIL).

Table 19.1

Mean confidence in laboratory skills of the students before and after using PLAH Manual

		Mean	Std. Deviation
PLAH	Post-survey	3.39	0.43
	Pre-survey	2.81	0.45
	Diff	0.58	0.59

Some students in the PLAH group realize that doing laboratory work is to practice their laboratory skills. Most said that the current chemistry laboratory is essential and valuable, and they all agree that learning a subject through books and lectures is insufficient. The chemistry laboratory assists them in physically applying all their biochemistry knowledge. One of the respondents said, ***"The current chemistry lab is indeed useful because all experiments given to us are related to the topics included in Biochemistry courses. By performing these simple experiments, we can expand our knowledge of how the body works and the nature, structures, actions, and interactions of the different biomolecules in sustaining the life of all organisms. Furthermore, we can also gather some laboratory skills and basic concepts of the procedures in the actual chemistry laboratory class."***

Some students also said that their experience in the laboratory was challenging, but they learned not only concepts and laboratory skills but also process skills. One of the students who responded said, ***"The questions we answer after the experiments help us develop our critical thinking skills. Aside from this, time management is also developed since we need to accomplish several tasks per unit. This includes taking a video of ourselves during the experiment and accomplishing the datasheet and the conclusion."***

Mean confidence in laboratory skills level of the students before and after using nPLAH Manual

The mean confidence in laboratory skills of the students' prior use of the nPLAH is shown in Table 19.2. It found that the students had high confidence (2.90 with a standard deviation of 0.44), which grew to very high confidence (3.36 with a standard deviation of 0.47) after utilizing it. The changes in confidence level after using nPLAH (0.46) are lesser compared with after using the PLAH manual (0.58). Most students under the PLAH and nPLAH groups agreed that observation skills progressed during the experimentation phase. These observations led them to think and construct scientific applications of their results. As seen in the data gathered from the respondents, the majority of the group stated that accurate and valuing precision in laboratory experiments helped generate output that they wanted to see or achieve. Accurate steps direct to the proper application of experimentation. One student said, "***The skills I've learned are being careful and accurate in experiments, such as putting on PPE to prevent possible hazards. Being accurate in each step in the procedure, such as what or how much substance is to be added, is also important to obtain the desired outcome of the experiment. I also learned to be observant and analytical, as these skills are essential in doing experiments. Being observant and paying attention to each detail will make us see what is happening in the experiments or what might have we done wrong, if there is any."***

Table 19.2

Mean confidence in laboratory skills of the students before and after using nPLAH Manual

		Mean	Std. Deviation
nPLAH	Post-survey	3.36	0.47
	Pre-survey	2.90	0.44
	Diff	0.46	0.66

Compared to the group that utilized the PLAH manual, the students under the nPLAH group are not that confident in interpreting the data they obtained and drawing a reasonable conclusion from the experimental data. The three different types of questions in the PLAH manual may have largely increased the confidence of students in the PLAH group. Directed questions focus on the student's awareness of characteristics of the experiment for which the solution may be derived directly from the experiment, while divergent questions are open-ended questions that require students to build upon their new information by thinking, further researching, and generalizing. Importantly, convergent questions aid students in synthesizing facts to arrive at a general conclusion or comprehension of the ideas (Haryati, 2018). After the five experiments conducted, students in the PLAH group learned to be critical thinkers. This includes using scientific equipment appropriately and safely, making observations, taking measurements, and following well-defined scientific methods was also imparted to them. One student said***, "..since the modules for the Biochemistry laboratory have listed several questions for us, it has tickled our minds and triggered the critical thinking skills that we possess, especially for the post-assessment part. Questions asked us to compare our group's results to the results of the other groups as well as there were also questions asking us to predict what would happen if a certain substance were used on another. Our reasoning skills, I believe, were also developed this semester because most of the questions provided in the module asked us to think and make causations."*** Laboratory experiences, according to Singer *et al.* (2006), can assist students in addressing the challenges inherent in directly observing and manipulating the material world, such as troubleshooting equipment or materials used to make observations, comprehending measurement errors, and interpreting and aggregating the resulting data.

Mean confidence in laboratory skills level of the students before and after using Video Manual

Table 19.3 shows that the students' mean confidence in laboratory skills before and after using the Video manual showed no difference with a high level of confidence. The students' mean confidence level for the pre-survey is 2.92 with a standard deviation of 0.40, and for the post-survey, it is 3.15 with a standard deviation of 0.45. This indicates that after using the Video manual, lab skills confidence has increased (0.22). However, the improvement is lower than that of PLAH (0.58) and nPLAH (0.46).

Table 19.3

Mean confidence in laboratory skills of the students before and after using Video Manual

		Mean	Std. Deviation
Video	Post-survey	3.15	0.45
	Pre-survey	2.92	0.40
	Diff	0.22	0.61

Not only for preparing for class but also for reinforcing concepts as part of a study plan and strengthening students' confidence in what they had studied, video modules were effective (Lancelloti *et al*., 2016; Pyatt & Sims, 2012). These findings could be linked to a study that found that, while watching appears to be passive, it actually involves a lot of cognitive activity, which is required for active learning. Adapting the use of videos in learning improves skill-based performance, reduces anxiety, increases confidence, and frees up memory inside the laboratory in this age of technology and digital media (Schmid *et al.*, 2005).

One student in the Video group when asked if he is confident in doing experiments said, ***"Actually, no. The confidence to perform laboratory activities will always be different if we performed it in a proper setting and have the chance to utilize materials and equipment for it".*** Another said, "***I am not, sadly. It is for***

the sole reason that I never performed any myself. And that's the downside of watching compared to actually doing it".

Significant Difference of the Mean Achievement, Attitude, Motivation, and Confidence in Laboratory Skills Before and After Using the Interventions

To determine the appropriate test for comparing pre- and post-test, and survey scores, the researcher utilized the Shapiro-Wilk test for normality. If the data on the differences is normal, a paired t-test is employed; otherwise, a Wilcoxon-signed-rank test is used.

Table 20

Significant difference before and after using PLAH, nPLAH, and Video Manuals

	p-value		
	PLAH	nPLAH	Video
Achievement Test	*<0.0001**	**<0.0001***	*<0.0001**
Attitude	*<0.0001**	**0.0043***	*<0.0001**
Motivation	*<0.0001**	*0.0002**	**0.2932**^{ns}
Confidence	*<0.0001**	**<0.0001***	*0.0188**

Note. (1) italic- p-value of Paired t-test; bold- p-value of Wilcoxon signed-rank test
(2) *-significantly different, ns-not significantly different

Table 20 reveals that, with the exception of motivation toward laboratory chemistry for those who utilized the Video manual, all variables examined before and after any treatment exhibit a significant difference before and after the interventions.

At a 5% level of significance, there is sufficient evidence to say that there is a significant difference in the mean achievement score of the students for the pre- and post-test conducted under the PLAH learning mode. This means that using PLAH promotes and develops skills in learning, thinking, problem-solving, management, and assessment. This result can be supported by several studies (Shatila, 2007; Brown, 2010; Villagonzalo, 2014), which stated that the benefits of POGIL activities compared to regular education resulted in greater efficacy where POGIL participants received more excellent grades and mastery levels. However, there is also sufficient evidence to say that there is a significant difference in the mean achievement score of the students for the pre- and post-test conducted under the nPLAH learning mode. With the laboratory-at-home aspect, most students learn better when actively engaged and allowed to develop their knowledge (Hanson *et al*., 2001). The results of student performance show that there is minimal difference in student performance when utilizing home-experiment kits vs standard supervised laboratories (Kennepohl, 2007). However, according to the Monash University study, students who use the home kit regularly receive slightly higher scores for practical work and much higher final grades than on-campus students and those who attend the residential school. This is congruent with the findings of Boschmann (2003) and Casanova et al. (2006), who found that student performance in general chemistry is higher when home experiments are compared to on-campus facilities. Moreover, at a 5% level of significance, there is sufficient evidence to say that there is a significant difference in the mean achievement score of the students for the pre- and post-test conducted in the Video learning mode. This implies that the Video manual keeps the material structured and presented so that students do not miss out on the experience of science as the exchange and growth of ideas.In higher education, video has been utilized to convey course information, improve lab functionality, nurture academic integrity, and assist students in achieving (Ida, 2021).

For attitude level, at a 5% level of significance, there is sufficient evidence to say that there is a significant difference in the mean attitude level of the students for the pre- and post-survey conducted under the PLAH learning mode. Alghamdi and Alanazi (2020) found that the post-test POGIL groups varied substantially on Student

Cohesiveness, Cooperation, and Personal Relevance, indicating that POGIL had a favorable influence. In a research conducted by Bug-os and Caro (2019), pupils in POGIL lessons had considerably greater attitudes than those in non-POGIL classrooms. POGIL was found to boost student engagement, information retention, higher cognitive skill development, and application abilities (Simonson *et al.,* 2013). However, at 5% level of significance, there is also sufficient evidence to say that there is a significant difference in the mean Attitude level of the students for the pre- and post-survey conducted under the nPLAH learning mode and Video learning mode.

There is adequate evidence to say that there is a significant difference in the mean motivation level of the students for the pre- and post-survey done under the PLAH learning mode at the 5% level of significance. Table 18.1.2 shows the results of a comparison of student motivation before and after utilizing the PLAH Manual. Furthermore, there is adequate evidence to say that there is a significant difference in the mean Motivation level of the students for the pre- and post-survey done under the nPLAH learning mode. However, at a 5% level of significance, there is sufficient evidence to say that there is no significant difference in the mean Motivation level of the students for the pre- and post-survey conducted in the Video learning mode. This implies that there is there had been no significant change in the motivation of the students under Video group.

There is sufficient data to say that there is a significant difference in the mean confidence level of the students for the pre- and post-survey done under the PLAH learning mode at a 5% level of significance. This is similar to the findings of Hanson and Wolfskill (2000), who found that using POGIL enhanced 54% of respondents' confidence in chemistry. Furthermore, there is adequate evidence to declare that there is a significant difference in the mean Confidence level of the students for the pre- and post-survey done under the nPLAH learning mode at the 5% level of significance. Table 19.2 also shows a substantial difference in student users' mean confidence in laboratory skills before and after using nPLAH, demonstrating that higher education should prepare graduates with 21st-century skills. These skills, which include creativity and innovation, communication, collaboration, critical reasoning, and problem-solving, have been identified as a set of skills that students should develop in order to confront global problems (Irwanto *et al.,* 2018), and that collaborative inquiry-based learning can help students improve their critical thinking and problem-solving skills (Wartono *et al*., 2018). There is sufficient data to say that there is a significant difference in the mean confidence level of the students for the pre- and post-survey done in the video learning mode at a 5% level of significance. Videos have long been seen as a useful tool for communicating laboratory skills (Kempa & Palmer, 1974). Because of the video demonstrations of these strategies, students who received either video had greater manipulating skills. According to Campbell *et al*. (2020), students were more confident in their abilities, spent more time engaging with theory, applied practical lab skills in a more targeted approach, and generated better outputs as a result of having access to the videos before, during, and after lab sessions.

In all aspects PLAH and nPLAH showed significant improvement. These results show that it was the hands-on activity and not the POGIL format that accounts for the improvement shown in all aspects.

Significant Difference in the Mean Achievement, Attitude, Motivation, and Confidence in Laboratory Skills among the Interventions

To choose the appropriate test for comparing the three treatments, the researcher utilized the Shapiro-Wilk test for normality and homogeneity. If the data for all three treatments are normal and have equal variance, the F-test with ANOVA is employed; otherwise, the Kruskal-Wallis test is used.

Except for confidence in laboratory skills, none of the variables in Table 21 demonstrate a significant difference. Treatment 3 (Video manual) is substantially different from the other treatments in a multiple comparison test for confidence in laboratory skills using Dunn's test with Bonferroni adjustment.

Table 21

Significant differences among PLAH, nPLAH, and Video Manuals

	p-value
Achievement Test	0.4731
Attitude	0.1895
Motivation	0.1531
Confidence	0.0034*
1vs2	0.3351
1vs3	0.0011*
2vs3	0.018*

Note. *-significantly different

The outcomes for all treatments show that using a well-designed instructional manual can improve students' knowledge and understanding of Biomolecules subjects. The considerable differences in mean pre- and post-test scores are positive, demonstrating the usefulness of all instructional guides. This is consistent with previous findings that show how instructional materials can help teachers present their lessons to students in a logical and sequential manner (Isola, 2010), as supported by Abdu-Raheem (2014), who demonstrated how instructional materials aid explanations and make subject matter learning understandable to students during the teaching-learning process. According to the comparison treatment using Kruskal-Wallis test results, the p-value is 0.4731, which implies no significant difference in the mean achievement scores of student users among PLAH, nPLAH, and Video Manuals. This means that despite the materials or methods used to give information, students still excel and show a significant impact that bring them success. This also means that despite the highest increase in achievement scores among the interventions, PLAH manual use is still comparable in terms of achievement scores of students. This is similar to the study findings of Walker & Warfa (2017) and Ahmad (2007) that the quantitative data concerning achievement revealed no significant difference between groups; students who used POGIL did not differ from students who did not. This is in contrast to the findings of Rumain & Giliebter (2020) that students (both low and high achieving) scored significantly higher than those taught by traditional methods when using POGIL. This is also different from the interview replies of students under the PLAH manual wherein they perceived that their conceptual understanding increased due to the POGIL aspect of the manual where their critical thinking skills were enhanced. This is also different from the perception of the instructors who handled different interventions (PLAH, nPLAH, Video). According to one instructor, based on her observations while utilizing the PLAH manual, the students gained more confidence with their replies, began to have extensive answers, and began to express more of their ideas on the topic. They improved their skills and learned self-discipline as a result. Students are instructed to learn new knowledge in a POGIL framework while employing process skills such as teamwork, communication, and problem-solving. As a result, while learning discipline-specific topics, students develop transferrable skills. The PLAH manual encouraged students to be more active, elaborate, and self-assured. An instructor described how POGIL increased students' engagement. ***"Actually, the PLAH manual group has been more active compared to the nPLAH and Video groups. In those groups, they seem unsure and hesitant about their answers."*** A participant showed how POGIL could make a student involved, she said, ***"In the PLAH group, the students are more elaborate in***

answering the questions, and when asked, they are more confident to answer." Another participant shared how POGIL changes the students, ***"The other groups are more relaxed, unlike the PLAH group that, they are more aggressive to answer, they seemed trained and obviously mastered self-discipline."*** Another instructor shared that she likes the PLAH manual more, ***"Weakness of the nPLAH manual is that there are no comparisons. That is why I like the POGIL better because I myself am learning from it."***

The findings for PLAH and nPLAH show that these interventions are helpful in changing students' attitudes toward Chemistry lab. The Video manual, on the other hand, contradicts this with the decrease in attitude levels of students. However, there is still no significant difference in the mean attitude level of the respondents among the three manuals at a 5% level of significance using the Kruskal-Wallis Test. The finding is similar to the study of Chase *et al.* (2013) that students' attitudes toward chemistry results indicate little to no impact, although positive trends favoring POGIL students were observed. This may be due to the laboratory-at-home aspect of both PLAH and nPLAH manuals which may have affected their attitude towards the chemistry laboratory largely. However, for students under the PLAH manual they say that what they like performing laboratory even if they are only at home is it enhances their skills, especially because when acting in groups, they are in different places, which makes it more challenging to communicate with their groupmates makes them think of a strategy and techniques to still work efficiently as a group which can, later, help them. One student said, ***" My laboratory experiences in Biochemistry are fantastic this semester. I learn to engage a lot by doing different roles like being the manager, reflector, presenter, and scribe… My groupmates and I worked hard on every experiment and enjoyed it. Wearing personal protective equipment also***

motivates and inspires me, as I already envision myself as a true professional. I hope to enjoy all the remaining experiments and acquire more knowledge in Biochemistry." Instructors also appreciated the value of the laboratory-at-home aspect of the PLAH and nPLAH manuals and stated that the manuals demonstrated that chemistry is everywhere and that it can be done at home and outside of the four walls of a laboratory. One instructor mentioned that the activities and groupings are beneficial to students. According to another instructor, the students were able to study and have fun while dealing with the pandemic. She said, ***"the laboratory at home activity is effective. You will also be able to see that the kids are enjoying themselves and they are proud of what they do. They even post it on their stories online. That even if we cannot have face-to-face classes, they can still try to wear their lab gowns, and they are always excited to do the experiment at home."*** This aspect of the manual helped students feel less anxious about performing the experiments, which promotes active learning. One instructor said, ***"The activities that can be done at home reduced the fear of my students to do experiments since they are handling simply only things found at home and fruits that are not expensive."*** They said that you do not even have to be a high-level thinker to understand and apply principles to real-world situations. Furthermore, it is simple to understand and does not include many complex materials. One stated that ***"Even I, as a teacher, was astounded, and I appreciate it since the materials needed are readily available. It's simple to use and provides opportunities to learn and unlearn."***

The findings for all interventions suggest that they are effective in increasing students' motivation to work in the Chemistry lab. At a 5% level of significance, there is sufficient evidence to prove that the respondents' mean Motivation Level is equal across the three teaching approaches. Students often have difficulty learning since they are completely focused on the lab manual and lack real-world connections. People's views toward science change as they are exposed to it, according to Craker (2006), but the direction of change is impacted by the quality of the exposure, the learning environment, and the teaching method. In contrast to the findings, students are more motivated after using the PLAH Manual because of the detailed step-by-step approach that POGIL takes with regard to process learning objectives, collaborative structure, content learning, pedagogic structure, and self-assessment. Students were expected to develop a sense of understanding of the topics through hands-on activities, concept formation, teamwork, and self-discovery that this technique provides, students were expected to develop a sense of understanding of the topics through hands-on activities, concept formation, teamwork, and self-discovery that this (Chiao, 2013). Students utilize scientific inquiry to discover problems, come up with solutions and alternate answers, search for information, evaluate it, and communicate with their classmates. Although the increase in motivation level is much higher in the PLAH group compared to nPLAH and PLAH, the no significant difference among the three suggests that incorporating the laboratory itself affects grade motivation, self-efficacy, self-determination, career motivation, and intrinsic motivation.

There is enough information to suggest that the mean Confidence Level of the respondents is not equal among the three teaching techniques at a 5% level of significance. PLAH and Video; and nPLAH and Video are two pairings of learning modes that have substantial distinctions. In a nutshell, the Video manual differs greatly from the other two manuals in terms of confidence in laboratory skills. The improvement and differences in the mean confidence of the students before and after using the different laboratory manual modalities can be extrapolated from Table 20.

This is evident in the replies of students in the Video group when asked if they are confident after utilizing the manual. Even students in the PLAH and nPLAH groups agree that their confidence lies in the fact that they are able to do hands-on activities and not solely watch videos.

Significant Relationship between Achievement and Attitude, Motivation, and Confidence in Laboratory Skills

To establish the best test for correlation analysis, the researcher used the Doornik-Hansen test to test bivariate normality. If the two variables are bivariate normal and have equal variance, Pearson's correlation is employed; otherwise, Spearman's correlation is used.

Attitude, motivation, and confidence in laboratory skills are not substantially correlated with achievement, as shown in Table 22. There is adequate data to establish no association between research participants' achievement and their attitude, motivation, or confidence in laboratory skills at the 5% significance level. This contrasts with studies that achievement is correlated with attitude (Narmadha & Chamundeswar, 2013). It is somewhat in accordance with Godwin and Okoronka's (2013) results that attitude has little to no influence on student success. This is most likely owing to other variables such as the subject's abstract and quantitative character (Maranan, 2017). It is also in contrast to the study of Bliglete (2013) and Aktamiz & Ergin (2008) that there is a correlation between student achievement and skills. Although in both studies, process skills are evaluated instead of confidence in laboratory skills.

However, this is in line with the findings of the meta-analysis of Agustian *et al.* (2022) of 355 empirical research on university chemistry laboratory instruction which reveals that laboratory learning is inherently multifaceted. The notion of multidimensional learning has its roots in educational psychology, namely the challenge to cognitivism as the main approach of understanding human learning in the twentieth century. According to Dai and Sternberg (2004), a cognitivist-reductionist view of reasoning in which motivation and attitude are considered as extraneous to cognition (achievement) ignores critical components of cognitive functioning and growth.

Table 22

Significant relationship between achievement and attitude, motivation, and confidence in laboratory skills of the students

Treatment/ Variable	**Correlation coefficient**	**p-value**	**conclusion**
PLAH			
attitude	*-0.1387*	0.1046	not substantially correlated
motivation	*0.0393*	0.6471	not substantially correlated
confidence	*-0.1012*	0.2376	not substantially correlated
nPLAH			
attitude	*-0.0495*	0.5682	not substantially correlated
motivation	*0.0109*	0.9	not substantially correlated
confidence	*-0.0909*	0.2946	not substantially correlated
Video			
attitude	*-0.2121*	0.167	Negative weak correlation; not significant
motivation	*-0.0919*	0.5532	not substantially correlated
confidence	**-0.0307**	0.843	not substantially correlated

Note. (1) italic- Spearman correlation; bold- Pearson correlation

Perceptions of Chemistry Laboratory of Students before, during, and after using the PLAH Manual

The students were interviewed before using the PLAH Manual to determine their experiences and what they think the value and use of the Chemistry Laboratory. This step will serve as a baseline to determine how their experience and perception of the Chemistry laboratory change using the PLAH Manual. They were also interviewed after using three modules of the PLAH Manual to determine their experiences and what they think the value and use of the Chemistry Laboratory. This step determined how their perception changed with the introduction of the PLAH Manual. And they were also interviewed after using the PLAH Manual to determine their overall experience and what changed with what they think the value and use of the Chemistry Laboratory is.

The transcription of interviews undergone *"horizontalization"* of data which refers to the process whereby relevant quotes of the studied topic are listed and given equal value with regard to the expressions of the group. This is then followed by grouping of the relevant themes.

Table 23

Themes and subthemes of Experiences and Perceptions towards Chemistry Laboratory of Students Before, During, and After using the PLAH Manual

Themes	Before using the PLAH Manual	After 3 Experiments	After using the PLAH Manual
Experience	-Boring and limited -Fun and exciting	-Different types of chemistry laboratory -Fun and exciting -Challenging	-Fun and exciting -Challenging -Fulfilling
Learning	-Application of concepts -No learning	-Application of concepts -Deeper understanding of concepts	-Application of concepts -Deeper understanding of concepts (through different experiments across groups)

Value and Usefulness	Valuable and Useful -Critical thinking skills -Teamwork -Practical laboratory skills Not Valuable and Useful	Valuable and Useful -Communication skills -Being versatile -Teamwork -Distance laboratory learning -Critical thinking -Practical laboratory skills -Real-life application -Confidence	Valuable and Useful -Communication skills -Being versatile -Teamwork -Distance laboratory learning -Critical thinking -Practical laboratory skills -Real-life application -Confidence -Creativity -Time management -Working independently
Difficulties	No or limited experience -Chemistry lab classes in high school --only lectures and discussions --lack of laboratory equipment, resources, and laboratory classroom -Chemistry lab classes in 1st-year college --due to the pandemic/ no face-to-face classes (online videos and written activities)	-Lack of time -Some materials are not readily available	-Lack of time -Difficulty editing videos

Note. Data collected on September, November, and December 2021.

Before using the PLAH Manual

Thematic analysis of the students' Chemistry Laboratory experience before, during, and after using the POGIL-based laboratory-at-home manual showed the progress from a boring and limited laboratory experience to a challenging then fulfilling laboratory experience. However, with or without utilizing the PLAH manual, the laboratory experience is fun and exciting. Few students have experimented with their High School for the Pre-semester interview. Many students stated that they lack experience because of the termination of face-to-face classes owing to the COVID-19 outbreak. They had to complete modules and drawings or watch videos; this was difficult. One student said, ***"I didn't have much experience in a laboratory setting at this point because of the pandemic. All I ever did was draw lab apparatuses and label their parts."*** Though, there are also those students who did not experience much in Chemistry laboratory class, even in high school. ***"I don't have much experience working inside the laboratory since we didn't have activities in chemistry back in high school. I can't exactly remember any experiments we did, if any, because it is more on lectures",*** one student said.

In terms of what they think about learning from the laboratory, those students who experienced Chemistry laboratory classes responded that they were able to apply theoretical concepts to practical processes. The most common learning that the respondents acquire from laboratory activities is skills and first-hand knowledge. For instance, one student explained that ***"Learning from the laboratory gave me a chance to experience practical processes. Some of these practical applications include experimental and data collection, observation/ investigation, having an educational guess or hypothesis, and being able to experience and see reactions or experiments face to face."*** Negative statements from those who haven't experienced any hands-on laboratory experiments were gathered. For example, a student said, ***"I guess it is how to trace pictures from books properly."***

The majority of the participants believe that the laboratory is valuable because it is where they hone their skills to be better prepared for their future professions in the medical field. In terms of their abilities, many of the respondents gained critical-thinking skills, analytical skills, and good team working skills in the laboratory. One student said, ***"The laboratory is valuable, most especially in science. It is where we***

perform research and experiments that allow us to interact directly with the given materials and perform it first-hand, which largely contributes to the student's learning and development." As to their experience working in groups, many respondents stated that working in groups in the laboratory makes the work finished faster and more organized. One student said, ***"By working in groups, I think I have learned better and quicker. Maybe that's because teamwork typifies real-world science better than learning independently."*** They indicated that working in groups always makes the activities and discussions very interactive and enjoyable. It helps everyone in the group understand the lessons easier during group discussions. However, others had a different experience working in groups in a laboratory class. ***"Working in groups sometimes tends to be chaotic as some people do not take procedures seriously or do not care at all,"*** one student said.

Some students stated that their Chemistry laboratory class in high school is a memory they will forever treasure. They feel blessed to have an excellent laboratory class during their high school years. While others weren't excited about their experiments, ***"Most experiments are done inside the classroom, and I can barely remember what it was about."*** Others had only lectures and discussions in their laboratory classes. One student explained, ***"I would say that it was not much of an experience even though I am from the science curriculum. We didn't experience working inside the laboratory as they turned the supposed laboratory into a classroom."*** Another student said, ***"We didn't have chemistry laboratory class in high school. It was a pure lecture about concepts."*** Further, some students said that due to a lack of laboratory equipment, resources, and laboratory classroom, they could only do limited activities. As one student said, ***"Due to lack of resources, we only got to experience some basic experiments inside our classroom, as our***

school doesn't have a budget for a laboratory room." However, some of the students didn't experience chemistry laboratory classes because the school's lab pieces of equipment were incomplete, so we weren't allowed to do more. One student said, ***"We did not perform experiments that will be helpful for us in our tertiary education. That is one of the reasons why I did not appreciate Chemistry that much when I was in high school and one of the reasons why I'm struggling with my Chemistry class at present."*** All said that the Chemistry laboratory class in their 1st year of college was challenging because they had not experienced doing lab physically. One said, ***"As part of our chemistry laboratory class, our professor sent us videos that we can watch to learn basic knowledge in the laboratory. Such as what to do when there is an emergency inside the laboratory and the different uses of lab apparatus."*** However, the majority experienced none at all. ***"Knowing that we are not allowed to perform activities face-to-face due to the pandemic, we never do any experiment in my chemistry laboratory class; it was just a pure lecture,"*** one student sadly replied.

After using three modules of the PLAH Manual

After three modules, the students unanimously agreed that the chemistry they studied last semester was different from the chemistry they looked at this semester since they do laboratory-at-home activities, giving them the experience they needed. Some respondents also said that their experience in the laboratory was thrilling and challenging for a few reasons – some of the materials to be used were not available at home. For example, one said, ***"The laboratory experience I had this semester with my biochemistry subject was challenging, exciting, and fun. It is challenging because it is hard to find all the materials needed in every experiment and how to document it, and exciting thus fun because I get to***

experience experimenting even though it was not inside the laboratory, and I get to observe how things react first handily."

In terms of learning, most respondents answered that their chemistry laboratory is helpful in the current semester because they performed different experiments, which made them understand the lessons better. ***"The current chemistry laboratory is useful because it represents our lessons this semester. For example, it helps me understand how enzymes work on different materials"***, one respondent said. Some students admitted that they are not fast learners and with the mere fact that it is hard for them to grasp most things by merely just reading. One student said, ***"It is advantageous. Doing experiments on our own enabled us to try new things and remember topics more than just watching people conduct experiments."*** Most students responded and agreed that their biochemistry laboratory classes allow them to gain a deeper understanding of the topic, apply all their learnings, and observe how various chemical reactions involving biomolecules occur. One said***, "The current laboratory is instrumental because it is timely and opens our minds to think critically during and after the experiment. It also motivates us to look forward to more experiments."***

Some students also feel more confident performing experiments because they can repeat and do the experiments again since they do this at home and use household items. Still, due to having many activities, they hope to give them more time to finish the said tasks. One said, ***"It was fun but time-consuming because the other members of the group are not managing their time properly, so the others are adjusting, and we tend to rush the things that should be done earlier than the deadline, but overall, it was and wonderful that we have experiments in biochemistry.***" Another student said, ***"There are times when our schedules are***

loaded with synchronous classes from other subjects that take up most of our hours in a day; as a result, I find it difficult to take the time to experiment and document it. However, this may not be a major issue because it is case-by-case, and everyone manages their time differently." Some of the respondents say that one source of difficulty in their chemistry laboratory class is that some materials are not readily available, the reason that students live in far-flung areas; moreover, some municipalities and establishments are strict in conforming to IATF guidelines which makes access to the needed materials more complicated.

After using five modules of the PLAH Manual

After using the manual, the students appreciated the different skills they enhanced by using the PLAH manual, such as communication skills, versatility, being creative, time management skills, and working independently, in addition to the critical thinking, collaborative and practical laboratory skills which the students are aware of before even using the PLAH manual. The students appreciated that they could experience laboratory classes amidst the pandemic using household materials and the POGIL approach, which made them confident to do experiments.

One student said, ***"All five laboratory experiments are amazing, and they made my semester fun and memorable. First, I got to work with my classmates even though it was in an online setup, and we became close to each other and much more comfortable working together. I was also able to explore many things through experimenting, and it gave me excitement to anticipate the results of every experiment I did. Also, in the roles given, I was able to experience five different roles and develop and discover several skills. I would say that this is one of the best experiences I have had."*** Laboratory courses are believed to be essential in scientific theory courses, allowing students to acquire experimental and collaborative learning skills (Lunetta, 2016). Through the variety of experiments that they have encountered, many said they never thought how exciting and fun it was to learn new things in this online setup. The student's willingness and eagerness to learn, even if their classes were not face-to-face, agreed that the experiments were undeniably interesting as the pre-pandemic life. Most simply, students could cope with the needed materials that involved mainly their kitchen, where they will execute or perform the said experiments.

In this setup, most of the students were able to gain communication skills with their group. Some had quite a trouble at first, especially introverted individuals. But along the journey, they were able to build communication skills and relationships with their classmates. Curricula in allied health typically engage students in communication and critical thinking related to patient interaction, and students must communicate with other constituents to protect and advance their profession. One said, ***"I was also able to develop my communication skills because of the bond that we had established with my groupmates, even if we just met online for the first time."*** Having a groupmate in every experiment has helped students make the job easier and faster. Social Media is now considered the most widely used medium of communication since face-to-face setup cannot be pushed through due to the pandemic and was a challenge to some students. In addition, poor internet connection contributed to some students, making group discussion difficult for them. However, most of the students learned camaraderie through laboratory experiments. ***"At first, I was worried that I wouldn't be able to cooperate well in a group because I used to work alone, but I learned to work well in a group. I was the one who reminded them of their responsibilities, making sure that they were all comfortable working with each other, and I was the one suggesting how to assign roles and***

tasks for everyone's convenience and benefit…Overall, my groupmates and I have collaborated to attain a common goal: a high-level group performance." Laboratory experiences, according to Singer *et al.* (2006), may also improve a student's capacity to interact successfully with others in carrying out difficult activities, share work duties, adopt different roles at different times, and offer and respond to ideas. Group effort has always been a great help to most students since more hands would be utilized to finish the job faster.

After the five experiments conducted, most students also learned to be critical thinkers. This includes using scientific equipment appropriately and safely, making observations, taking measurements, and following well-defined scientific methods was also imparted to them. One student said***, "..since the modules for the Biochemistry laboratory have listed several questions for us, it has tickled our minds and triggered the critical thinking skills that we possess, especially for the post-assessment part. Questions asked us to compare our group's results to the results of the other groups as well as there were also questions asking us to predict what would happen if a certain substance were used on another. Our reasoning skills, I believe, were also developed this semester because most of the questions provided in the module asked us to think and make causations."***

Most respondents agreed that observation skills progressed during the experimentation phase. These observations led them to think and construct scientific applications of their results. As seen in the data gathered from the respondents, the majority of the group stated that accurate and valuing precision in laboratory experiments helped generate output that they wanted to see or achieve. Accurate steps direct to the proper application of experimentation. One student said, "***The skills I've learned are being careful and accurate in experiments, such as putting on***

PPE to prevent possible hazards. Being accurate in each step in the procedure, such as what or how much substance is to be added, is also important to obtain the desired outcome of the experiment. I also learned to be observant and analytical, as these skills are essential in doing experiments. Being observant and paying attention to each detail will make us see what is happening in the experiments or what might have we done wrong if there is any."

Predominantly the respondents said that after the five experiments, they are better involved with the subject by applying ideas that are seen regularly in the comforts of their houses. Additionally, understanding said activities made the learners more confident in doing the experiments and answering their laboratory manuals. One student said, ***"Doing experimental things on my own and learning to observe results is what I have gained in this laboratory class. Back in high school, I was not used to experiments if they were not by a group; that's why I said that self-confidence and believing in myself that I can do it is what I have gained."*** In connection with this, they could generate or develop a hypothesis backing up their crafts if queries arise.

Most of the respondents learned how to be creative in their experiments. Since some of the needed materials were unavailable in the market, the respondents were forced to unleash their creativity by using alternatives. The skill of being creative is one good learning to acquire in this laboratory because it will be helpful in their practice in the future. Another student said, ***"This Biochemistry laboratory takes us to another level of understanding and learning about the modules to be introduced. It opens our creative minds to be imaginative and apply it to the real setting."*** Finally, some advanced their creativity in terms of video editing. One respondent said, ***"… Another skill I got from this laboratory class is my creativity***

in editing. I was the group's editor, and editing the videos improved my skills in media editing. It was entertaining to see how our output turns out!"

Conducting experiments in an online setup was indeed a challenge for many students. One of the students said, ***"It was hard and stressful sometimes, especially when the materials needed are not available in our kitchen."*** Some students also find the laboratory experience difficult since they have trouble editing the videos of the experiments they have conducted, and instances of "retakes" or "reshoots" occur when unwanted events happen while filming. However, students still found their experiments fun and valuable as they could still better understand concepts and skills. As one student explained, ***"I feel extremely fortunate to be able to experiment on my own in our current chemistry laboratory class amidst difficulties such as time-constraint and editing videos.."***

Perceptions of Chemistry Laboratory of Instructors before, during, and after using the PLAH Manual

The instructors were interviewed before, during, and after using the PLAH Manual to determine the changes in their perceptions of the chemistry laboratory. This step determines how the PLAH Manual may have helped the students and the instructors.

Table 24.1

Pre-semester Perceptions of Chemistry Laboratory of Instructors

Themes	Sub-themes
Gaps affecting chemistry laboratory teaching	Low confidence level (pre-pandemic and during pandemic) Pandemic (no training, alternatives used)
Recommendations for continuous knowledge and skill improvement in teaching	Curriculum enhancement Training Application

Managing chemistry laboratory class	High and low confidence level (pre-pandemic) Pandemic (no experience) Challenges (lack of equipment, lack of reagents, large class size, lack of time)

Note. Data collected on September 2021.

Gaps affecting chemistry laboratory teaching

All of the participants stated that they were not confident in their competence in teaching chemistry laboratory. Multiple variables influence this, including the pandemic, their teaching and laboratory experiences during the pre-pandemic period, and their requirement for retraining in hard science, such as chemistry. Instructors with training experience are typically capable of carrying out their laboratory practices (Akdemir, 2006). Some instructors are unsure about their abilities to teach Chemistry laboratory. ***"I truly admit that that is one of my waterloos,"*** one stated. ***"My undergrad Biochemistry course does not have a laboratory, and I taught in a department that similarly does not have a lab, so I am actually not that sure,"*** stated another. They also stated that with the 'new normal' that we are experiencing, chemistry lab has become more difficult. Educators argue about the new normal since they have not been educated about emergency online instruction (Talidong & Toquero, 2020). ***"Compared to re-pandemic times, I was more confident back then because we can assess it first when we ask students to do a task. We prepare the reagents, so as the instructor, you also prepare to make sure to come up with a positive answer; you are confident, and you know that the expected outcome will be met even before the experiment,"*** one instructor said. Participants also stated that they are struggling to keep up with the changes, such as transitioning from the dry lab and blackboards to the wet lab and then back to the old ways; they only have PowerPoint presentations, links, YouTube videos, and tutorials to share with their students. Online technology-based learning is not without issues; there are several challenges to employing online distance learning, including students' trouble understanding chemistry subject matter and their lack of practical chemical skills (Reeves & Kimbrough, 2004; Swenson & Lents, 2012). This constraint on instruction has a detrimental impact on their confidence even more. ***"Back in the day, I was used to drying lab,"*** one person added. ***"It's like going back to the conventional manner of teaching where you utilize chalkboard during laboratory class, which acts as the dry lab. There have been exercises but no actual implementations. You offer directions; then the students examine the findings; they can just study for their response as if they were dreaming things."***

Recommendations for continuous knowledge and skill improvement in teaching

The participants answered that ongoing knowledge and skill growth in providing instructions could raise their confidence in teaching chemistry laboratory. During the interview, participants shared some of their ideas for improving their confidence in teaching chemistry labs. This comprises curriculum development, training, and implementation. Professional development programs centered in laboratories have produced results that have increased instructor effectiveness, provided practical experience, and promoted high technical and scientific standards (Wenglinsky *et al*., 2007). One participant stated that he might be more confident in teaching chemistry laboratory, saying, ***"Of course, I am used to that. I've been teaching since 1983, and I still don't open my notes. However, during this epidemic, I am reopening my notes, particularly on lab; you will need to verify whether there are any available videos. That's why I save videos." "Students are excited during***

laboratory activities; when they are able to create a soap, they are able to apply the concepts and measure the pH," said one of the participants***, "instructors should have both basic and advanced training in order to stay ahead of students."*** Another participant stated, ***"When there is a new unit, I was able to review, which is why we also need a refresher, verify references, and so on. When it comes to information, I'm OK, but when it comes to the lab, I can't recall anything. That is why I continue to study and learn from our lessons."***

Managing chemistry laboratory while teaching

Because of a variety of circumstances, participants indicated that they lack confidence in managing a chemistry laboratory class. According to one of the answers, the pandemic has also impacted their capacity to supervise and regulate their laboratory class. The instructor was able to compare how she managed her laboratory class before and after the pandemic throughout the interview. She said, ***"Pre-pandemic, you can assess if what they did is correct if the execution is correct. And if ever you see that there are no positive results, as the subject instructor, you have the chance to investigate as well because it is embarrassing to students if you are not able to rationalize why such a thing happened. During the pre-pandemic, you are more confident, but during this pandemic, I am not really confident. During this pandemic, we can only do written activities, watch these clips, then answer questions."*** One of the participants also said that her ability to manage chemical laboratory classes is affected by her experience in teaching chemistry and doing experiments. She said, ***"Since I haven't tried it face-to-face, I also do not have the chance to do it hands-on with the students. But I think I can do it; however, it will be better if I have experience with it. During this pandemic, there are real lab activities to do that I wasn't able to try yet. That's why I am not***

confident to manage." Furthermore, another stated that the main challenge for her in managing a chemistry laboratory is the student population. She said, ***"Actually, we have a lot of students. That's my complaint when it comes to management, that the lab should be divided into two. Imagine 50 students in one laboratory. Back then, it was different; the class was also divided into two. And to think that you must monitor them one by one, let's say you have eight (8) groups in class, and it's already quite challenging and mind-blowing. And to think also that we only have one piece of equipment, and reagents only have one container. That's why students are only chit-chatting with one another, waiting for their leader's command. Managing a laboratory class also depends on class size. But when it comes to an online class, I haven't tried it yet."*** This is consistent with the findings of other studies, which found that many instructors had difficulty performing laboratory activities owing to the huge number of students in each class, as well as insufficient equipment and resources (Suleiman, 2013; Moloayonge & Park, 2017; Pareek, 2019).

Table 24.2

Perceptions of Chemistry Laboratory of Instructors after using the 1st Module of PLAH Manual

Themes	Sub-themes
Improvements in chemistry laboratory teaching	Accessible materials Experiments at home
Positive outcomes	Improvement in knowledge and skills Perceived benefits to students Advantages to instructors
Managing chemistry laboratory class	Positive feedback to manual, distance, and groupings
Feedback on the laboratory the home aspect of the manual	Learning, fun, creativity, talent
Feedback on the POGIL format of the manual	Learning from other groups, independent learning, clear understanding of the topic
Plan/suggestions	Considerations for the next practice

Note. Data collected on October 2021.

Improvements in chemistry laboratory teaching

After utilizing the first module of the PLAH manual, all participants said their confidence in teaching chemistry laboratory had grown. Participants were pleased to find that their students were enjoying and applying what they had covered because the experiment could be done at home, and materials were easily accessible to them. They also determined that their students were learning from their class. One said, ***"Actually, compared to last year, where we only depended on videos, it's already a big help for this time that they are able to do some experiments at home. For me, I can see that they are learning, so my confidence as a teacher is also improving."***

Positive outcomes

All of the participants indicated that using the first module of the PLAH improved their knowledge and abilities, not only for themselves as instructors but also for their students. In terms of knowledge and abilities, one stated that her confidence in teaching chemistry laboratory classes has improved. POGIL educators believe that their students were more engaged and active, had better communication and collaboration skills, and had higher learning results while utilizing the POGIL technique (Hu *et al*., 2016). The interviews revealed that the instructors valued the usage of the PLAH Manual because it helped them reduce misunderstandings, increase student engagement, increase knowledge and accomplishment, and engage their students. This suggests that using the PLAH Manual boosted students' attention, involvement, and active learning.

Managing chemistry laboratory class

All the participants agreed that adopting the PLAH's first module made class management simpler. They were cautious at first but have become more confident as the class has been better managed than in prior years (pre-pandemic and pandemic). According to their interview, a variety of reasons led to the improvement of their laboratory class management. According to the participants, the PLAH manual makes all supplies for experiments easily available to students, and the directions are simple to follow, which discourages students from asking questions. One said, ***"the material is well-crafted, and it is easy to follow; it actually can help to manage."*** One of the participants also said that distance and groupings have also helped in managing their laboratory classes. She said, ***"Management becomes easier; sometimes distance can cause better management because if they are inside one lab, they will try to walk around, chat, and do this and that, but during online laboratory class, they are divided into groups, you can check on them anytime."*** This demonstrates that POGIL is, in fact, a student-centered and collaborative learning technique in which students work in groups with individual roles.

Feedback on the laboratory at home aspect of the PLAH Manual

Meanwhile, participants offered their experiences and views from chemistry laboratory lessons after utilizing the PLAH Manual. One participant mentioned that the activities and groupings are beneficial to students. According to one instructor, the students were able to study and have fun while dealing with the pandemic. One instructor said, ***"The activities that can be done at home reduced the fear of my students to do experiments since they are handling simply only things found at home and fruits that are not expensive."*** Further, according to the participants, the laboratory-at-home aspect promotes resourcefulness and preparedness and improves the laboratory skills of students. ***"Most of the materials can be found at home, but***

those that have none, look at alternatives that can be used and have them approved first. They even take good videos of how they prepared themselves and their workplaces before conducting the experiment and even how they carefully did the experiment. That is actually a laboratory skill that they need to develop."

Feedback on the POGIL format of the manual

During their interview, participants also shared their thoughts and opinions on the manual's POGIL structure. They were able to explain the benefits of utilizing the manual, its general content and organization, and how it helped them as educators. One said, "***Actually, this type of design actually promotes independent learning in a way that you do not micromanage because everything is provided, even the process."*** Another also added, ***"In POGIL format it is more interactive, you check on everyone's work and output, and on the part of the students they also learn from the other group, what they did wrong, and right, then they formulate their 'what.' In the POGIL format, they have different tasks, and everyone has their own assignments, which means they cannot copy from anyone and that each of them really has to work. POGIL is more interactive and engaging, that is why it is also more effective for the students."*** According to recent research, instructors believe that POGIL is an effective teaching strategy since they have seen greater student participation, active engagement, and comprehension of science (Mamombe *et al*., 2021). Participants mentioned how POGIL helped students improve their abilities, such as resourcefulness.

Plan/suggestions

One of the participants stated that the POGIL-based manual is highly student-friendly and advised that she use the same system in her other classes. One said that there is only a need for a little enhancement on the background of the module's format. She also said that there should be restrictions set for every activity in the module. The participant said, ***"The lab actually is the one that triggers them because of the assignments and activities; they can do it during lectures. It depends on the instructor's skill if they can do that. But this lab makes them more engaged in their subject. In the lab, there's the experiment that triggers them. They are excited about their lab because they have experiments to do; however, they immediately ask for the next activity. That's why there should be restrictions on the posted activity because otherwise, they will be able to finish all experiments without the explanations or corrections of their lab reports."***

Table 24.3

Perceptions of Chemistry Laboratory of Instructors after using the 2nd and 3rd modules of the PLAH Manual

Themes	Sub-themes
Self-perceived development of instructors	Deeper and clearer understanding Increase knowledge in terms of laboratory techniques Ability to teach Chemistry laboratory effectively
Positive outcomes	Useful even after the pandemic Applicable to other subjects Student-centered learning Evolution of laboratory instruction
Better than the nPLAH Manual	More engaging Limited student-instructor interaction Doable workload Longer time for submission More knowledge
Changes in experience from the 1st module of PLAH	Lesser questions from students Evolution of activities

Note. Data collected in November 2021.

Self-perceived development of instructors

In terms of topic comprehension, pedagogical expertise, and laboratory abilities, the participants recounted their experiences teaching Chemistry laboratory.

One of the participants noted that when she saw her students' video outputs, she learned new things that she, as an instructor, did not know previously. It goes the same for the other participant; she said, ***"in terms of knowledge, I think that I become more knowledgeable on laboratory techniques in Biochemistry, especially when the treatment changes and those factors affecting it."***

In terms of their degree of confidence in managing a chemical laboratory classroom, all instructors reported that they are more confident and successful at managing the classroom. In some aspects, they are more confident today since the students used to have a lot of questions about the issue, but things have changed, and they can now easier directed, more conditioned, and more educated about the routine. Furthermore, it is superior in management in certain respects since it is easy to learn and allows you to work quickly and efficiently. Following the three experiments, they discussed their confidence and abilities to teach Chemistry laboratory. Most noticed an increase in their level of confidence.

Positive outcomes

In terms of laboratory skills, they all agreed that it was good and effective since students could practice the necessary skills from the comfort of their own homes. One also expressed interest in attending face-to-face sessions because the data and reagents used will be valuable long after the pandemic.

On the emphasis on their teaching experience and their strengths and weaknesses, the first participant stated, ***"As a result, I give my students more feedback. For example, if this is the outcome of the experiment, I'll apply it to our subject. Another option is that I will watch videos and study them beforehand. I also want us to undergo training so that we can better react to the feedback and so that my students will understand that the concepts are not***

distinct but rather intertwined." This is more on feedback and relearning process for both the instructor and students.

The second participant, on the other hand, indicated that she succeeds at supporting her students in answering their questions. POGIL pedagogy offers a lot of potential as an option for chemistry instructors looking for effective teaching techniques that result in a decrease in alternative conceptions held by their students (Barthlow & Watson, 2014). They have mentioned that it is more of a strategic intervention, such as it is useful to examine this type of strategy in teaching this content to lessen the students' fear of it. Students can also overcome their anxiety by having the instructor provide them with the necessary knowledge for the experiment. Furthermore, in all aspects of teaching, the stronger and deeper their comprehension of the subject matter will be if they do it on their own and find it on their own, rather than depending just on route or memory learning. One said, **"*it still really proves that the learning is child-centered, and the closer you are to the experience of the actual case, the more you understand what you are doing."*** However, owing to the recurrent LMS issues, she recognizes that she must enhance her feedback skills. This issue made her realize that as an instructor, she truly needed a student assistant to help her examine her students' work. She also recommended that there is a need for a different instructor for lectures and laboratories and that this should be based on the instructor's strengths and capabilities.

Better than the nPLAH Manual

Participants observed students' confidence and involvement, as well as their strengths and limitations in utilizing non-POGIL laboratory at-home manuals. According to one participant's observations while using POGIL, the students developed confidence in their responses, began to provide more detailed responses, and expressed more opinions on the issue. They improved their skills and learned self-discipline as a result. Students are instructed to learn new knowledge in a POGIL framework while employing process skills such as teamwork, communication, and problem-solving. As a result, while learning discipline-specific topics, students develop transferrable skills. The manual encouraged students to be more active, elaborate, and self-assured. A participant described how POGIL increased students' engagement. ***"Actually, the PLAH manual group has been more active compared to the nPLAH and Video groups. In those groups, they seem unsure and hesitant about their answers."*** Another participant shared how POGIL changes the students**,** ***"The other groups are more relaxed, unlike the PLAH group that, they are more aggressive to answer, they seemed trained and obviously mastered self-discipline."*** Furthermore, the second participant claimed that, in addition to being more comfortable to use, POGIL helps minimize student stress by giving them more time to submit videos and laboratory results. Furthermore, there were fewer queries since it was doable and understandable. A participant shared that she likes the POGIL more, ***"Weakness of the nPLAH manual is that there are no comparisons. That is why I like the POGIL better because I myself am learning from it."***

Changes in experience from the 1st module of PLAH

The student's behavior improved in terms of tranquility, adaptability, and contentment, according to the participants. They saw how the students adjusted and progressed since the first module. Their viewpoint as an instructor is crucial because if they are unsatisfied and find the intervention unsatisfactory, the educational basis itself will be eroded (Nambiar, 2020). A participant shared the changes she observed with her students, ***"Compared to Experiment 1, students have minimal questions***

on the activity, they are calmer, and when you ask an update, they even give positive feedback."

All instructors showed appreciation for the different experiences of every experiment of the manual. One said, ***"The experiments are changing and evolving, different reagents, different outputs per experiment."***

Table 24.4

Perceptions of Chemistry Laboratory of Instructors after using all modules of the PLAH Manual

Themes	Sub-themes
Overall self-perceived development of instructors	Qualities gained and observed Laboratory skills developed Pedagogical skills developed Confidence in teaching chemistry laboratory Confidence in classroom management
Overall feedback on the PLAH Manual	Positive effects on the students Good structure for a laboratory manual
Suggestions	Intensify strengths Improve weaknesses

Note. Data collected in December 2021.

Overall self-perceived development of instructors

According to one study, instructors' learning ability is also boosted while teaching (Florian & Linklater, 2010). The instructors noticed this after utilizing all of their modules since they were able to obtain or observe some attributes, increase their laboratory abilities, and improve their pedagogical skills. According to one research, the usage of manuals has provided a structure for a classroom to follow so that students may readily comprehend a topic (Ravshanbekovna, 2021). The instructors noticed several attributes that they obtained and witnessed when teaching Chemistry laboratory after using all of the modules. Participant one said, **"It is surprisingly good to be creative and innovative to students and to try something new once in a**

while.” Another said, “*We are being creative and also encourage the students to become more innovative. In terms of knowledge, overall, I am more knowledgeable in terms of Biochemistry laboratory.”*

Instructors believe that they were able to develop their laboratory skills with the utilization of the module. One said**, “*I felt that my lab skills also improved. Although most are basic, I am refreshed and reviewed of the simple laboratory techniques since I have not much experience in laboratory teaching*.” Another said, “*With the proper training and mastery of the components of things around you in real life, it enhances the important laboratory skills that I, as an instructor, should have mastered*.”**

According to one of the responses, the modules are student-centered and help in the development of critical thinking skills in students. On the other side, one of the participants acknowledged the modules' benefits to them as instructors. **"*And it seems like when they are performing what is on the video, they are able to grasp it better*," she said, "*which I think is a good point since I am learning as well while watching them on the video*."** She also added that through the experiments done at home, students could appreciate what they study and execute. She added, **“*Now that everything we do is hindered by the pandemic, they are able to appreciate things such as nucleic acid can be found in food, proteins, and milk is like this and that.”*** An instructor was able to enhance his pedagogical skill by laying the topics for the students to enhance their critical thinking and innovative thinking. **“*You just have to lay to them the manual, and it is up to them to find means and ways to get it, and that is critical thinking and not merely spoon-feeding them. This manual is not just letting me teach my students what would happen in the***

***activities but also the preparation for the experiment, which is another thing*"**, he said.

After using all of the PLAH Manual modules, all participants stated their confidence in teaching chemistry laboratory had grown. According to one of the answers, all that is necessary to perfect its execution in a classroom setting is training. They are more certain that they are doing it correctly and effectively since students are gaining information as planned because all activities are doable and materials are available. The second participant expressed confidence in her ability to teach chemistry laboratory now that she has had the opportunity to review and refresh some of her laboratory knowledge and abilities. **"*It is amazing to expect students to execute the experiments successfully without me doing so much talking; it is indeed a very helpful strategy.*"**

All the participants also stated that the PLAH manual provided them with ease when it came to the management of their chemistry laboratory class. One said, ***"For me, the approach was holistic. The given examples are specific and more organized, and with this, I am now more confident in managing my class and teaching more efficiently".*** Another participant stated that virtual classes had helped to ease classroom management in the chemistry laboratory. According to one research, creating a virtual laboratory for science courses might be difficult, especially during pandemics (Zibers & Estes, 2021). The utilization of teaching resources such as laboratory worksheets and manuals aids in the overall classroom framework (Delgado *et al.*, 2021).

Overall feedback on the PLAH Manual

The instructors expressed gratitude for their participation in the study, stating that it has boosted their confidence in teaching as well as their abilities and experience as chemistry laboratory instructors. One of the participants also said that this is beneficial to the instructors, as well as their students. She said, ***"It is why I think this is a good idea because you can truly put your laboratory skills to use, and students can feel what they are doing since they're wearing gowns, and they can share it online. As you can see, this POGIL class was the luckiest since they were able to participate in all the activities. The strategy is good, and it can be used in other laboratories as well."*** Since the manual is designed at home, the repetition of the activities is possible, which makes the students enhance their laboratory skills and be able to deeply understand the activity using the manual. One said, **"*In this manual, the students are not scared to do the experiment because they might do things wrongly or break some glassware. They do not even share pH papers or use equipment. They can even repeat as many times since they have been using the reagents and tools they are tasked to use. This enhances their curiosity."*** **Another said*, "While they are doing the activity and collate it in a video, and watch other groups' video, they understand better, deep understanding."***

The instructors have described the structure of the manual that helped them while teaching Chemistry Laboratory. The manual was described as a student-centered, organized, generalized form and flexible which makes it easier for students to understand. The most senior participant said that **"*Though the learner-centered pedagogies have been introduced long before, this has been applied to lectures since the laboratory itself is already learner-centered, but then I realized that reagents and tools could also be made learner-centered with this PLAH Manual. This made them resourceful as well*."** The participant who handled three different groups said, **"*The manual is very organized, and to compare with the nPLAH and***

***Video groups, the effect is really a lot better to students, especially the factors that affect the biomolecules*.**" The last participant said, ***"In the PLAH Manual, you can see the totality, I am sure that creation of different tasks for different groups is taxing, but this format is really good and effective.*"** Another response of this instructor is that **"*this is how it should be, the questions are constructed in a way that they are not able to Google the answers since they need to synthesize it from their experiment*."**

Suggestions

Instructors revealed that the PLAH manual has an impact on the understanding of the students and the teaching strategy of the instructors. However, the instructors also revealed that it needs some modifications. One said, **"*As to the materials, level of readability, the ability of everyone to understand, and feasibility to execute the experiment is excellent,"* one said, "*because you can see among your students that it is not that difficult for them*."** Meanwhile, another participant suggested that there should be a separate lecture and laboratory instructor, explaining, **"*Because part of the implementation of projects like this should consider the instructor's ability*."** Improving educational, cultural, and technical obstacles adds to the overall picture. Prior planning and preparation lead to better results and wider acceptance is achieved (Tuma, 2021). One said, **"*It is not part of your study, but the capacitation of teachers is a must. A program that immerses Biochemistry and Chemistry teachers so that we could give better feedback to students and heavily discuss with them apart from what they did in the activity.*"** Another instructor suggested that this can be used to motivate students at the start of a lecture instead of after a lecture to motivate students because they remember the experiment more than the lecture.

Chapter V

SUMMARY, CONCLUSION, AND RECOMMENDATION

This chapter presents a concise summary of the findings, the derived conclusions, and recommendations based on the study.

Summary

Biochemistry laboratory work enhances science topic mastery, scientific reasoning, awareness of empirical work's complexity and ambiguity, practical skills, scientific knowledge, motivation in science and science learning, and teamwork. Hence, students need considerable laboratory experience even during a pandemic, disaster, or socioeconomic and geographical constraints. Hence, this study aimed to develop and assess a POGIL laboratory-at-home manual and determine its effect on student achievement attitude, motivation, and confidence in laboratory skills in the general biochemistry course of the second-year students of the Bachelor in Medical Laboratory Science during the pandemic.

The first phase of the study covered designing, developing, pre-testing, and evaluating instruments. Only reliable and valid instruments are used for the succeeding phases of the study.

The second phase involved designing, developing, and evaluating the POGIL-based Laboratory-at-Home (PLAH) and non-POGIL Laboratory-at-Home (nPLAH) Manuals on Biomolecules. The experts' and instructors' overall average ratings on the developed PLAH and nPLAH manuals are 4.57 and 4.53, signifying an excellent evaluation of acceptability. While student participants generally perceived excellent acceptability of the PLAH manual (4.54) and very good acceptability of the nPLAH manual (4.46).

The students are first profiled to establish homogeneity before evaluating the effect of PLAH Manual. Statistical tests showed that there is no significant difference among the participants' demographic, economic, and education profile among PLAH, nPLAH, and Video groups.

The third phase involved evaluating the effect of the PLAH on student achievement attitude, motivation, and confidence in laboratory skills using a quasi-experimental pretest-posttest research design. The results were compared to other treatments using nPLAH and the Video Manuals. After exposure, there is an increase of 18.26 in the mean achievement scores of students for the PLAH group, 17.73 in the nPLAH group, and 17.83 in the Video group. Students' overall mean attitude level increased to 3.23 for the PLAH group and 3.24 for the nPLAH group, while students' overall mean attitude for the Video group level decreased to 3.15. While students' overall mean motivation level increased to 3.58 for the PLAH group, 3.51 for the nPLAH group, and 3.51 for the Video group. And students' overall mean confidence level increased to 3.39 for the PLAH group, 3.36 for the nPLAH group, and 3.15 for the Video group.

With the exception of motivation toward chemistry laboratory for those who utilized the Video manual, all variables examined before and after any treatment exhibit a significant difference before and after the interventions. However, except for confidence in laboratory skills, none of the variables demonstrate a significant difference. The use of the Video manual is substantially different from the other treatments in a multiple comparison test for confidence in laboratory skills using Dunn's test with Bonferroni adjustment. Further, there is adequate data to establish that there is no association between research participants' achievement and their attitude, motivation, or confidence in laboratory skills at the 5% level of significance.

Perceptions of chemistry laboratory of students before, during, and after using the PLAH Manual were determined. Before utilizing the PLAH Manual, some students viewed chemistry laboratory as boring and limited, whilst others found it fun and exciting. They view the chemical laboratory as a venue for concept application. Although some students believed the laboratory class was neither valuable nor useful, others saw it as an opportunity to develop their critical thinking, teamwork, and laboratory skills. However, students had no chemistry laboratory experience in high school or the first year of college (pandemic), while others were confined to online videos and written assignments during their first year of college, owing to the pandemic. After utilizing three modules of the PLAH Manual, students reported that it is a unique laboratory experience that is fun and exciting, and challenging. They viewed the laboratory to be for application and conceptual elaboration. All students stated that the chemistry laboratory improved their communication skills, versatility, teamwork, distance laboratory learning, critical thinking abilities, practical laboratory skills, real-world application, and confidence. However, they encountered challenges in terms of time and resources. And after using the five (5) modules of the PLAH Manual, the students' experience remained unchanged (after three modules). As a result of the varied trials and outcomes between groups, conceptual knowledge was refined for learning purposes. In addition to creativity, time management, and independent work, the value and utility assessed by students remained unchanged. However, some students struggled with video editing.

Perceptions of chemistry laboratory of instructors before, during, and after using the PLAH Manual were also determined. Low confidence (both before and during the pandemic) and a lack of training and alternate resources to be utilized during the pandemic are among the gaps affecting the chemistry laboratory teaching of instructors prior to the use of the PLAH Manual. Instructors felt that curriculum improvement, training, and application were necessary. Before the pandemic, one had tremendous confidence in managing the chemical laboratory, but during the pandemic, everyone lacked confidence. Prior to the pandemic, operating a chemical laboratory was challenging because of a shortage of equipment, reagents, class size, and time. After utilizing the first module of the PLAH Manual, instructors highlighted the use of accessible materials and the ability to conduct experiments at home as improvements. According to instructors, positive results include the enhancement of their knowledge and abilities, the benefit to their students, and the enhancement of their teaching delivery. They provided favorable feedback on the manageability of the chemical laboratory class, even from a distance, and the ability to form groups. In addition, they provided favorable feedback on the 'at-home' aspect, which made studying enjoyable and creative, and the POGIL structure of the manual, which supports individual learning and clear comprehension of the subject. Instructors' self-perceived progress after utilizing the second and third modules of the PLAH Manual includes a deeper and clearer comprehension, an increase in laboratory procedures knowledge, and the capacity to teach chemistry laboratory efficiently. Positive effects perceived include the usefulness of the manual even after the pandemic, the adaptability of the format to different disciplines, student-centered learning, and the growth of laboratory teaching. According to the instructors, the PLAH manual is superior to the nPLAH manual because it is more engaging, there is less student-instructor contact, the workload is manageable, and more information is created. Compared to the first module of the PLAH Manual, there have been fewer student questions, and the experiments have been completely changed. And after utilizing all PLAH modules, instructors report gaining and observing several attributes, developing laboratory and pedagogical abilities, and gaining confidence in teaching and managing chemistry laboratory classes. Positive impacts on students and a well-structured laboratory manual comprise the majority of the manual's reviews.

Conclusion

The overall evaluation of experts, instructors, and students on PLAH and nPLAH manuals is high. The students in the PLAH and nPLAH groups had an increase in their mean achievement score, motivation, and confidence in laboratory skills level as measured by their higher scores in the post-test and survey. The students in the PLAH and nPLAH groups had an increase in their mean attitude levels, while the Video group decreased as measured by their scores in the post-survey. The gain of the students in the PLAH group was higher compared to the other interventions.

Between pre- and post-test and surveys, except for motivation level using the Video manual, statistical analysis showed that there was sufficient evidence to say that there was a significant positive change in terms of mean achievement, attitude, motivation, and confidence in using the manuals. Moreover, among interventions used, except for confidence in laboratory skills in the Video group, the mean achievement, attitude, motivation, and confidence in laboratory skills changes are comparable.

Students' perceptions of the chemistry laboratory before, during, and after using the PLAH changed positively in terms of learning and usefulness. This is in consonance with the perceptions of instructors, which changed from low confidence to high confidence in terms of their knowledge, delivery, and managing the chemistry laboratory. They gave positive feedback on the ‘at-home’ and POGIL format of the manual, which they suggested can be used even if the pandemic ends and can be replicated in other laboratory subjects.

Implications of the Study

The study's conclusions have major practical ramifications for biochemistry lecturers and lab instructors. The findings demonstrate that utilizing the PLAH and nPLAH manual improves achievement, attitude, motivation, and confidence in laboratory skills and may be utilized as an adjunct to their instruction. When there are not enough lab spaces and tools, not enough chemicals and other resources, or classes are canceled, instructors may utilize the manual as an alternative or supplement to their teaching. This would encourage and motivate the lecturer to teach the laboratory portion of biochemistry.

The conclusions of the study may be utilized as a starting point for curriculum designers and administrators to enhance Chemistry programs in terms of their laboratories, lab teaching materials, methodology, and assessment procedures. In situations when a face-to-face laboratory classroom is not feasible, administrators may utilize the findings of this study to create and carry out training sessions for teachers handling laboratory-related material. For Chemistry subjects without laboratory component, the PLAH Manual may be used to engage and motivate students during lecture sessions.

In addition, CHED and DepEd will use the findings of the study to encourage laboratory activities that may be conducted at home despite the country's socioeconomic and geographical limits.

Recommendation

Recommendations for each target sector are as follows:

1. Biochemistry instructors without laboratory course components to adapt the PLAH Manual to boost their motivation in teaching and to engage their students. This could improve instruction by making chemistry concepts more meaningful and relevant to students by using ordinary things they see every day.

2. For Biochemistry instructors with laboratory course components, to adapt the PLAH Manual as a supplement or alternative when there are instructional challenges such as insufficient laboratory rooms and equipment, inadequate chemicals and materials, time constraints, and large class sizes. This could help them manage and handle the laboratory part of their teaching without sacrificing the hands-on learning of each student.

3. For curriculum developers to reconfigure programs with Biochemistry courses through the utilization of the results of this study as the basis for improving laboratory management, instructional materials, and approaches in teaching. This could improve instruction delivery.

4. For school administrators to use the results of this study in planning and conducting training for instructors handling laboratory subjects when face-to-face laboratory classroom is not possible. This could help improve the versatility and competency of instructors in teaching Biochemistry.

5. For CHED and DepEd, to promote laboratory activities using materials found at home, and safe to do at home. They can use the results of the study as the basis for funding programs or the creation of instructional materials for other hard-to-understand subjects that needs laboratory to supplement a greater comprehension of abstract

notions and theories obtained through experiencing and seeing them as genuine events.

6. For the LGU, particularly in far-flung areas, and Chemistry instructors' affiliations, to disseminate the study results and train instructors using the PLAH manual.

Recommendations for future research studies related to the results and limitations of this study are:

1. To determine the relationship between the Biochemistry achievement of students to their profile variables (demographic, socioeconomic, and learner);
2. To utilize more thorough measures such as better or more laboratory-related questions to evaluate the achievement of students;
3. To account for and evaluate other dimensions and variables mediating achievements such as instructor factor, problem behavior, school problems, and problematic peer interactions;
4. To conduct a practical laboratory test to gauge the students' laboratory skills.
5. To utilize the PLAH or the nPLAH manual as a supplement to Biochemistry lecture and/ laboratory classes;
6. To capacitate instructors on the use of the manuals; and
7. To develop similar laboratory manuals using the POGIL format.