

Effectiveness of Laboratory Worksheet with Problem-Based Learning Approach for Enriching the Least-Learned Competencies in Life Science

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Abstract. The study aimed to address gaps in life science literacy by developing a laboratory worksheet tailored to the least learned competencies of students. A quasi-experimental design with a non-equivalent group approach was used, involving 21 students as the experimental group and 11 as the control group. A standardized test was initially administered to identify the students' least learned competencies, followed by creating a pretest and post-test questionnaire validated by experts. The laboratory worksheet was then developed based on these identified competencies and administered to the experimental group. Results indicated that the worksheet was highly effective, with the experimental group's proficiency level increasing from 30.00 to 69.68, more than double the initial score. Statistical analysis revealed a significant difference between the scores of the control and experimental groups, confirming the laboratory worksheet's efficacy in improving student proficiency in life science. The findings imply that targeted instructional materials, such as the developed worksheet, can significantly enhance learning outcomes, suggesting their broader application in educational settings to address specific competency gaps.

Keywords: Life science; Laboratory worksheet; Quasi-experimental design; Competencies, Proficiency level.

1.0 Introduction

Inclusive education ensures that no student is left behind and is a central objective of the K-12 primary education curriculum established by the Department of Education in the Philippines (De Jesus, 2019). Central to this objective is the idea that all learners should progress at their own pace, facilitated by diverse learning activities. Biology education shapes societal literacy by fostering an understanding of scientific concepts, ideas, and principles essential for informed citizenship (Delos Santos et al., 2021). However, delivering effective science education presents ongoing challenges, especially in equipping students with the core competencies necessary for global competitiveness and scientific literacy (Delos Santos et al., 2021).

In the context of the Philippine educational system, significant barriers hinder the effective teaching of science, particularly in public schools. These barriers include a shortage of science laboratories, insufficient laboratory materials, inadequate teacher training, and a lack of preparedness to ensure safety during laboratory experiments (Borja et al., 2020). These issues are exacerbated by the country's low performance in international assessments. For instance, the Programme for International Student Assessment (PISA) highlights a significant learning gap, with Filipino students scoring below the global average in science and mathematics, reflecting nearly a full academic year's deficit in learning (Azevedo et al., 2021; Kaffenberger et al., 2021). Furthermore, the Trends in

International Mathematics and Science Study (TIMSS) data reveal that many students fail to meet the minimum achievement benchmarks in these subjects, underscoring the urgent need for educational reforms (DiRanna et al., 2008). The challenges science education faces in the Philippines have been further compounded by the COVID-19 pandemic. During the 2020-2021 school year, there was a marked decline in support for science education, with only 60% of the usual supplemental instructional materials being provided (Holquist et al., 2020; Morrar, 2020). Many students, especially those in underprivileged areas, lacked access to essential resources such as reliable internet, technology, and instructional materials, which are critical for effective science learning (DiRanna et al., 2008).

In addition to these logistical challenges, the content and delivery of science education face significant issues. Appropriate textbooks and classroom resources are limited, and science teachers need better preparation and training. Moreover, there is resistance, often rooted in political and religious beliefs, to teaching certain scientific concepts, which further hampers the development of scientific literacy (Anderman et al., 2018). Specific topics within the biology curriculum, such as Mendelian genetics, the nervous system, and cellular processes like mitosis and meiosis, have been identified as particularly challenging for students (Delos Santos et al., 2021; Etobro & Fabiru, 2017). This is reflected in the consistently low scores in science on the National Achievement Tests (NAT), indicating a critical need for improved facilities, equipment, and teaching strategies (Bajana, 2019).

The K-12 curriculum in the Philippines is designed to present science concepts and skills in a spiral progression, where topics such as Life Science, Physics, Chemistry, and Earth Science are introduced at progressively higher levels of complexity (De Jesus, 2019). This approach aims to deepen students' understanding of core concepts over time. To achieve this, science teachers are encouraged to adopt varied teaching methods that actively engage learners and promote exploration and understanding (Dagang & De Mesa, 2017). However, achieving these educational goals requires more than just a well-structured curriculum; it also demands that students access the necessary instructional materials and laboratory experiences integral to learning (Eviota & Boyles, 2022). Laboratory work is vital in science education as it provides students with hands-on experience in observing and manipulating scientific materials, which is essential for developing a deeper understanding of scientific principles (Pareek, 2019). However, the availability of laboratory resources is often limited, particularly in public schools. Instructional materials facilitate effective teaching and enhance students' learning outcomes by engaging their interest, improving memory retention, and helping them apply theoretical knowledge to practical situations (Asrizal et al., 2019; Amos et al., 2022).

Constructivist learning models, which emphasize the active role of students in constructing knowledge through experience, have been shown to positively impact science learning (Tuerah, 2019). Problem-based learning (PBL), a constructivist approach that involves students in solving real-world problems, has gained widespread recognition for its effectiveness in promoting deep learning and critical thinking (Funa & Prudente, 2021). PBL encourages students to take responsibility for their learning, work collaboratively, and apply their knowledge to complex situations, preparing them for real-life challenges (Bispo et al., 2018). Given the critical role of laboratory work in science education and the demonstrated benefits of problem-based learning, this research aims to address the gaps in science education within the local context. Specifically, the study focuses on developing a laboratory worksheet as an intervention tool to support teaching the least-learned competencies in Life Science. The worksheet is designed to scaffold student learning by providing structured opportunities for inquiry and experimentation, aligned with the principles of problem-based learning. By addressing the inadequacies in laboratory resources and instructional materials, this research seeks to enhance students' understanding of key biological concepts and their ability to apply this knowledge in real-world contexts, thereby contributing to the overall goal of improving scientific literacy in the Philippines.

2.0 Methodology

2.1 Research Design

This study employed a quantitative quasi-experimental design utilizing a non-equivalent group pretest-posttest approach. The primary objective was to enhance the least-learned competencies in Grade 11 Life Science by implementing a laboratory worksheet incorporating a problem-based learning approach. Two participants were involved: the experimental group, which utilized the developed problem-based laboratory worksheet, and the

control group, which did not. Both groups were administered a pretest and a posttest to assess learning outcomes (Mertler & Charles, 2011; Bajana, 2019).

2.2 Research Participants

The participants comprised 32 Grade 11 Senior High School learners: 21 students (12 females and 9 males) as the experimental group and 11 students (7 females and 4 males) as the control group. The participants' ages ranged from 15 to 20 years. The selected participants represented the entire population of Grade 11 learners enrolled in the Earth and Life Science subject under the Technical-Vocational and Livelihood (TVL) Track curriculum. The participants were chosen to evaluate their current learning levels in Life Science and assess the potential improvement in proficiency resulting from the intervention. This study employed a purposive sampling technique. These students were enrolled in Earth and Life Science as part of their curriculum, necessitating assessing their basic skills in this subject area.

2.3 Research Instruments

Two primary research instruments were used. The Department of Education-Caraga Standardized Test Questionnaire and Table of Specifications were employed to identify the least-learned competencies. The experimental and control groups utilized the same test questionnaire, with item analysis conducted to determine these competencies. A validated and quality-assured 30-item test questionnaire was administered as the pretest and posttest for both groups. This questionnaire underwent validation using the Survey Instrument Validation Rating Scale. The test focused on competencies related to evolutionary processes and the concept of descent with modification, as specified in the curriculum (S11/12LT-IVfg-26).

The laboratory worksheet developed followed the 4A's Model of Learning – Activity, Analysis, Abstraction, and Application – integrated into all activities, serving as supplementary intervention material targeting the least-learned competencies. The data gathered were analyzed and interpreted accordingly.

2.4 Data Collection Procedures

Data collection commenced with obtaining permission from the respective school heads and securing informed consent from parents and students. The least-learned Earth and Life Science competencies for the school year 2022-2023 were identified using the DepEd Caraga 50-item Standardized Test and analyzed through item analysis. Upon validation, the laboratory worksheet was implemented with the Grade 11 learners. Both groups underwent pretesting and post-testing, with all collected data kept confidential and used solely for research purposes.

The students' proficiency levels were assessed using the criteria outlined in DepEd Order No. 31, s. 2012. Table 2 provides the proficiency levels, their corresponding numerical values, and verbal descriptions used to interpret the students' pretest and posttest scores. The proficiency levels ranged from "Beginning" (74% and below) to "Advanced" (90% and above), reflecting the students' abilities to understand and perform authentic tasks independently or with minimal assistance.

2.5 Statistical Analysis

The data collected from the test questionnaires were systematically tallied, tabulated, and organized. Descriptive statistics were used to analyze the students' scores and the laboratory worksheet's validation ratings, including frequency, mean, and percentage. An independent t-test was conducted to determine the statistical significance of the differences between the two groups' pretest and post-test scores.

3.0 Results and Discussion

3.1 Least-Learned Competencies of Grade 11 Life Science Students

Following the administration of the standardized test by DepEd Caraga, the scores of the two groups were compiled, and an item analysis was conducted to identify the least mastered competencies. The competencies are aligned with the K to 12 Basic Education Curriculum for Senior High School, specifically within Earth and Life Science as a core subject (Department of Education, K to 12 Basic Education Curriculum Senior High School – Core Subjects, 2016).

The pretest results revealed that the least mastered competencies primarily involve moderate and higher-order thinking skills, as indicated in Table 1. Seven competencies were identified as least learned, with a common challenge being the ability to explain how populations of organisms have changed and continue to change over time. This demonstrates patterns of descent with modification from common ancestors, which produce the diversity of organisms observed today (S11/12LT-IVfg-26). This competency will serve as the foundation for developing the laboratory worksheet.

Table 1. Least-learned competencies of Grade 11 Life Science students

	School A	School B
Least Learned Competencies, Code, Item Number	Explain how populations of organisms have changed and continue to change over time, showing patterns of descent with modification from common ancestors to produce the organismal diversity observed today. (S11/12LT-IVfg-26) (Item #41, MOTS)	Explain how populations of organisms have changed and continue to change over time, showing patterns of descent with modification from common ancestors to produce the organismal diversity observed today. (S11/12LT-IVfg-26) (Item #39, MOTS)
	Describe the general and unique characteristics of the different organ systems in representative animals. (S11/12LT-IIIaj-21)	Describe the process of genetic engineering. (S11-12LT-IIIej-17)
	Describe how unifying themes (e.g., structure and function, evolution, and ecosystems) in the study of life show the connections among living things and how they interact with each other and their environment. (S1112LT-Iia-3)	Describe how the present system of classification of organisms is based on evolutionary relationships. (S11/12LT-IVfg-27)
	Explain the evolving concept of life based on emerging pieces of evidence. (S11-12LT-Iia-1)	Categorize the different biotic potential and environmental resistance (e.g., diseases, availability of food, and predators) that affect population explosion)

According to Bloom's taxonomy (Krathwohl et al., 1964), moderate and higher-order thinking skills require learners to apply knowledge, solve problems, identify connections, make inferences, and find evidence to support generalizations. Developing higher-order thinking skills enables students to enhance their ability to construct structures or patterns and critically evaluate information and its validity. Addressing the learners' needs in these areas will foster the development of their cognitive skills and potentially improve their proficiency in the subject matter. Furthermore, transferring learning to new contexts by explaining concepts consistent with firsthand information provided by the teacher is a crucial lifelong learning skill (Ichsan, 2019).

Learning life sciences emphasizes an educational approach that prioritizes methodical and logical thinking. The development of 21st-century biology education should focus on understanding fundamental concepts and fostering analysis and critical thinking skills. Ideally, all life sciences topics and materials should cultivate these aspects (Song, 2016). However, challenges arise as reports indicate that teachers often concentrate on lower-order thinking skills in science education (Rahman, 2018). Therefore, teachers must design assessments that promote higher-order thinking skills. Such assessments and instructional materials should enhance students' critical thinking, problem-solving, metacognition, communication, collaboration, information literacy, and creative innovation abilities. The importance of assessment in fostering these skills cannot be overstated (Van Der Zanden et al., 2020). Teachers can effectively support skill development by crafting assessments that engage students in these higher-order thinking processes (Heyck-Williams, 2017; McCormick et al., 2015; Ferlazzo, 2021b).

It is essential to recognize the challenge highlighted by reports showing that teachers often prioritize lower-order thinking skills in science education (Idulog et al., 2023). This highlights the need for a pedagogical shift towards a more balanced focus on higher-order thinking skills (Kim et al., 2019; Cappiali, 2023). By integrating assessments and instructional materials that target these skills, educators can create learning environments that effectively develop students' abilities to analyze, evaluate, and synthesize information (Liu et al., 2023; Azid, 2022). This approach enhances students' mastery of the subject matter and equips them with the essential lifelong learning skills needed for success in the 21st century.

3.2 Assessment of the Effectiveness of the Laboratory Worksheet Developed

The effectiveness of the laboratory activity is determined by how accurately the assessment tool reflects students' learning outcomes. This process allowed the researcher to review and make necessary revisions to various aspects of the laboratory worksheet, including its content, format, presentation, organization, accuracy, and relevance.

The laboratory worksheet was quality assured by Department of Education Order No. 018, s. 2020 (Department of Education, 2020) and the guidelines outlined in the Department of Education's "Guidelines and Processes for LRMDs Assessment and Evaluation" (2009), using Enclosure 1 by the Master Teachers responsible for science subjects. The summary table of the evaluation ratings for the laboratory worksheet includes the areas of assessment, mean scores, and verbal descriptions, all of which indicate that the assessment areas are rated as very satisfactory (Table 2).

Table 2. Summary of the evaluation rating of the laboratory worksheet in four areas of assessment

Area of Assessment	Mean	Verbal Description
1. Content	4.0	Very Satisfactory
2. Format	3.9	Very Satisfactory
3. Presentation and Organization	4.0	Very Satisfactory
4. Accuracy and up-to-datedness	3.9	Very Satisfactory
MEAN	3.95	Very Satisfactory

Content

Science educators have long emphasized the numerous benefits of involving students in laboratory activities. These activities have traditionally occupied a central and essential role in the science curriculum (Dori et al., 2006; Hofstein, 2004). Therefore, it is critical to design instructional materials and assessments that align with students' needs and meet the objectives or learning competencies of the subject matter. The results in Table 2 reflect the laboratory worksheet's content evaluation. The overall score of 4.0 indicates that the worksheet's content is rated as very satisfactory, according to the guidelines established by the Department of Education Order No. 018, s. 2020, and the Department of Education's Guidelines and Processes for LRMDs Assessment and Evaluation, 2009, using Enclosure 1.

Two significant factors impede students' ability to achieve a deep understanding of the subject. First, students often spend excessive time verifying the correctness of their answers. Second, the design of the laboratory activity sheets tends to promote only lower-order thinking skills. The content of the activities is a crucial tool for formative assessment (Andrade & Zuin, 2023). Given these considerations, it is noteworthy that the laboratory worksheet's content is rated very satisfactory, suggesting that the assessment objectives, associated learning competencies, and higher-order thinking skills are effectively addressed. This implies that the content appropriately evaluates learning outcomes and aligns with the holistic assessment process emphasized in DO No. 31, s. 2012, Section H (Department of Education, 2012), which underscores the developmental purpose of student learning. The content of the laboratory worksheet is essential for understanding students' learning levels and identifying potential interventions to enhance their learning. A problem-based learning approach catalyzes students to develop and acquire higher-order thinking skills (Ali, 2019).

Format

The structure of the laboratory worksheet was also evaluated in terms of formatting, including print quality, illustrations, design and layout, and paper and binding. Proper formatting is crucial as it significantly influences the reader's perception and comprehension of a document's content. Effective formatting involves dividing the material into sections with appropriate headings, emphasizing key ideas through bold or italicized text, and ensuring a polished appearance with a suitable font (Wahlin, 2023). The laboratory worksheet received an overall formatting score of 3.94, indicating that the printing, illustrations, design, layout, and paper binding are appropriate for student use. Worksheets should be easily accessible to students and designed with low reading difficulty. Initial questions should cater to students with lower reading abilities, with subsequent questions progressively increasing in complexity. Proper control of material organization, syntax, word and sentence length, word frequency, typeface, and line spacing can improve student engagement and on-task behavior during activities (Lee, 2016).

Presentation and Organization

Effective communication of ideas and content requires well-organized and structured presentation skills, which are vital across all fields. A well-presented idea or content facilitates the creation of learning materials that are both comprehensible and engaging for students (Swathi, 2015). The laboratory worksheet achieved an average

score 4.0 for presentation and organization, indicating a very satisfactory rating. This suggests that the worksheet is well-presented and organized in an engaging, understandable, and comprehensive manner for students. The relationship between worksheet use and science achievement is consistent regardless of students' reading abilities when teachers carefully manage content elements, use readability algorithms to reduce reading load, or provide oral explanations of worksheet terms (Lee, 2014).

In the context of online learning, it is increasingly important to design instructional materials that are accessible across various platforms. Well-organized instructional materials enhance content understanding and improve lessons or competencies delivery. Notably, 56% of online college students use smartphones or tablets for at least some course-related activities (Clinefelter et al., 2019). The quality of teaching is also reflected in the use of instructional materials, including textbooks and publisher-provided resources, as well as the adaptation of materials to meet specific student needs. Teachers may also develop their instructional materials when existing resources do not align with students' cultural experiences or educational requirements (Sowers & Rahim, 2019).

Accuracy and Currency

The accuracy and currency of learning materials are crucial for effectively delivering and presenting learning objectives. The laboratory worksheet received an average score of 3.94, with a very satisfactory rating for accuracy and up to date (Table 2). This indicates that the worksheet is accurate regarding its concepts, syntax, and facts. Textbooks must contain up-to-date information to remain relevant. The currency of textbooks can be determined by examining the publication dates of the literature referenced. Staying current with relevant literature is essential for understanding developments in each discipline (Afidah et al., 2023).

The results further suggest that the laboratory worksheet includes content relevant to the least learned competencies, leading to a high composite mean reflecting the educational materials' quality. Using established worksheets, visual aids, and text styles allows effective teaching beyond conventional classroom delivery methods (Buniel & Monding, 2021). Worksheets foster positive classroom engagement and demonstrate cognitive benefits related to student motivation and retention (Estacio, 2015). Incorporating competencies that address the least learned skills provides teachers with a valuable tool for effectively communicating subject matter and enhancing the teaching and learning process.

The evaluation results in terms of content, format, presentation and organization, and accuracy and currency indicate that the laboratory worksheet is rated overall as very satisfactory. This implies that the laboratory worksheet is effective according to these criteria. As a teaching support material, the worksheet reflects the role of teachers in fostering student growth and providing a facilitative mechanism that encourages students to exceed their current capabilities. It motivates learners to fully engage with the activities and achieve the desired learning objectives (Torrefranca et al., 2017).

3.3 Proficiency Level of Students After Using the Laboratory Worksheets

Performance requirements that integrate science procedures, cross-cutting concepts, and core subject knowledge are essential for defining proficiency in science. These definitions of scientific understanding and practice pose challenges for assessment design and implementation, both at the systemic level for monitoring the advancement of scientific education and at the instructional level within classrooms (Pellegrino, 2019).

Two groups of students were assessed to evaluate the improvement in student proficiency. As illustrated in Table 3, the experimental group demonstrated a notable increase in proficiency. The scores on the pretest and posttest indicate a twofold improvement, rising from 30.00% to 69.68%. The posttest, which utilized the laboratory worksheet, likely contributed to this significant increase in proficiency. Although this level of proficiency remains below the criteria set by the Department of Education (2012) for student proficiency levels, the observed improvement is substantial. This is attributed to the use of laboratory worksheets. According to Pellegrino (2019), effective assessment implementation should involve valid, useful, and applicable tools and be integrated into the pedagogical process to enhance educational outcomes.

Table 3. Pretest and posttest scores of the control and experimental groups

Descriptive statistics	Control		Experimental	
	Pre-test	Post-test	Pre-test	Post-test
Mean	7.91	7.46	9.00	20.91
SD	2.39	1.64	3.15	4.68
Min	4.00	5.00	2.00	11.00
Max	11.00	10.00	16.00	28.00
Proficiency level (%)	26.4	24.8	30.00	69.68

One of the challenges highlighted by (Pellegrino, 2019) is the design and use of valid and reliable assessments in reflecting the integration of practices and core ideas in science. This challenge can be met by using evidence- and data-based assessment tools so that students can construct the integrated knowledge that problem-based learning approach integrated assessments can attain (Ali, 2019). Statistical results in Table 3 revealed that the experimental group significantly differed ($p < 0.05$) from the control group, which did not use the instrument. This notable significant difference leads to the conclusion that the effectiveness of the learning material used is evident.

Table 4. Analysis of the difference in pretest and post-test scores of the control and experimental group

Groups	Mean	Std. Deviation	Min	Max	p-value	Remark
Control	7.46	1.64	5	10	0.000	Significant
Experimental	20.9	4.68	11	28		

Tested at 0.05 level of significance using an independent t-test

These results support the conclusion that the learning material is effective and may have contributed to the increased proficiency observed in the experimental group, in contrast to the control group, which exhibited a decline in proficiency, as shown in Table 4. Using instructional materials has been shown to improve student learning outcomes to a degree equal to or greater than other interventions. Effective and high-quality instructional materials enhance classroom organization and enable students to achieve substantial learning gains over a relatively short period. Such materials provide a clearer understanding of the subject matter, aligning with the curriculum's objectives and fostering a deeper comprehension of the standards the subject area aims to meet (Allan & Leifer, 2023). Well-designed inquiry-based tasks in science textbooks are particularly important for supporting students' engagement with scientific inquiry and developing their understanding of scientific concepts (Liu & Yang, 2016; Acosta, 2020). The results indicate that the developed Laboratory Worksheet is effective in content, format, presentation and organization, accuracy, and up-to-date. The study participants' post-test scores improved, demonstrating the material's effectiveness in fulfilling its intended purpose. This improvement in student proficiency suggests that well-crafted instructional materials can significantly enhance understanding of the subject matter and better align with the curriculum's goals (Tseng et al., 2022).

4.0 Conclusion

In conclusion, this study highlights the significant impact of well-developed laboratory worksheets on student proficiency, particularly in moderate and higher-order thinking skills. The results indicate that these worksheets were evaluated positively in content, format, presentation, and accuracy – scoring between 3.94 and 4.0 – this notes that the crafted worksheets effectively enhanced the student learning outcomes and supports the effectiveness of the problem-based learning approach and the quality of the instructional materials. Furthermore, the observed increase in student proficiency, with posttest scores rising from 30.00% to 69.68%, underscores the effectiveness of the worksheets in fostering deeper understanding and skills development. Future research could explore the long-term impacts of such instructional materials on student learning and proficiency across different subjects and educational settings. Additionally, investigating the integration of similar worksheets in diverse learning environments could provide further insights into their broader applicability and effectiveness.

5.0 Contribution of Authors

The authors confirmed equal contributions in each part of this work and reviewed and approved the final version.

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7.0 Conflict of Interest

The author declares that they have no conflicts of interest.

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