Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

NatPro LabPro: An innovative laboratory package in plant extract screening for scientific research projects

Ricky B. Acanto *

College of Arts and Sciences, Carlos Hilado Memorial State University, Talisay City, Negros Occidental, Philippines

ARTICLE INFO

Article history:
Received 13 December 2023
Received in revised form
27 April 2024
Accepted 28 April 2024

Keywords:
Innovative laboratory package
Natural products
Plant extract screening
Science investigatory project
STEM education

ABSTRACT

Challenges in teaching science require innovative approaches—creating new methods and materials to improve student learning experiences. Innovations are essential for national development, fostering growth and positive change. This study focused on developing and evaluating an Innovative Laboratory Package (ILP) designed for science projects in natural product screening. It used a developmental research design and followed the ASSURE instructional model. The study identified that the least common lab tests conducted by students and teachers on natural products included basic pharmacological-toxicological, antioxidant, and cytotoxic assays of plant extracts. Access to laboratory materials and financial support presented moderate challenges for the participants. Laboratory analysts rated the ILP as outstanding, and Science, Technology, Engineering, and Mathematics (STEM) teachers highly evaluated its content, structure, coherence, learning activities, usefulness, appearance, organization, and innovativeness. Teachers reported that using the ILP provided new, meaningful, and engaging experiences, promoted critical thinking and scientific attitudes, allowed easy and flexible experiments, and equipped students with new scientific skills in a cost-effective way. The ILP could enhance science projects and develop research expertise in plant screening for both students and teachers. The findings can help curriculum developers create innovative learning resources and prioritize curriculum innovations.

1. Introduction

The science laboratory has become a distinctive feature of science education throughout the century and provides an indispensable role in the science curriculum (Lunetta et al., 2005; Hofstein, 2017; Hofstein and Lunetta, 1982; Hofstein and Mamlok-Naaman, 2007) as a laboratory activity can enhance mastery of concepts with low criteria (Suryanti et al., 2019) and improve academic performance (Shana and Abulibdeh, 2020). Blosser (1983) suggested a need to continue studying the role of the laboratory in science teaching. Science investigatory projects (SIP) or capstone projects are science-based research projects that provide students with an engaging approach to learning science and the concept of performing scientific research. According to Cuartero (2016), the best way to bring a good attitude towards science in school and increase students' interest in a science classroom is through SIP and capstone projects, stressing that the purpose of learning science is not only to learn concepts but to develop a positive attitude and a greater appreciation of science. The Philippines' scientific development is anchored on its pool of scientists and researchers who significantly provided scientific solutions to address the simplest to the most complex daily problems. The 1987 Philippine Constitution, Article XIV (Section 10), states that science and technology are essential for national development and progress and provides the basis for SIP in developing the country's future scientists and engineers. Moreover, to achieve an effective enhanced primary education curriculum in the country, Section 5 of Republic Act No. 10533 (also known as the Enhanced Basic Education Act of 2003) mandates that the curriculum must be flexible enough to enable and allow schools to localize, indigenize, and enhance based on their respective educational and social contexts. The production and development of locally produced teaching materials shall be encouraged, and the approval of these materials shall devolve to the regional and division

* Corresponding Author.
Email Address: ricky.acanto@chmsu.edu.ph
https://doi.org/10.21833/ijaas.2024.05.008
Corresponding author's ORCID profile:
https://orcid.org/0000-0003-3508-6847

education units. However, students need more opportunities to develop scientific investigatory skills, especially in public high schools, due to the need for more laboratory materials and limited exposure to laboratory activities. Mentoring students in SIP is also limited to those who join competitions in science fairs as learning resources are not readily available, and acquiring funds for laboratory expenses is challenging. This is because most processes are expensive and beyond the financial capacity of most students (Butron, 2018; Errabo et al., 2018). Further, school laboratories' overcrowded and miserable conditions due to a shortage of physical facilities, combined science laboratories for all science subjects, and the lack of necessary apparatus and adequate consumable materials are common scenarios in rural public high schools (Akani, 2015; Khan Niazi et al., 2018; Pareek, 2019). SIP advisors also encounter financial difficulties and limited access to regulated research institutions due to distance, bureaucratic red tape, and unwillingness to accommodate sample analysis requests.

Considering the students' and teachers' challenges in conducting science investigatory/capstone projects, the researcher introduced the Innovative Laboratory Package (ILP) to benefit both teachers and students. The package includes innovative laboratory procedures and low-cost tools for the developed procedures. The ILP is a developed instructional material which can be one of the essential innovations to complement face-to-face instruction in laboratory activities. Marasigan (2019) and Torrefranca (2017) revealed that a developed and evaluated self-instructional material, such as ILP, can improve students' performance, create a more favorable attitude toward learning science concepts, facilitate their interest as well as provide novel empirical evidence by creating and analyzing counterfactual situations (Brüggemann and Bizer, 2015). To enhance the inclusivity and effectiveness of Science, Technology, Engineering, and Mathematics (STEM) education, Khushk et al. (2023) provided insights into current research and areas for further exploration that guide policymakers, educators, and future research in the field through a systematic literature review and content analysis.

The developed ILP may also help students acquire scientific skills through a step-by-step procedure using locally available low-cost materials, which eventually stimulates students' interest in doing science laboratory activities, strengthens their motivation to learn science and technology at home, and provides a backbone of science research fundamentals, embracing the practical application in addressing the phenomena. Furthermore, the ILP would give contextual experiences and observations underlying natural products and their practical applications in everyday life and an opportunity to do natural product research in the future.

NatPro LabPro, or Natural Product Laboratory Project, is designed to provide students with experience designing laboratory activities for natural product screening that show potential lead compounds for drug development and industrial use. The laboratory activities would give students and teachers opportunities to learn essential skills required to perform the extraction, phytochemical screening, antioxidant activity, cytotoxic activity, UV protective activity, antiangiogenic/angiogenic activity, and antimitotic/mitotic activity of plant extract. Through these activities, students and teachers could prove and link scientific concepts previously learned to new knowledge through scientific principles to explain phenomena such as the healing properties of plants that can treat diseases.

The study sought to evaluate the common laboratory tests and analyses used in SIP and capstone projects on natural products by senior high school (SHS) STEM students and their advisers. This evaluation served as the foundation for developing an ILP in science. Specifically, the study aims to answer the following questions:

1. What are the least and most common laboratory tests/analyses used by students and teachers in conducting science investigatory/capstone projects in natural products?
2. What challenges do students and teachers encounter in conducting science investigatory/capstone projects in natural products?
3. What innovative laboratory procedures and tools can be developed based on students' and teachers' assessment of science investigatory/capstone projects in natural products?
4. What are the experts' validations of the innovative laboratory procedures and tools in natural product screening regarding content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness?
5. What are the teachers' evaluations of the innovative laboratory procedures and tools in natural product screening regarding content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness?
6. What are teachers' experiences using the developed laboratory procedures and tools in natural product screening?

2. Methodology

2.1. Participants of the study

The survey assessing the laboratory analyses and tests used in SIP and capstone projects on natural products was conducted using Google Forms. It included responses from 42 students and 30 STEM teachers during the academic year 2021-2022, all from Region VI in the Philippines. Purposive sampling was used to select the participants. Students must have conducted SIPs/capstone projects in natural products, specifically plant screening. For STEM teacher participants, they must have taught STEM students for at least three years or served as STEM student advisers in their SIP/capstone projects.

The study also involved 20 expert validators who determined the validity of the developed ILP before the implementation. The validators, composed of chemists, chemical technicians and engineers, pharmacists, and medical technologists who worked as analysts in regulated laboratories and industries, were chosen based on their work as licensed analysts in their respective fields for at least two years. Each evaluator was provided with the ILP and the 7-parameter rating sheets. The validation and rating were used to describe the validity of the developed ILP. The ILP was also evaluated by 22 STEM teachers who pilot-tested it and logged their experiences using the package. The teacher-participants from the Department of Education (DepEd) Division of Negros Occidental were chosen based on their availability during the scheduled activity and their willingness to learn and participate in the laboratory activities, which were filmed and sent to the panelists for feedback. The evaluators' ratings were used as a basis for the overall appraisal of the ILP. The matrix of participants involved in different phases of the study is shown in Table 1.

Table 1: Represents the number of participants involved in the different phases of the study

Research participants	Number of participants	Criteria
A. Pre-assessment survey	72	Must have taught STEM students for at least three years or served as STEM students' adviser in their SIP and capstone projects; Must have undergone SIPs/capstone projects
STEM teachers	30	
STEM Students	42	
B. Validation of ILP	20	Professionals with at least two years of laboratory/ research experience
Chemical technicians	8	
Chemists	5	
Pharmacists	4	
Chemical engineers	2	
Medical technologist	1	
C. Evaluation and feedback of ILPS	28	Must have taught STEM students for at least three years or served as STEM students' adviser in their SIP and capstone projects; Member of the research committee
STEM teachers	22	
Panelists	6	

2.2. Research instruments

The study utilized three validated instruments: an assessment survey form, a validator's rating sheet, and a teachers' evaluation guide.

1. The assessment survey tool consisted of five sections: an introductory letter to participants, personal information, details of analyses/tests used in conducting SIPs and capstone projects, challenges faced during these projects, and participants' overall experiences. The survey was evaluated for content validity by subject experts using the Lawshe Content Validity Ratios (CVR) method, requiring a minimum critical value of 0.538 for 13 panelists. The survey achieved a Content Validity Index (CVI) of 0.861, surpassing the required threshold and confirming its validity. Additionally, the reliability of the instrument was established with a coefficient (r) of 0.814 and a significance (p) of 0.040, indicating it is a reliable tool.

The scale below is used to evaluate the level of difficulty that students and teachers face when working on science investigatory or capstone projects:

- 75.01% - 100%: Very Challenging
- 50.01% - 75.00%: Moderately Challenging
- 25.01% - 50.00%: Slightly Challenging
- 0 - 25.00%: Not Challenging at All

This format ranks the challenges from highest to lowest based on the percentage range.

2. The validator's rating sheet: A researcher-made rating scale for validating the ILP rated the package in different parameters, including content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness. The scoring system was based on four categories: outstanding, very satisfactory, satisfactory, and unsatisfactory. A score of four has a descriptive rating of outstanding, meaning the ILP conforms with the stated parameters. A score of three is very satisfactory, meaning the ILP does not totally conform to the indicated parameters. In contrast, a score of two, or satisfactory, means that the ILP barely meets the stated parameters. Lastly, a score of one, or unsatisfactory, means that the package does not conform to the parameters.

The instrument has been subjected to content validity using Lawshe CVR with a critical value of 0.667 for 12 panelists. The CVI value for the instrument is 1.0, an excellent CVI value higher than the critical value of 0.667, which implies that the instrument is valid. The instrument was found to be reliable (r=.945, p=.017). The scores used by expert validators to rate the developed Integrated Learning Program (ILP) are categorized as follows:

- 3.51 – 4.00: Outstanding - The ILP fully meets the parameters.
- 2.51 – 3.50: Very Satisfactory - The ILP mostly meets the parameters.
- 1.51 – 2.50: Satisfactory - The ILP somewhat meets the parameters.
- 1.00 – 1.50: Unsatisfactory - The ILP does not meet the parameters.

This categorization helps in evaluating how well the ILP adheres to the specified parameters, ranked from highest to lowest based on the given scores.

3. The evaluation guide for teachers: A four-level Likert scale researcher-made instrument was used to evaluate the ILP by STEM teachers of the DepEd Division of Negros Occidental. The ILP was evaluated in content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness with five items in each category. The scoring system was based on four categories: outstanding, very satisfactory, satisfactory, and unsatisfactory. A score of four is rated as outstanding, meaning the package conforms with the stated parameters. A score of three, or satisfactory, means the ILP does not totally conform to the indicated parameters. A score of two, or satisfactory, means that the package barely meets the stated parameters, and a score of one, or unsatisfactory, means that the ILP does not conform with the parameters.

The instrument has been subjected to validity using Lawshe CVR with a critical value of 0.667 for 12 panelists. The CVI value for the instrument is 0.957 (higher than the critical value of 0.667), which implies that the instrument is valid and reliable (r=.847, p=.021). The scores given to describe the ratings of STEM teachers are presented as follows:

- 3.51 – 4.00: Outstanding - The developed Integrated Learning Program (ILP) fully meets the parameters.
- 2.51 – 3.50: Very Satisfactory - The developed ILP mostly meets the parameters.
- 1.51 – 2.50: Satisfactory - The developed ILP meets the parameters only minimally.
- 1.00 – 1.50: Unsatisfactory - The developed ILP fails to meet the parameters.

These scores help in assessing how well the ILP aligns with the set standards, ranked from highest to lowest based on performance. The summary of the three instruments used in the study is shown in Table 2.

Table 2: Matrix of the instruments used in the study

Name of instrument	Purpose	Type
Assessment survey form	Assessment of the analyses/tests conducted and challenges encountered in conducting SIPs/capstone projects	Researcher-made survey form
Validator's rating sheet	Used by validators to validate the ILP	Researcher-made rating scale
Evaluation guide for teachers	Used by teachers in evaluating the ILP	4-level researcher-made Likert Scale

2.3. Data collection procedure

Preparation stage: The preparation stage involved the assessment survey of the analyses/tests conducted and challenges encountered by STEM students in conducting their SIPs/capstone projects in natural products. Other participants in the survey were teachers handling research subjects or advisers of the students' SIPs/capstone projects. The assessment result was used to develop the ILP and prepare the tools needed.

Development stage: Based on the result of the assessment survey, the design of the ILP was crafted. The development stage involved drafting the innovative laboratory procedure and the preparation of the kits. The development of ILP followed the ASSURE model of the instructional design shown in Fig. 1.

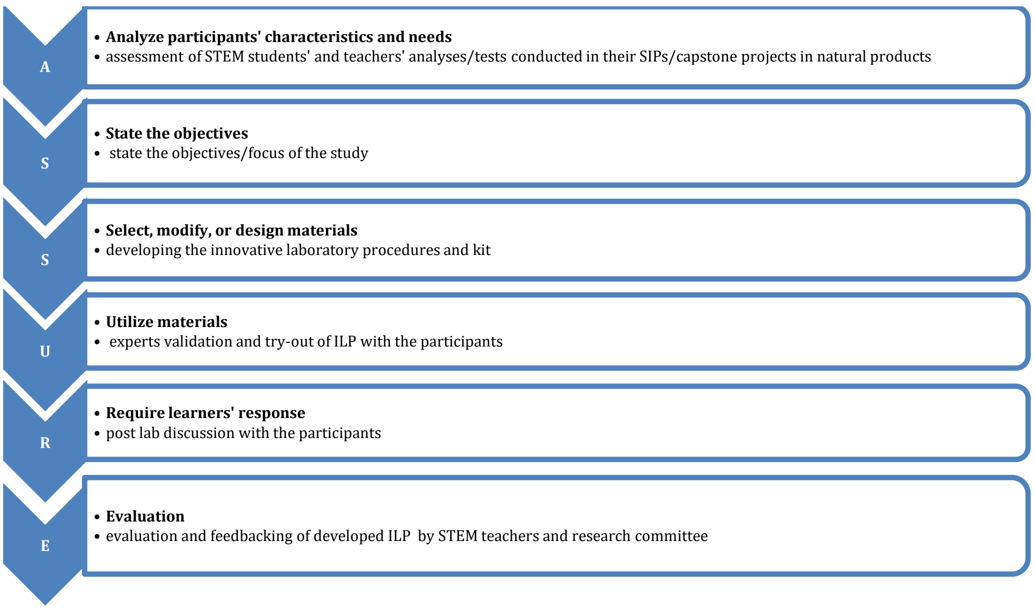

Fig. 1: The ASSURE model of instructional design in the context of the study

A–Analyze learners: The result of the pre-assessment survey form was analyzed. Included in the assessment were analyses/tests conducted, challenges encountered, and their overall experiences in conducting their SIPs/capstone projects.

S–State the objectives: After analyzing the pre-assessment survey, the standards and objectives of the ILP were formulated, focusing on what the learners can know or can do as a result of the instructions. The objectives can be used to assess the success of STEM students in conducting research focusing on natural products.

S–Select, modify, or design materials: The ILP was developed based on the assessment of the analyses/tests conducted by students and teachers, modified to suit the needs of the learners, and innovated to lessen the costs of the analyses. Technical experts validated the ILP and made revisions based on their comments/suggestions.

U–Utilize materials: This step was concerned with how participants utilized the ILP. During the conduct of the laboratory activities, the following five P's processed were observed:

- Preview – How the ILPS would be conducted for the participants was planned out.
- Prepare materials – Materials were prepared and provided to the participants, including lab gowns, eye protectors, masks, gloves, and other materials needed for compliance with laboratory and IATF-EID protocols.
- Prepare the environment –The laboratory room was prepared, and hazards found in the area were removed and kept clean.
- Prepare the learners – There was a pre-lab discussion and overview of the laboratory activities included in ILPS, as well as a short lecture on natural products to give them an idea of the direction of the activities they are dealing with.
- Provide learning experience – The ILP provided learning experiences for participants conducting an actual scientific study.

R–Require learners' response: After the laboratory activities were conducted, post-laboratory discussions and data processing on LC_{50}, IC_{50}, and image J were discussed. Feedback from participants was solicited.

E–Evaluation and revision: The ILP was evaluated using the teacher's evaluation sheet soon after the activities were conducted. The teacher-participants evaluated the developed ILP in content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness.

2.4. Limitations of the study

The study focused on senior high school students and teachers in Region VI (Western Visayas), Philippines, who were involved in SIP/capstone projects related to natural product screening and excluded participants not from the fields or not directly involved in natural product research. The study examined their research topics and the challenges they encountered in conducting the study. The methodology used may limit the scope, the findings are context-specific, and it may not be universally applicable due to the study's focus, participant group, and geographical setting.

2.5. Data analysis procedure

The data collected were subjected to statistical treatment and analysis using descriptive statistics, primarily during the preparation and development phases. A frequency count was employed to identify the least and most common laboratory analyses conducted by students and teachers in their science investigatory and capstone projects involving natural products. Percentages were used to show the proportion of responses related to the least and most common laboratory tests and the challenges faced during these projects relative to the total number of participants. The mean was utilized to represent the average validation ratings given by experts and the evaluation ratings of the ILP by teachers. Standard deviation was used to measure the spread of test scores or responses on a four-level Likert scale from the average value.

The study employed Braun and Clarke's (2006) thematic analysis method to extract themes from the participants' responses. Thematic analysis is a technique for identifying, analyzing, and reporting patterns or themes within data. This approach was used to identify, analyze, and present themes from the data collected in order to explore teachers' experiences with using the ILP.

3. Results and discussion

The least and most common laboratory analyses/tests in natural product screening conducted by the respondents.

Fig. 2 shows the least common laboratory analyses/tests used by students and teachers in conducting science investigatory/capstone projects in natural products. Basic pharmacological-toxicological assay (analgesic property, anti-inflammatory property, antipyretic property) (5.86%), antioxidant assay of plant extract (8.33%), and cytotoxic assay of plant extract (ALD, LD50, LC50, BSLA) (8.33%) were the least standard laboratory analyses conducted by students and teachers.

The basic pharmacological assay of plant extract needs animals, such as guinea pigs or rats, to conduct laboratory analyses, and as such, requires animal care and handling protocols, which are limited only to institutions with an animal ethics committee. Additionally, the analyses require experts in the field and entail financial resources. Couto and Cates (2019), Hansen et al. (2013), and Houde et al. (2009) stated that animal research is highly regulated by the government and at the institutional levels. Researchers must have a thorough knowledge of the procedures to be conducted and collaborative relationships with key institutional players, such as the veterinary staff, the Institutional Animal Care and Use Committee, and top administrators. Varga

(2013) stated that animal research initiatives are approved or rejected based on the conclusions of ethical committees. Because the quality of experimental animal protection is highly dependent on the work of ethics committees, it is critical to review them regularly.

Meanwhile, the most common ones were the insecticidal property of plant extract (30.56%), microbiological screening of plant extract (antimicrobial activity, MIC, MBC) (23.61%), and molluscicidal properties of plant extract (22.22%). These SIPs/capstone projects' laboratory analyses/tests are easy to conduct and inexpensive as the materials are readily available, and the methods for the tests are easily understandable as these pertain only to the mortality rate of insects.

However, standard protocol in the microbiological screening of plant extract requires a biosafety level for the laboratory and expert/trained analysts in handling specific microorganisms. Biosafety levels are determined by considering multiple factors, such as the risk group of organisms. Educators using higher-risk group organisms must be highly trained in biosafety principles. Streak plating *Staphylococcus epidermidis* is an example of a procedure requiring BSL-1 (McCormick-Ell and Connell, 2019).

The results also imply that, generally, teachers and students were more bent on investigating the ability of plants to protect themselves from being damaged and to provide desirable health benefits rather than examining substances in plants that can kill bad cells in the human body. Although the participants could have considered the antioxidant and cytotoxic assays of plant extracts that contain many active compounds that are tremendously fruitful for plant defense against several insect pests, the students and the teachers are more engaged in doing tests like insecticidal and microbial activity of the plants. The results, though, supported the studies of Dunnett et al. (2019), Dunnett and Bartlett (2018), and Khoiri et al. (2017) that students can develop a scientific perspective and increase collaborative performance skills, gain practical experience in solving problems based on phenomena seen or investigations conducted, and can also find evidence for theories through laboratory works and able to analyze physical and experimental data.

Looking into these factors, the development of the ILP stands significant to both teachers and students as the package will then provide an opportunity to develop and enhance knowledge and laboratory skills in developing natural product research, specifically in plant screening. From preparation to product development, the ILP promotes an understanding of the nature of the phytochemical components of *C. speciosus* and its pharmacological activities. The data would also provide a more substantial basis for the research and applications. Moreover, in the province of Negros Occidental, laboratory analyses, such as antioxidant assays and cytotoxic assays of plant extract, are offered by only two regulated laboratories and cost more than ten thousand pesos, making it quite difficult for teachers and students to engage in such laboratory tests frequently.

Laboratory teaching assumes that first-hand experience in observing and manipulating science materials is superior to other methods of developing understanding and appreciation. Laboratory training is also frequently used to develop more advanced study or research skills. Further, the theory of constructivism for laboratory practice provides a roadmap to enhanced learning based on the teacher's research data in the classroom to design laboratory activities. Laboratory practice is seen as more than acquiring process skills; it is essential in understanding science.

Assuming the importance of laboratory work in science education, ILP would answer the need, be helpful in the teaching-learning process, and contribute to the development of laboratory-based research in the community. Science investigatory/capstone projects among STEM students and teachers would become well-facilitated and efficient with the help of ILP.

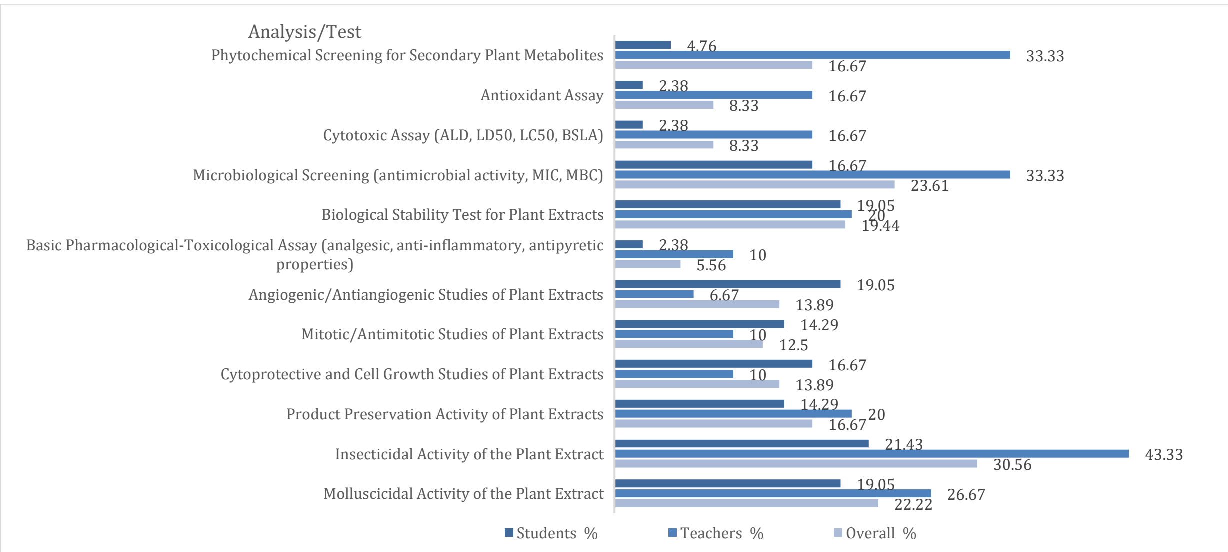

Fig. 2: The least and most common laboratory analyses/tests used by students and teachers (42 students, 30 teachers)

3.1. The challenges encountered by students and teachers

This part uses a validated survey instrument to analyze the difficulties encountered instead of using a qualitative method. The findings provide insights into high school research projects leading to improved research outputs and educational experiences for teachers and students.

Fig. 3 shows that the 72 participants found the availability of laboratory materials (equipment, reagents) (66.67%) and financial support (expensive laboratory analysis) (58.33%) to be moderately challenging. The study found that the participants considered the availability of laboratory materials, such as equipment and reagents needed for the analysis, as well as financial support due to the expensive laboratory analysis being moderately challenging. The results are in congruence with the study of Qasem and Zayid (2019), which pinpointed laboratory requirements as among the top challenges encountered, and that of Dabesa and Cheramlak (2021), which divulged that the lack of financial support was apparent in the responses of the respondents vis-à-vis the conduct of SIP. In Manalo's (2021) study, the specific types of resources were not defined. However, he emphasized that a shortage of resources was a significant challenge faced by students when conducting SIP.

As to the reported scarcity of laboratory resources and restricted exposure to laboratory activities faced by the respondents, this is supported by the studies of Butron (2018) and Errabo et al. (2018), which found that most processes are expensive and beyond the financial capabilities of most students. As such, students have limited opportunities to acquire scientific investigative abilities, particularly in public high schools.

Financial support was very challenging for the educators, followed by access to regulated institutions and the availability of laboratory materials. Financial issues, restricted access to licensed research institutes owing to distance, bureaucratic red tape, and a refusal to accommodate sample analysis requirements are among the challenges faced by science investigatory/capstone project advisers.

Similarly, Khan Niazi et al. (2018) found that in a rural high school, overcrowded and deplorable conditions of laboratories, merged science laboratories for all science disciplines, and a lack of basic apparatus and consumable supplies are prevalent occurrences.

Science educators believe that a laboratory is essential in instructing the subject. Laboratory activities and other experiments aid students by providing training in observation, supplying detailed information, arousing students' curiosity, and developing students' higher-order thinking skills. From the theory standpoint, the student's activity, the sensorimotor nature of the experience, and the individualization of laboratory instruction also contribute positively to learning. This is supported by the Constructivism Theory, which posits that when learners take control of the learning situation, such as problem-based learning, they understand the problem's importance, comprehend the topic's relevance, and construct knowledge through their experiences.

With the data drawn from the assessment of the tests/analyses and the challenges encountered by the respondents in conducting their SIPs/capstone projects, the researcher designed innovative laboratory procedures and low-cost kits for plant screening. The procedures can be done at home with minimal expert supervision, and kitchen items can be utilized if the required materials are unavailable. Also, data analysis is not expensive since it uses reliable free software (downloadable) and Excel files. SIPs/capstone projects can now be done in the comfort of home without the trouble of scheduling with regulated institutions/ laboratories.

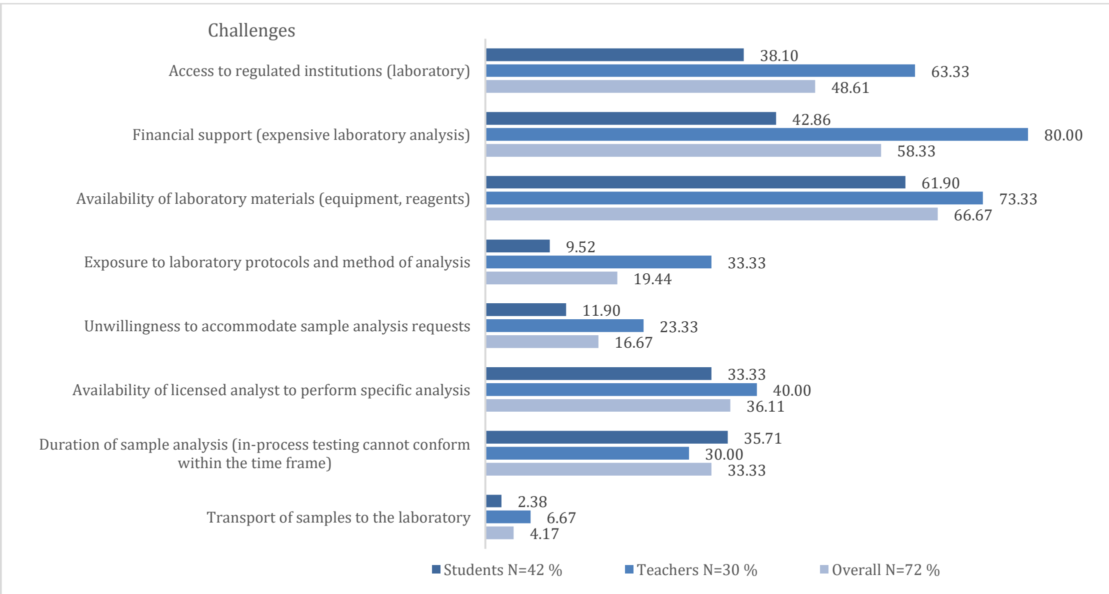

Fig. 3: The challenges encountered by students and teachers (N=72)

3.2. Development of ILP

The assessment of the least and most common analyses/tests used by students and teachers and the challenges they encountered in conducting science investigatory/capstone projects were all considered in developing the ILP for natural product screening, which includes innovative laboratory procedures and tools for the analysis.

The ILP addresses explicitly the difficulties in the availability of materials needed, such as reagents and equipment, lack of financial support due to expensive laboratory costs, and limited access to regulated institutions for the completion of science investigatory/capstone projects by providing a laboratory kit that can be used for a minimum cost and minimal supervision of an expert—providing portability and safety while maintaining the standard laboratory practices and quality of output were the primary objectives of the development of the laboratory kit.

The ILP includes an improvised water bath for extraction, a paper-based DPPH device, a hatching device for nauplii, and a laboratory kit. These kits are an essential component of laboratory analyses in plant screening. Both innovative laboratory procedures and kits were validated by the experts who work as analysts in regulated institutions (laboratories) or industries and evaluated by teacher participants.

1. Paper-based DPPH device: The antioxidant assay can be innovatively quantified using this kit, impregnated with 2,2'-diphenyl-11-picrylhydrazyl (DPPH). The paper-based kit comprises readily available materials such as laminating film, filter paper, aluminum foil, and DPPH reagents. Unlike conventional analysis, which requires sophisticated equipment to quantify antioxidants in a sample, the device is simple, rapid, and cost-effective. After a 30-minute analysis, picture the kit with a high-resolution camera and process it using the Image J software to determine the mean intensity of the pigment. The DPPH assay is the most frequently used method and offers the first approach for evaluating the antioxidant activity of plant extract due to its simplicity, reproducibility, and robustness. A paper-based DPPH device offers a straightforward and cost-effective method for antioxidant testing, requiring minimal reagent and sample amounts. This device, measuring 4 inches by 1 inch, was created by laminating a piece of paper. A hole was punched into it to form the test zone, where the DPPH reagent was applied. To conduct the analysis, an antioxidant or plant sample was dropped onto this test zone. The antioxidant in the sample reacts with the DPPH radicals, reducing them to stable molecules and causing the color to change from deep to light violet. The strength of the antioxidant activity in the samples was determined by the extent of color change, analyzed using Image J software. The device was then stored at 4°C for further analysis.
2. Paper-based chlorophyll device: This tool is similar to the DPPH kit and comprises laminating film, filter paper, and aluminum foil. The acetone extract of the leaves is directly impregnated in the kit; take a picture of it using a high-resolution camera and process the picture using the Image J software to determine the mean of the green pigment. The higher the green pigment content of the extract, the higher its chlorophyll content. This kit determines the UV protective activity and the chlorophyll content of plant extract.
3. Laboratory kit: The laboratory kit is composed of vials, test tubes, droppers, a capillary tube, an evaporating dish, Pasteur pipettes, a funnel, masking tape, a plunger, an aspirator, filter paper, and a magnifying glass intended for extraction, phytochemical screening, antioxidant assay, and cytotoxic activity using the brine shrimp lethality assay. The kit also includes paper-based DPPH and chlorophyll devices, as well as brine shrimp eggs. The materials can be easily obtained from local stores and are needed to conduct laboratory activities safely. Personal protective equipment, such as laboratory gowns, safety goggles, masks, and gloves, are also provided during the activities.
4. Improvised water bath: The water bath is a valuable device for evaporating the solvent from plant extract at a constant temperature over a long period. Materials and instructions on setting up an improvised water bath can be found in the appendices of the laboratory guide. Some materials are recyclable and obtained from local junk shops; some are bought online and from local electronics shops. Unlike a rotary evaporator, the improvised water bath is low-cost equipment costing thousands of pesos.
5. Hatching kit for nauplii: The improvised hatching kit for nauplii is an alternative to the aquarium with a pump. The hatching kit comprises a plastic container and divider bought from a local supermarket. The shallow plastic container was divided into smaller and bigger portions using a plastic division punched with small holes. The shallow plastic container is filled with artificial seawater. The brine shrimp eggs were sprinkled in bigger portions and covered with black paper. The smaller portion was exposed to light using a study lamp. The purpose is for the hatched brine shrimps or nauplii to be attracted to the illuminated side, and the shell will remain in the dark compartment. Easy-to-follow instructions or procedures are included in the appendices of the laboratory guide.
6. MS Excel file for data analysis: The procedures and programs needed to analyze data in an MS Excel file. Teachers and students were provided with this file to enter the data and automatically determine the result for IC50 and LC50.
7. Image J procedure for data processing: The procedure for data processing using image J

software is included for the quantification. Image J is free software developed by the National Institute of Health, USA.

The ILP is a novel tool designed to provide a thorough understanding of scientific concepts and methodologies in plant screening through hands-on experimental activities, thereby enhancing students' science process skills (SPS). By integrating the SPS into the curriculum, students can better understand and apply the scientific method effectively, thus improving students' performance and retention (Padilla, 2018). With the practical application of the skills within the structured framework of the ILP, students can grasp scientific theories and learn to apply them in different contexts, bridging the gap between theoretical knowledge and practical application. The connection between the ILP and the enhancement of SPS is crucial for cultivating a generation of well-equipped learners to address the complexities of the scientific and technological realm. A study revealed a positive correlation between SPS and students' cognitive domain, indicating higher proficiency leads to better learning outcomes (Putri et al., 2019), emphasizing the need for teachers to incorporate inquiry learning models during practical activities to engage students and foster a spirit of scientific inquiry (Anggereini et al., 2019; Hardianti and Kuswanto, 2017; Wijayaningputri et al., 2018). Ekici and Erdem's (2020) study on mobile scientific inquiry demonstrated significant improvements in pre-service teachers' SPS, including scientific thinking and self-efficacy. The study underscores integrating technology into science education to enhance student's learning experiences and develop essential 21st-century skills. Teachers are essential in fostering the students' SPS by acting as facilitators, guides, and mentors in the learning process (Artayasa et al., 2017). Errabo and Prudente (2018) evaluated the Science Investigation Skills (SIS) of Grade 7 in-service teachers and revealed that teachers excel in basic process skills but need improvement in integrated skills like controlling variables and data interpretation. The study suggested that targeted training and curriculum improvements can enhance teachers' preparedness for science investigation, enabling institutions to customize professional development programs and curriculum revisions to improve teaching practices and student engagement.

Despite substantial benefits in enhancing the hands-on learning experiences in natural product research, the ILP has limitations in the scope and scale of scientific inquiry it can facilitate, particularly when compared to advanced analytical tools. It may not delve into the intricacies of standard analyses, limiting students' and teachers' ability to perform detailed and comprehensive scientific investigations. The ILP's analyses are preliminary and qualitative, which may not always provide the precise and numeric data that more sophisticated quantitative methods would provide. Quantitative analysis would rely on software like Image J, which may not offer the same precision or functionality as standard laboratory equipment.

3.3. ILP framework

The assessment of the analyses/tests used by students and teachers and the challenges encountered in conducting the science investigatory/capstone projects determined the coverage of the laboratory guide for natural product analyses.

In conducting science investigatory/capstone projects, the most common challenges encountered by the respondents were the lack of financial support for expensive laboratory analysis, which was rated as very challenging by teachers and moderately challenging by students, followed by the availability of laboratory materials such as equipment and reagents needed for the analysis, rated as moderately challenging by both teachers and students. Dabesa and Cheramlak (2021) revealed that stakeholders' lack of financial support and knowledge contributed to the hindrance of conducting SIPs. It also pointed out the need for more education resources and that SIP implementation was plagued by weak management, community mobilization, and teamwork.

In the study by Aparecio (2018), most Grade 10 students could improve their science process skills when conducting investigatory projects. The study, though, indicated that mentoring students in the conduct of investigatory projects impacts their performance. This is supported by Manalastas and De Leon's (2021) study, which found that implementing SIP/capstone projects in STEM students had a positive impact since they could develop the essential skills for conducting research.

The development of ILP was based on the ASSURE model of instructional design, which intended to utilize learning materials that ensure learning is appropriate for students. The ASSURE framework is based on Robert Gagne's events of instruction, which is constructivism-based. The framework assumes that learners must actively participate in learning, interact with their environments and peers, and recognize students' learning styles. Following ASSURE's Model of Instructional Systems Design, the ILP in natural product screening will help impact much research, be an integral part of the educational process and bring importance to transforming abstracts into constants, increase motivation for both teachers and the learners in engaging themselves in laboratory activities hence, contribute to the development of the solid foundation of scientific researches as the cornerstone for the Science curriculum.

The Innovative Laboratory Procedure. The ILP laboratory guide for teachers and students included seven innovative laboratory procedures. These are (1) Identification, Preparation, and Extraction of Plant Sample, (2) Phytochemical Screening of *Cheilocostus speciosus* Ethanolic Extract, (3) Antioxidant Screening using Paper-Based DPPH (2,2-diphenyl-1-picrylhydrazyl) assay with Image J software, (4) Cytotoxic Test using the Brine Shrimp Lethality Assay, (5) UV Protective Activity of Plant Extract, (6) Antiangiogenic/Angiogenic Assay of Plant Extract using Chorioallantoic Membrane Method (CAM), and (7) Antimitotic/Mitotic Assay (Allium cepa Root Tip Method). Innovative laboratory procedures can be done at home with minimal supervision, and kitchen materials can be utilized if the required materials are unavailable. Also, data analysis uses reliable free software (downloadable), and Excel files for data analysis are included. SIPs/capstone projects can now be done in the comfort of home without dealing with scheduling with regulated institutions such as diagnostic laboratories.

Laboratory innovations make practical work more exciting and challenging for teachers and students. New ideas improve the quality and quantity of experimental procedures and experiments in the laboratory. Generally, in public institutions, where there are insufficient resources for experimentation or the same sort of laboratory experiments (with complete instructions supplied) are consistently repeated, teachers and students are not forced to think and act independently. Innovations would help shatter this preconception and help meet essential curricular needs (Mathew and Earnest, 2004).

Utilizing ILP will bridge the gap between teachers' and students' difficulty in conducting laboratory work and the pursuit of efficiency in doing laboratory research. The ILP helps students develop scientific skills through a step-by-step procedure using locally available low-cost materials and natural products, helps stimulate students' and teachers' interest in doing science laboratory investigations, and strengthens their motivation towards doing more research at home. Most importantly, this will provide a backbone of science research's fundamentals, embracing the practical application of theories learned in the four corners of the typical classroom. The study is new, and the researcher has yet to find a similar one. The utilization of ILPS will be a milestone in the field.

The following is the content outline of the sample innovative laboratory procedures for plant extract screening:

1. The cover: The laboratory guide's cover design has a simple visual appearance that still creates branding and initial impressions on potential users—considered one of the most crucial parts of marketing the product to its intended users. The cover design shows the user should 'feel' it rather than 'tell' about the content.
2. Introduction: The introduction provides background information, introduces the topic, and gives an overview of the laboratory activity based on the related studies.
3. Separator page: A separator page is provided in each innovative procedure to differentiate one procedure from another and emphasize a particular procedure.
4. Safety notes: This section aims to provide safety information to teachers and students before, during, and after the laboratory activity, specifically to prevent any accidents in the laboratory. Personal protective equipment such as laboratory gowns, goggles, gloves, and masks are emphasized. Safety notes also include this disclaimer: The laboratory procedure does not claim to cover all of the risks involved. Before trying this laboratory procedure, participants are responsible for the complete safety and hazard instructions.
5. Reagents: The list of reagents needed in a particular laboratory activity and a warning if the reagent has a strong acid or strong base can cause harm if not handled carefully. Reagents are utilized in as minute amounts as possible to minimize waste and cost.
6. Materials: Materials are vital components of laboratory analysis. Students and teachers should familiarize themselves with the materials in a particular laboratory analysis. Substitute materials, such as those readily available in the household, are also listed.
7. Procedure: The procedures are detailed, simplified, and modified to suit the teachers' and students' needs and understanding. Procedures are presented in a step-by-step manner to guide and reduce the possibility of missed steps or other errors that can impact the result of the laboratory analysis. The procedure also included the steps for data analysis.
8. References: A list of references is included to put the innovative laboratory procedures into context, and users can easily check them to confirm the method used. The references will allow the users to examine the sources of a text for validity or to learn more about the topics. In practice, references are listed at the end of each innovative procedure.

The ILP is an adaptive solution for natural product screening in educational settings with limited resources. It provides hands-on activities, encourages resourcefulness and creativity, develops science process skills, makes science education accessible, and supports educational equity. Likewise, it allows students from diverse economic backgrounds to participate in hands-on scientific learning and supports teachers' instructional roles by providing experiential learning and relevant science instruction. The ILP's adaptability and resourcefulness make it valuable materials for students and teachers in disadvantaged school settings. The ILP is crucial in fostering the development of future scientists and informed citizens by enabling relevant research despite resource limitations.

The ILP as instructional material can benefit students and teachers beyond natural product research. It helps to develop basic scientific skills, stimulates scientific curiosity, and supports multidisciplinary learning and STEM education. The ILP can inspire community engagement and service learning, provide a framework for inquiry-based learning, promote digital literacy, and foster cross-curricular connections.

Studies on the development of ILP have yet to be found, but several studies related to the science investigatory/capstone projects/research implementation have been undertaken. One is using a project-based approach as a pedagogical tool to improve students' skills in undertaking science investigation projects. Gomez (2013) posited that students who took a project-based approach improved their self-efficacy and learned how to collaborate, solve problems, and think critically. The student's abilities to perform investigative projects improved in general due to their exposure to this collaborative teaching technology. The quality of student research has improved, which has resulted in a rise in participation in science fair contests.

An intervention program called Project i-CREATE (Intensive Collaboration through Research Enhancement and Advancement Training and Exercise) at San Pablo City Science Integrated High School, Philippines, helped develop young researchers and improve the school's science research program. Thematic analysis was used to derive emerging themes, such as SIP providing improvement and development opportunities and challenges, such as lack of resources and training (Manalo, 2021). Schmidt and Kelter (2017) proved that science fair participation increased understanding of scientific inquiry and positively influenced attitudes toward science, technology, engineering, and mathematics (STEM) careers and coursework for high school students, while Cuartero (2016) found that doing SIP have an impact on the interest and process skills of elementary students.

Meanwhile, an InoChemLaW package (innovative laboratory workbook in chemistry) developed by Nainggolan et al. (2020) was found to help students learn chemistry independently. Students' knowledge and skills in experimental groups were higher than in the control group. The InoChemLaW package had projects and character-based chemistry to build students' investigation abilities. It was also integrated with computer technology to make it simple and attract students to study independently. Macale and Bulasag (2017) showed that the development of chemistry laboratory manuals and students' experiences allowed them to analyze social problems and understand how science is relevant to their lives. Including science-based societal issues in a chemistry laboratory activity is an essential factor in the reform of science education. Students are made more aware and reactive to the different issues in their community.

Further, a community-based learning resource package developed by Magwilang (2019) has been shown to improve students' academic performance. Students exposed to the resource package performed better than those taught without it. Inorganic chemistry lessons can thus be made more culturally relevant and meaningful to the students by integrating local products, everyday activities, agricultural practices, natural resources, and local industries.

Studies have shown the impact of developing and validating a guidebook or instructional material on high school students conducting SIPs in writing investigatory projects. Butron (2018) developed a guidebook that was proven to improve the student's performance. The study's findings revealed that students from the exposed and non-exposed groups significantly improved their performance based on the pre-test and post-test. This is supported by Rogayan and Dollete (2019), who developed a workbook in physical science intended for SHS students under the K12 curriculum. Expert validators strongly agreed that the instructional material, which follows differentiated instruction and encourages independent learning, possesses adequacy, coherence, appropriateness, and usefulness. Further, Sagcal et al. (2017) developed context-based laboratory activities and low-cost chemistry kits to improve the chemistry skills of Grade 10 students. The teaching materials' effectiveness was assessed and quantified by 24 science teachers, one junior high school principal, and 30 student respondents and found to be effective and highly acceptable.

3.4. Experts' validation of the ILP

As shown in Fig. 4, the experts deemed the content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness of the ILP as outstanding. The results suggest that the ILP can be readily utilized. It must be stressed that, so far, a thorough online search failed to show studies that dealt with laboratory packages that may be used in natural product screening. Consequently, no study can be cited to support the experts' validation of the ILP. Multiple studies, though, support a validation process.

Validation of laboratory procedures/methods is a multi-tiered process for evaluating the effectiveness of procedures, often compared to an existing methodology or protocol. In its broadest definition, method validation is the examination of test performance after a change in reagents, apparatus, methodology, or, specific to chemistry laboratory activities, natural product screening. The ultimate goal of method validation is to give objective evidence that the tested method will demonstrate acceptable reproducibility and accuracy, allowing it to be used in clinical settings (Walton, 2001). The acceptability of the data provided frequently requires consultation between a licensed expert and analysts, and a successful validation yields usable reference material or laboratory procedures. Method validation and verification provide objective evidence that a method is fit for purpose; it meets the specified requirements for a particular intended use (NATA, 2012).

Moreover, validation and verification procedures in clinical chemistry focus on using harmonized concepts and nomenclature, fitness-for-purpose evaluations, and procedures for minimizing overall measurement and diagnostic uncertainty. The need for mutually accepted validation procedures in all fields of bioanalysis becomes apparent in meeting international accreditation and certification standards.

Manufacturers of highly automated in vitro diagnostic methods provide most measurement methods used in actual clinical chemistry. Validated by the manufacturers for their intended use and fitness-for-purpose, they need to be verified in the circumstances of the end-users. Unfortunately, there is no general agreement on the extent of the verification procedures required (Theodorsson, 2012). Method validation is the first stage in implementing Lean-Total Quality Management in a new clinical laboratory. All new tests were validated (with particular attention to alkaline phosphatase) by checking reference intervals, analytical precision, and precision. A high recovery rate further validated the lean idea. Validation guarantees that precise and reliable results are reported in a clinically appropriate timeframe (Das, 2011). Researchers most typically use validation to discuss the status of new or planned test procedures. Various variables would facilitate and speed progress toward the reduction, refinement, and eventual replacement of assessment or laboratory analyses (Basketter et al., 2010). In particular, research questionnaires are one of the most extensively utilized data collection instruments. The fundamental goal of a questionnaire in research is to collect essential data as accurately and validly as possible. As a result, survey/questionnaire accuracy and consistency, often known as validity and reliability, are essential aspects of the research technique. New researchers frequently need clarification when choosing and conducting the appropriate validity type to evaluate their research instrument (questionnaire/survey) (Taherdoost, 2018).

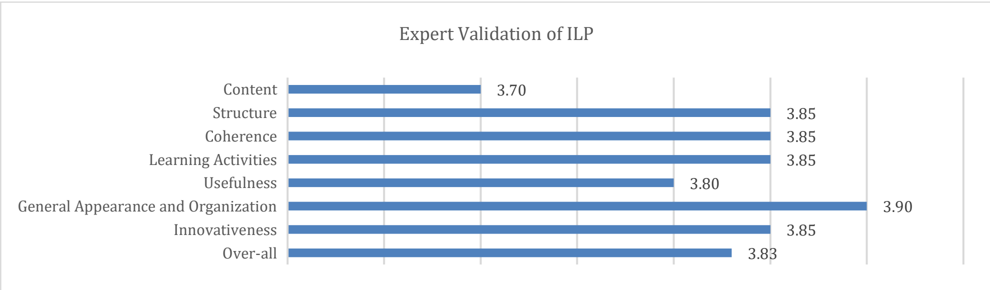

Fig. 4: The experts' validation (N=20)

3.5. Teachers' evaluation of the ILP

As shown in Fig. 5, the teachers evaluated the content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness of the ILP as outstanding—teachers' evaluation of educational materials. As facilitators of learning, they ensure that learning materials serve their objective of facilitating an effective teaching-learning process. The teachers' evaluation results demonstrate that the ILP is practical for science investigatory/capstone projects.

No study can underpin the great significance of ILP, but several studies have evaluated developed instructional materials and their positive impact. Avianti et al. (2018) evaluated the CORE (Connecting, Organizing, Reflecting, Extending) approach in improving students' learning outcomes when studying chemical bonding and was found to be effective after observation, test, questionnaire, and validation.

Using the Isman Instructional Design model, a study on the design and development of a Physics module was also conducted based on learning styles and appropriate technology. The modules were successful for visual, active, and reflective learners in a Malaysian secondary school and potentially improved the teaching and learning of physics in secondary educational settings (Alias and Siraj, 2012). Similarly, high school students in Bandung, Indonesia, were studied by Liliawati et al. (2018) on how teaching materials based on multiple intelligences helped them absorb content on global warming. Most students demonstrated an understanding of several subjects using the learning materials provided. Lestari et al. (2019) developed modules using the Plomp development model to examine their validity and practicality. Validated by eight experts and tested in two medium and low-ability schools, the modules met the valid criteria in terms of content, constructs, graphics, and language aspects, as well as module practicality, attractiveness, ease of use, efficiency, and benefits for teachers and students with high module practicality categories. Usmeldi (2018) found that research-based learning modules with Predict Observe-Explain strategies can improve students' competence in Physics. Cramer et al. (2018) found that students who received learning modules before or after a midterm improved their performance on the midterm and final exams. Students who completed the modules indicated they enjoyed them, scoring significantly higher on their final examination.

In evaluating a science learning module with problem-solving methods developed and used in plant breeding materials, results revealed that students had increased learning outcomes characterized by thinking skills, concept planting, and physical or spiritual skills, and the formation of mental attitudes and behaviors of students will not be separated from the question of planting values (Arpan et al., 2018)—the evaluation of modules on clinical decision-making in Prosthodontics, didactic lectures with computer-assisted case-based learning. Deshpande et al. (2015) proved that it helped overcome the drawbacks of traditional teaching, such as knowledge compartmentalization. It also promoted clinical problem-solving skills, resulting in a significant improvement in the field of clinical decision-making quality. However, another developed module, when evaluated, was proven to have a favorable impact on student involvement and the development of student teamwork skills based on the staff and students who participated in evaluating the innovative year-long module for students. Willmot and Perkin (2015) showed that after the introduction of the module, the working relationships between personal tutors and their tutees improved.

Khabibah et al. (2017) found it effective in improving generic science skills in the discovery learning module. Likewise, inquiry-based learning modules effectively empowered cooperation skills in the learning process. Noroozi and Mulder (2017) conducted a study on a digital learning module with peer feedback to engage students in more intensive learning and writing processes on a controversial issue in biotechnology and molecular life sciences. Students' attitudes toward the topic of GMOs changed from pre-test to post-test as a result of exchanging diverse and multiple conflicting opinions. Although peer feedback support was expected to be the primary cause of student attitudinal change or learning gains, it was still possible that other factors, such as textual and graphical information representations, influenced learning gains.

In delivering instructions, instructional materials act as a medium between the teacher and the students, and the former can motivate the latter during the teaching-learning process. The materials are also required to evaluate the learners' knowledge and capacity to complete activities and deliver exams. Thus, the creation of instructional materials and modules is encouraged and produced by the Department of Education. One such is the Grade 7 Biology modules assessed by Biology subject specialists on seven dimensions: content, presentation and organization, learning activities, evaluation activities, information accuracy and up-to-dateness, format, and sufficient available materials. These seven dimensions were rated satisfactory, and the evaluators suggested improving the module (Tan, 2019). Calamlam (2021) developed a 21st-century e-learning Module Assessment Tool for evaluating learning modules. Content validity was established through expert validation, while reliability was established by pilot testing. The developed assessment tool is recommended as a guide for future learning modules and a standard for evaluating existing ones. Meanwhile, a study conducted by Yazon (2018) on the validation and effectiveness of a module in Assessment of Students Learning revealed that the student respondents strongly agreed that the lessons have precise objectives described in behavioral terms that are quantifiable, practical, and attainable, and presented in grammatically correct paragraphs/sentences.

Manalastas and De Leon (2021) developed an Electronic Instructional Module and Teacher's Guide in Matter using the developmental method of research and Esquivel Research and Development Design. The E-Module was evaluated by Science Teachers, Science Experts, IT Experts, and students and found to possess high educational qualities and be ready for use in public schools. Oribe et al. (2015) developed an interactive learning module (ILM) for pre-service teachers following the K- 12 curriculum in Grade 7 Science. The evaluation of the developed ILM revealed that it is an effective tool for teaching Grade 7 Science, and students learn best when ILM is incorporated into instructions.

For specific subjects, Urbano (2019) developed a module in Earth and Space that provides activities and lessons to improve students' academic performance in science. The module was evaluated and was influential in measuring the students' understanding of the lessons and reflecting on behavioral activities that are highly appropriate for learners' mental development. Meanwhile, Auditor and Naval (2014) developed and validated a physics module in physics, revealing that the generated modules were an effective tool for teaching and learning physics in the 10th grade.

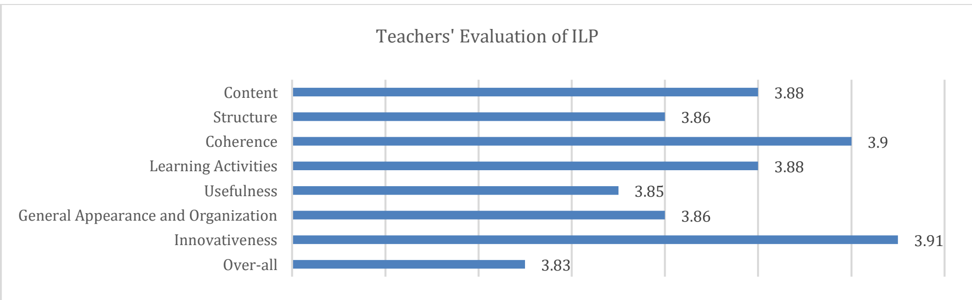

Fig. 5: The teachers' evaluations (N=22)

3.6. Teachers' experience in using the ILP

The teachers were enjoined in utilizing the laboratory procedures and kit for natural product screening. The assessment of the ILP was a fun-filled learning activity that equipped the participants with laboratory and collaboration skills. The activities were engaging and enriching in that the teachers could develop innovativeness and explore the available materials in conducting experiments. They said their involvement in this study was a lifetime experience since it was their first time doing those laboratory activities. The ILP enabled the participants to realize practical concepts on science investigatory project themes that they may use in their school laboratories or at home, making learning and training experiences more meaningful and relevant.

3.7. Teachers' feedback after using the ILP

New, meaningful, and engaging experience: The ILP provided the teacher participants with a new, meaningful, engaging experience. Participant 3 was able to use the instructional package in teaching chemistry subjects. "It was another new experience to me," according to Participant 3, while for Participant 4, the laboratory package was a "fruitful and fulfilling experience." Participant 16 shared that using the instructional package was a "challenging experience," while Participant 2 found it a meaningful experience to use the laboratory package. Participants 1, 7, 8, and 19 felt like using the package was a "fun experience." To Participants 10 and 20, the laboratory package was "engaging" and provided an "informative and interactive" experience. Learning opportunities that promote critical thinking and scientific attitudes: The ILP is designed to promote students' critical thinking and scientific attitudes. To Participant 1, the package will help students "enhance their knowledge and skills in the field of research," while Participants 17 and 18 "provide learning opportunities that promote critical thinking." For Participants 6, 7, 8, 9, 15, and 17, the laboratory package is tailored to promote scientific attitudes such as resourcefulness, teamwork, and collaboration. It promotes teamwork and collaboration," according to the participant, while to Participant 7, "It developed resourcefulness and interest towards doing science investigatory projects." The statement is supported by constructivism theory, which states that students can construct learnings concerning their previous understandings. Serafín (2014) also argued that learners construct meaning by building on prior knowledge and experiences. New ideas and experiences are accorded with the current understanding, and learners create new or adapted rules to make sense of the world.

Easy and flexible experiments: The laboratory package provides hands-on activities that are easy to carry out. To Participant 4, the laboratory experiment "went on smoothly." The activities and the procedures were systematic, as experienced by Participants 12, 13, 14, and 19. They shared that the package is "well-arranged" and "easy to follow." Empirical tasks equip students with new scientific skills. The laboratory package has provided practical activities based on the learners' real-life experiences. To participants 2, 4, and 17, the package has given them "hands-on" experience. Participants 5 and 17 learned new skills they could use in the laboratory. "It also gives me additional skills, especially in handling laboratory apparatus and as well as on handling chemicals," Participant 5 shared. Participant 17 said, "I learned some scientific procedures by doing and engaging in this activity."

Cost-effective instructional innovation: The laboratory package was a cost-effective instructional innovation. Participants 13 and 16 stated that the "materials and the activities were cost-effective" and "much cheaper and effective." The package also exemplifies innovation based on economically and locally available materials, as participants 5 and 10 mentioned. "It is very innovative, especially in conducting SIP by the students, because most materials are locally available and economically friendly compared to standard laboratory testing," shared Participant 10. Eidetic insight: The teachers' experience in using the ILP was favorable. Innovation could improve the quality of education and provide more benefits in times of budget pressures and rising demand. The ILP, which utilizes the ASSURE instructional design model, offers an array of benefits to the stakeholders. It can motivate learning, enhance hard and soft skills, and be cost-efficient for the researchers.

4. Conclusion

Both teachers and students have encountered challenges in conducting science investigatory/capstone projects, such as the availability of materials and students' financial capacity that impede the progress or movement of their research. Given the challenges encountered, an ILP was developed. The goal was to develop a doable and less expensive analysis method and foster a positive scientific attitude among students focusing on plant screening research. The ILP met the standards for chemical preparations and analyses and was examined and validated by experts regarding content, structure, coherence, learning activities, usefulness, general appearance and organization, and innovativeness. The teachers also regarded using the ILP as a favorable experience during its try-out. The ILP was deemed to have the potential to facilitate SIP/capstone projects and to develop students' and teachers' research expertise in plant screening. Doing laboratory work would be convenient and cost-efficient when used in the field.

The ILP is set to undergo extensive research to validate its effectiveness and enhance its features and applications. Future research could include cost-benefit analysis, comparative effectiveness studies, scalability and adaptation, and integration of advanced technologies. These studies would provide valuable insights into the effectiveness, financial advantage, long-term impact on students' science process skills, and potential global applicability.

5. Implication to theory and practice

The Philippine K-12 science curriculum is a learner-centered and inquiry-based discipline. The development of ILP can facilitate laboratory experience for both teachers and students. The importance of laboratory procedures and tools in conducting science investigatory/capstone projects must be recognized. Innovations are crucial to nation-building and development; they reinforce growth and positive change. Students and teachers are encouraged to engage in research activities. The ILP fills the gap between the challenges encountered in conducting SIPs/capstone projects and the quest for innovation and development.

Innovations in science curricula and programs intended for SIP/capstone projects and other research-related activities may further enhance the scientific skills of teachers and students. Research advisers may consider using the developed ILP for their experiments to address the challenges they encounter. Textbook writers and instructional material developers may draw insights from the findings of the study and design textbooks and other learning materials that promote innovation.

Acknowledgment

The researcher would like to acknowledge the Department of Science and Technology – Science Education Institute Capacity Building Program in Science and Mathematics Education (CBPSME) for the grants to finish this endeavor.

Compliance with ethical standards

Ethical consideration

The study prioritized the well-being and autonomy of participants during the COVID-19 pandemic. Voluntary participation, informed consent, confidentiality, risk minimization, and sensitivity to the pandemic context were included in the study. Participants have the right to opt-out at any study stage, and all responses are treated with the utmost confidentiality. Data collection was conducted remotely via Google Forms, ensuring safety. The study's instruments and interactions are designed to avoid exacerbating pandemic-related stress. The ethical consideration ensures the integrity and rigor of the research process.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Akani O (2015). Laboratory teaching: Implication on students' achievement in chemistry in secondary school in the Ebonyi State of Nigeria. Journal of Education and Practice, 6(30): 206–213.

Alias N and Siraj S (2012). Design and development of physics module based on learning style and appropriate technology by employing Isman instructional design model. The Turkish Online Journal of Educational Technology, 11(4): 84–93.

Anggereini E, Septiani M, and Hamidah A (2019). Application of guided inquiry learning model in biological learning: It's the influence to science process skills and students' scientific knowledge in class XI MIPA high school. Journal of Physics: Conference Series, 1317(1): 012179. https://doi.org/10.1088/1742-6596/1317/1/012179

Aparecio MBM (2018). Mentoring, self-efficacy and performance in conducting investigatory projects: A mixed method. Asia Pacific Institute of Advanced Research, 4(2): 65–76. https://doi.org/10.25275/apjcectv4i2edu7

Arpan P, Aunurrahman A, and Fadillah F (2018). The development of science learning module with problem solving method. Journal of Education, Teaching and Learning, 3(2): 195-205. https://doi.org/10.26737/jetl.v3i2.747

Artayasa IP, Susilo H, Lestari U, and Indriwati SE (2017). The effectiveness of the three levels of inquiry in improving teacher training students' science process skills. Journal of Baltic Science Education, 16(6): 908–918. https://doi.org/10.33225/jbse/17.16.908

Auditor E and Naval DJ (2014). Development and validation of tenth grade Physics modules based on selected least mastered competencies. International Journal of Education and Research, 2(12): 145–152.

Avianti R, Suyatno, and Sugiarto B (2018). The development of learning materials based on core model to improve students' learning outcomes in topic of chemical bonding. Journal of Physics: Conference Series, 1006(1): 12012. https://doi.org/10.1088/1742-6596/1006/1/012012

Basketter DA, Kimber I, and Hartung T (2010). The evolution of validation: A commentary. Cutaneous and Ocular Toxicology, 29(1): 1-3. https://doi.org/10.3109/15569520903367843 **PMid:19883246**

Blosser PE (1983). The role of the laboratory in science teaching. School Science and Mathematics, 83(2): 165-69. https://doi.org/10.1111/j.1949-8594.1983.tb10107.x

Braun V and Clarke V (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2): 77–101. https://doi.org/10.1191/1478088706qp063oa

Brüggemann J and Bizer K (2015). Laboratory experiments in innovation research: A methodological overview and a review of the current literature. Journal of Innovation and Entrepreneurship, 5(1): 2–13. https://doi.org/10.1186/s13731-016-0053-9

Butron V (2018). Validation and acceptability of a guidebook in writing an investigatory project. International Journal of Science and Research, 7(4): 1247–1254.

Calamlam JMM (2021). The development of 21st-century e-learning module assessment tool. Journal of Educational Technology Systems, 49(3): 289-309. https://doi.org/10.1177/0047239520953792

Couto M and Cates C (2019). Laboratory guidelines for animal care. In: Pelegri F (Ed.), Vertebrate embryogenesis: Embryological, cellular, and genetic methods: 407-430. Volume 1920, Humana, New York, USA. https://doi.org/10.1007/978-1-4939-9009-2_25 **PMid:30737706**

Cramer KM, Ross C, Plant L, and Pschibul R (2018). Efficacy of learning modules to enhance study skills. International Journal of Technology and Inclusive Education, 7(1): 1251–1259. https://doi.org/10.20533/ijtie.2047.0533.2018.0153

Cuartero OL (2016). Impact of doing science investigatory project (SIP) on the interest and process skills of elementary students. International Journal of Multidisciplinary Academic Research, 4(5): 27–41.

Dabesa F and Cheramlak SF (2021). Practices, opportunities, and challenges of SIP in primary schools of Ilu Gelan Woreda, West Shoa Zone, Oromia Regional State. Middle Eastern Journal of Research in Education and Social Sciences, 2(2): 58–84. https://doi.org/10.47631/mejress.v2i2.162

Das B (2011). Validation protocol: First step of a lean-total quality management principle in a new laboratory set-up in a Tertiary Care Hospital in India. Indian Journal of Clinical Biochemistry, 26(3): 235-243. https://doi.org/10.1007/s12291-011-0110-x **PMid:22754186 PMCid:PMC3162948**

Deshpande S, Lambade D, and Chahande J (2015). Development and evaluation of learning module on clinical decision-making in Prosthodontics. The Journal of the Indian Prosthodontic Society, 15(2): 158-161. https://doi.org/10.4103/0972-4052.158080 **PMid:26929504 PMCid:PMC4762306**

Dunnett K and Bartlett PA (2018). Asking the next generation: The implementation of pre-university students' ideas about physics laboratory preparation exercises. Physics Education, 53(1): 015016. https://doi.org/10.1088/1361-6552/aa9324

Dunnett K, Gorman MN, and Bartlett PA (2019). Assessing first-year undergraduate physics students' laboratory practices: Seeking to encourage research behaviours. European Journal of Physics, 40(1): 015702. https://doi.org/10.1088/1361-6404/aaf13b

Ekici M and Erdem M (2020). Developing science process skills through mobile scientific inquiry. Thinking Skills and Creativity, 36: 100658. https://doi.org/10.1016/j.tsc.2020.100658

Errabo DDR and Prudente MS (2018). Mainstreaming science investigation skills of grade 7 in-service teachers in the Philippines. DLSU Research Congress, De La Salle University, Manila, Philippines.

Errabo DDR, Cajimat RT, and Orleans AV (2018). Factors affecting the implementation of science investigatory projects and its implications to the National Science and Technology Fair. Advanced Science Letters, 24(11): 7885–7889. https://doi.org/10.1166/asl.2018.12449

Gomez RG (2013). A project-based approach to enhance skills in science investigatory projects among secondary school students in Northern Mindanao. The Mindanao Forum, 26(1): 63–83.

Hansen LA, Lawrence D, and Hansen A (2013). Institution animal care and use committees need greater ethical diversity. Journal of Medical Ethics, 39(3): 188–190. https://doi.org/10.1136/medethics-2012-100982 **PMid:23131895 PMCid:PMC3595150**

Hardianti T and Kuswanto H (2017). Difference among levels of inquiry: Process skills improvement at senior high school in Indonesia. International Journal of Instruction, 10(2): 119-130. https://doi.org/10.12973/iji.2017.1028a

Hofstein A (2017). The role of laboratory in science teaching and learning. In: Taber KS and Akpan B (Eds.), Science education: New directions in mathematics and science education: 357–368. Sense Publishers, Rotterdam, Netherlands. https://doi.org/10.1007/978-94-6300-749-8_26

Hofstein A and Lunetta VN (1982). The role of the laboratory in science teaching: Neglected aspects of research. Review of Educational Research, 52(2): 201–217. https://doi.org/10.3102/00346543052002201

Hofstein A and Mamlok-Naaman R (2007). The laboratory in science education: The state of the art. Chemistry Education Research and Practice, 8(2): 105–107. https://doi.org/10.1039/B7RP90003A

Houde L, Dumas C, and Leroux T (2009). Ethics: Views from IACUC members. ATLA Alternatives to Laboratory Animals, 37(3): 291–296. https://doi.org/10.1177/026119290903700311 **PMid:19678730**

Khabibah EN, Masykuri M, and Maridi M (2017). The effectiveness of module based on discovery learning to increase generic science skills. Journal of Education and Learning, 11(2): 146–153. https://doi.org/10.11591/edulearn.v11i2.6076

Khan Niazi MR, Aslam Asghar M, and Ali R (2018). Effect of science laboratory environment on cognitive development of students. Pakistan Journal of Distance and Online Learning, 4(1): 123–134.

Khoiri N, Riyadi S, Kaltsum U, Hindarto N, and Rusilawati A (2017). Teaching creative thinking skills with laboratory work. International Journal of Science and Applied Science: Conference Series, 2(1): 256–260. https://doi.org/10.20961/ijsascs.v2i1.16722

Khushk A, Zhiying L, Yi X, and Zengtian Z (2023). Technology innovation in STEM education: A review and analysis. International Journal of Educational Research and Innovation, 19: 29–51. https://doi.org/10.46661/ijeri.7883

Lestari RA, Dewata I, and Ellizar E (2019). Validity and practicality of buffer solution module based on discovery learning with a scientific approach to increase the critical thinking ability of 11th grade high school students. Journal of Physics: Conference Series, 1185(1): 012150. https://doi.org/10.1088/1742-6596/1185/1/012150

Liliawati W, Zulfikar A, and Kamal RN (2018). The effectiveness of learning materials based on multiple intelligence on the understanding of global warming. Journal of Physics: Conference Series, 1013(1): 012049. https://doi.org/10.1088/1742-6596/1013/1/012049

Lunetta VN, Hofstein A, and Clough MP (2005). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In: Abell SK, Appleton K, and Hanuscin DL (Eds.), Handbook of research on science education: 393-441. Lawrence Erlbaum Associates, Mahwah, USA.

Macale AM and Bulasag AS (2017). Development and validation of laboratory activities in high school chemistry based on societal issues. Journal of Nature Studies, 16(1): 27–33.

Magwilang EB (2019). Development and validation of a community-based learning resource package in inorganic chemistry. International Journal of Humanities and Social Sciences, 11(2): 33-41. https://doi.org/10.26803/ijhss.11.2.3

Manalastas RS and De Leon SP (2021). Development and evaluation of electronic instructional module in matter. European Journal of Humanities and Educational Advancements, 2(8): 107–127.

Manalo FKB (2021). Project I-Create (Intensive collaboration through research enhancement and advancement training and exercise): Direction towards improved science research program at San Pablo City Science Integrated High School. IOER International Multidisciplinary Research Journal, 3(1): 60–70. https://doi.org/10.54476/iimrj268

Marasigan NV (2019). Development and validation of a self-instructional material on selected topics in analytic geometry integrating electronic concepts. International Journal of Recent Innovations in Academic Research, 3(5): 2635–3040.

Mathew SS and Earnest J (2004). Laboratory-based innovative approaches for competence development. Global Journal of Engineering Education, 8(2): 167-174.

McCormick-Ell J and Connell N (2019). Laboratory safety, biosecurity, and responsible animal use. ILAR Journal, 60(1): 24-33. https://doi.org/10.1093/ilar/ilz012 **PMid:31423527**

Nainggolan B, Hutabarat W, Situmorang M, and Sitorus M (2020). Developing innovative chemistry laboratory workbook integrated with project-based learning and character-based chemistry. International Journal of Instruction, 13(3): 895-908. https://doi.org/10.29333/iji.2020.13359a

NATA (2012). Guidelines for the validation and verification of quantitative and qualitative test methods. National Association of Testing Authorities Australia, Parramatta, Australia.

Noroozi O and Mulder M (2017). Design and evaluation of a digital module with guided peer feedback for student learning biotechnology and molecular life sciences, attitudinal change, and satisfaction. Biochemistry and Molecular Biology Education, 45(1): 31-39. https://doi.org/10.1002/bmb.20981 **PMid:27322926**

Oribe VR, Tan JB, and Untalan LA (2015). An interactive module for pre-service teachers teaching grade 7 science. MSEUF Research Studies, 17(1): 81-94.

Padilla M (2018). The science process skills. National Association for Research in Science Teaching, Reston, USA.

Pareek RB (2019). An assessment of the availability and utilization of laboratory facilities for teaching science at secondary school. Science Education International, 30(1): 75–81. https://doi.org/10.33828/sei.v30.i1.9

Putri ER, Helendra H, Hartanto I, and Ahda Y (2019). Correlation of basic science process skills and learning outcomes of high and low level students in Junior High School 35 Padang. Jurnal Atrium Pendidikan Biologi, 4(2): 120-130. https://doi.org/10.24036/apb.v4i2.5854

Qasem FAA and Zayid EIM (2019). The challenges and problems faced by students in the early stage of writing research projects in L2, University of Bisha, Saudi Arabia. European Journal of Special Education Research, 4(1): 32–47.

Rogayan DV and Dollete LF (2019). Development and validation of physical science workbook for senior high school. Science Education International, 30(4): 284-290. https://doi.org/10.33828/sei.v30.i4.5

Sagcal RR, Valera NS, and Maquiling JT (2017). Development and Evaluation of context-based laboratory activities in chemistry using low-cost kits for junior public high school. KIMIKA, 28(2): 30–41. https://doi.org/10.26534/kimika.v28i2.30-41

Schmidt KM and Kelter P (2017). Science fairs: A qualitative study of their impact on student science inquiry learning and attitudes toward STEM. Science Educator, 25(2): 126–132.

Serafín Č (2014). Constructivism in the school of experimental work. In the SGEM 2014 International Multidisciplinary Scientific Conferences on Social Sciences and Arts, Albena, Bulgaria. https://doi.org/10.5593/sgemsocial2014/B11/S3.085

Shana Z and Abulibdeh ES (2020). Science practical work and its impact on students' science achievement. Journal of Technology and Science Education, 10(2): 199–215. https://doi.org/10.3926/jotse.888

Suryanti E, Fitriani A, Redjeki S, and Riandi R (2019). Virtual laboratory as a media to improve the conceptual mastery of molecular biology. Journal of Physics: Conference Series, 1317(1): 012202. https://doi.org/10.1088/1742-6596/1317/1/012202

Taherdoost H (2018). Validity and reliability of the research instrument; How to test the validation of a questionnaire/survey in a research. https://doi.org/10.2139/ssrn.3205040

Tan MLG (2019). An evaluation of DepEd-produced grade 7 biology modules by biology experts and science teachers. International Journal of Innovation in Science and Mathematics Education, 27(5): 27–42. https://doi.org/10.30722/IJISME.27.05.003

Theodorsson E (2012). Validation and verification of measurement methods in clinical chemistry. Bioanalysis, 4(3): 305–320. https://doi.org/10.4155/bio.11.311 **PMid:22303834**

Torrefranca EC (2017). Development and validation of instructional modules on rational expressions and variations. The Normal Lights, 11(1): 43–73. https://doi.org/10.56278/tnl.v11i1.375

Urbano JM (2019). Development and evaluation of module on earth and space. ASEAN Multidisciplinary Research Journal, 2(1): 8–13.

Usmeldi (2018). The effectiveness of research-based physics learning module with predict-observe-explain strategies to improve the student's competence. Journal of Physics: Conference Series, 1013: 12041. https://doi.org/10.1088/1742-6596/1013/1/012041

Varga O (2013). Critical analysis of assessment studies of the animal ethics review process. Animals, 3(3): 907-922. https://doi.org/10.3390/ani3030907 **PMid:26479540 PMCid:PMC4494455**

Walton RM (2001). Validation of laboratory tests and methods. Seminars in Avian and Exotic Pet Medicine, 10(2): 59-65. https://doi.org/10.1053/saep.2001.22053

Wijayaningputri AR, Widodo W, and Munasir M (2018). Effectiveness of guided-inquiry model to train science process skills of senior high school students. In the Proceedings of the Mathematics, Informatics, Science, and Education International Conference (MISEIC 2018), Atlantis Press, Yogyakarta, Indonesia: 59-63. https://doi.org/10.2991/miseic-18.2018.15

Willmot P and Perkin G (2015). Evaluating the effectiveness of a first year module designed to improve student engagement. Engineering Education, 6(2): 57-69. https://doi.org/10.11120/ened.2011.06020057

Yazon AD (2018). Validation and effectiveness of module in assessment of students learning. International Journal of Science and Research, 7(11): 1833-1836.