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Development and Validation of Microbiology and Parasitology Laboratory Manual for Science Education

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ABSTRACT

Purpose of the study: This study aimed to develop and validate a Microbiology and Parasitology Laboratory Manual specifically designed for Science Education students, in alignment with the Commission on Higher Education (CHED) Memorandum Order No. 75, series of 2017. The manual seeks to bridge theoretical knowledge with practical application through structured, inquiry-based laboratory activities that cultivate scientific skills, promote critical thinking, and reinforce adherence to laboratory safety protocols.

Methodology: The validation process was conducted in two phases. First, subject matter experts in microbiology, parasitology, and science education evaluated the manual based on content accuracy, instructional clarity, relevance, alignment with CHED competencies, and pedagogical soundness. Their feedback was systematically integrated to enhance the manual's quality. Second, pilot testing was conducted with science education students to assess usability, engagement, and impact on learning outcomes. Data were collected through expert validation checklists, student perception surveys, and performance assessments during laboratory sessions.

Main Findings: Findings revealed that the manual was highly satisfactory across all validation criteria. Quantitative and qualitative results from pilot implementation demonstrated significant improvements in students' comprehension of microbiological and parasitological concepts, laboratory competencies, and overall engagement.

Novelty/Originality of this study: This study offers a discipline-specific, standards-aligned laboratory manual developed for teacher preparation, filling a critical gap in localized instructional materials. It emphasizes not only scientific content but also the pedagogical approaches needed for future educators, contributing to quality enhancement in science teacher education.

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1. INTRODUCTION

The development of a comprehensive laboratory manual is essential in enhancing the quality of science education in the Philippine Higher Education Institutions. Laboratory activities play a critical role in fostering experiential learning, promoting scientific inquiry, and developing students' analytical and technical skills. As prescribed by the Commission on Higher Education (CHED) through Circular Memorandum Order (CMO) Number 75, series of 2017, the formulation of standardized laboratory manuals ensures the alignment of instructional materials with national educational standards, thus fostering uniformity, quality assurance, and academic excellence [1]. CHED CMO No. 75, series of 2017, emphasizes the need for institutions to adopt

standardized instructional materials to guarantee consistency and coherence in delivering laboratory-based courses [2]. This mandate seeks to address the growing demand for quality education by establishing clear guidelines on laboratory instruction and assessment. Through the development of laboratory manuals aligned with CHED standards, educators can provide students with structured and comprehensive learning experiences that bridge theoretical concepts with practical applications.

In the ever-evolving landscape of higher education, particularly in the sciences, the role of well-structured, pedagogically sound laboratory manuals is increasingly vital in cultivating student engagement and scientific literacy [3]. Laboratory experiences in microbiology and parasitology provide learners with practical insights into theoretical concepts, fostering inquiry-based thinking and diagnostic reasoning essential for future scientific and healthcare professionals [4]. Despite their significance, many institutions in the Philippines, including the Central Bicol State University of Agriculture (CBSUA), still rely on fragmented or outdated laboratory resources that do not align with current pedagogical frameworks or contextual realities [5].

A well-designed laboratory manual not only serves as a guide for conducting experiments but also enhances the learning process by clearly outlining objectives, methodologies, safety protocols, and assessment criteria. It fosters independent learning and critical thinking by encouraging students to engage with scientific problems systematically. Furthermore, it ensures that laboratory activities are conducted in a safe, effective, and educationally sound manner. The development of a localized and validated laboratory manual offers a pragmatic approach to address the gaps in science education by integrating contextual learning, biosafety, and cultural relevance [6]. As CBSUA is rooted in an agricultural context, its science curriculum should reflect both academic rigor and community relevance. Educational resources, particularly laboratory manuals, must be aligned with national standards such as CHED CMO No. 75 s.2017 and international best practices to ensure both compliance and innovation [7]. Recent studies emphasize the importance of constructivist learning designs in laboratory manuals, where students are not passive recipients but active participants in the scientific process [8]. Moreover, the application of scientific process skills—observation, classification, inference, and experimentation—is significantly enhanced when instructional materials are validated through expert input and student feedback [9]. The design of such manuals should also consider cognitive load theory and differentiated instruction to cater to diverse learning styles [10].

In response to CHED CMO No. 75, series of 2017, this laboratory manual is designed to meet the prescribed guidelines while addressing the specific needs of both educators and students. It aims to provide a robust framework for laboratory instruction that supports learning outcomes and prepares students for real-world scientific challenges. Adhering to national educational policies, this manual contributes to the continuous improvement of science education and aligns with the broader goal of producing competent and innovative graduates equipped with the necessary skills for professional practice. This study looked into the laboratory activity manual which may be developed as prescribed by the course description under CMO 75 series of 2017; the evaluation of the experts of the manual along; content validity, context validity, and usability. Lastly extension program which may be developed in adherence to the CMO 75 series of 2017 for science education.

The development and validation of a Microbiology and Parasitology laboratory manual is crucial in enhancing science education, particularly for health science students. Such manuals provide structured, hands-on experiences that reinforce theoretical knowledge and develop essential laboratory skills. The “Laboratory Manual in Microbiology and Parasitology for Allied Medical Courses” by Bognot et al, serves as a comprehensive guide for students in allied medical fields, offering practical exercises aligned with their curriculum [11]. Validation ensures content accuracy, pedagogical soundness, and practical usability. Several frameworks advocate for multi-phase validation involving content experts, target users, and iterative revision cycles [12]. Particularly in the biological sciences, validation extends beyond content to include safety protocols, ethical considerations, and alignment with laboratory competencies [13]. Furthermore, integration of agricultural and environmental contexts in microbiology and parasitology manuals adds layers of relevance and interdisciplinarity, crucial for students in agricultural universities [14].

In the Philippine setting, the Department of Education (DepEd) and Commission on Higher Education (CHED) have consistently called for the development of localized instructional materials that reflect Filipino realities and scientific advancements [15]. Yet, there remains a paucity of locally developed laboratory manuals tailored to the unique learning environments and ecological concerns of agricultural universities such as CBSUA [16]. Moreover, the COVID-19 pandemic further amplified the need for flexible, validated, and accessible laboratory manuals that can support hybrid and remote learning environments [17]. This shift calls for manuals that are not only scientifically sound but also adaptable to various modalities of delivery, including virtual labs and simulated experiments [18].

As educational paradigms shift towards student-centered frameworks and competency-based outcomes, instructional materials such as laboratory manuals must evolve to become tools of empowerment rather than mere procedural guides [19]. This study, therefore, aims to develop and validate a Microbiology and Parasitology Laboratory Manual specifically designed for the science education program of CBSUA. It seeks to fill the gap in contextualized, research-informed laboratory instruction and contribute to the enhancement of

science pedagogy in the Philippines. Similarly, the "Microbiology and Parasitology: Laboratory Manual for the Health Science" by Ho, Roldan-Gan, and Verbo is tailored for health science students, focusing on diagnostic techniques and the identification of pathogenic microorganisms and parasites [20]. Incorporating student feedback into the design and revision of these manuals enhances their effectiveness. Petersen and McLaughlin emphasized the importance of utilizing student input to create an open-educational resource microbiology lab manual, resulting in materials that are both cost-effective and tailored to student needs [21].

The validation process of these manuals often involves assessing their impact on student learning outcomes. Wright and Harding, developed an electronic guide for introductory microbiology skills, demonstrating that students who used the guide showed significant improvement in laboratory skills and theoretical understanding [22]. The continuous development and validation of laboratory manuals in microbiology and parasitology are essential for providing effective science education, ensuring that students acquire the practical competencies necessary for their future professional endeavors.

2. RESEARCH METHOD

Descriptive-evaluative research design used with qualitative method were significantly being utilized in the study. It used to gather feedback and validate the effectiveness, clarity, and appropriateness of the manual. Descriptive analysis through Max Qualitative Data Miner was utilized to interpret experts' evaluations. Themes and codes were highlighted to reveal the content, context, and usability of the manual [23], highlighted that using Max QDA generates a reliable and valid codings of the nested data. Five (5) experts from various fields aligned with biology were able to evaluate the manual's validity and usability fit to be used by science education students under the teacher education program following the CHED CMO 75 series of 2017. Total enumeration sampling was used for the college of teacher education which serves as the main program for this investigation with more than one-hundred fifty (150) science major students from first year to fourth year. Purposive sampling was used for the faculty with specialization in science education with specific number was composed of ten (10), the seven (7) of theme has a doctorate degree while three (3) of them are pursuing a doctorate with relevant masters' degree in the field of science.

Aside from the college syllabus and the CMO used in the prescribed program, data collection and data analysis used in the study were the primary and secondary data. Primary data used in the study were the in-service and pre-service reponses and the administrators within the local of the study while the secondary data used are the documents from the records of the college as associated with the desired objectives of the problem interest. A thorough validation for its content and context reliability and ethical considerations were followed in order to arrived at the desired output of the study.

For the data collection, the study employs a evaluative research design following the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Using this model, it can make the systematic approach sure that everything falls within a rational and planned strategy, or set of strategies, that has the ultimate goal of reaching the project's targets [24]. It integrates qualitative data collection methods during the development and validation phases of the laboratory manual. Interview and focus group discussions were implemented by the researcher in order to obtain the desired valid and reliable outcomes of the study. Cronbach's alpha value in this study was applied for the internal consistency reliability of a measurement for the instrument used. A reliability value of 0.7012 was noted revealing that the values above 0.70 are considered acceptable, and higher values indicate stronger internal consistency. Therefore, the instrument used in the study is acceptable, valid, and reliable to be used.

3. RESULTS AND DISCUSSION

3.1. Laboratory Activity Manual Developed as Prescribed by the Course Description under CMO 75 Series of 2017

The importance of following CHED Memorandum Order (CMO) No. 75 series of 2017 in developing a laboratory manual for science education lies in ensuring standardization, quality, and relevance in higher education programs. This CMO outlines the *Policies, Standards and Guidelines (PSGs)* for Bachelor of Science in Biology, emphasizing the integration of outcomes-based education (OBE), learner-centered pedagogy, and research-based content. Adhering to CMO 75 s. 2017 ensures that laboratory activities are aligned with core competencies, such as scientific inquiry, critical thinking, and ethical responsibility skills that are essential for scientific literacy and global competitiveness [1]. Furthermore, the framework fosters consistency in curricular offerings across institutions, allowing for seamless academic progression and transferability. Studies have shown that well-designed laboratory manuals that align with national standards significantly improve student engagement and comprehension [25]. Therefore, utilizing CMO 75 s. 2017 as a foundational guide in developing laboratory manuals supports both instructional effectiveness and the long-term goals of Philippine science education reform.

The Laboratory Manual of Microbiology and Parasitology, is a comprehensive guide that is designed to provide tertiary students, researchers, and education science specialization with essential knowledge and hands-on experience in the captivating world of microbiology and parasitology. Philosophical Foundations of Microbiology and Parasitology in Science Education enhances the students' ability to connect the ideas to the root of science education application in teaching laboratory subjects. The manual is exploring the microbiology and parasitology context for education students, it seeks to understand the foundation and content of science teaching. It reveals context from the tiniest bacteria to complex fungi and viruses, into their structure, function, and significance in various ecosystems. Understanding the basics of microbiology is crucial as it forms the foundation for advanced studies and practical applications. Culturing techniques and aseptic practices like aseptic techniques are the backbone of microbiological research and diagnostic procedures. It covers various culturing techniques, media preparation, and the principles of maintaining sterile conditions in the laboratory. Mastering these skills is vital for accurate experimentation and analysis. Identification of Microorganisms identifying microorganisms is like solving a puzzle. It introduces to the methods used to identify different types of bacteria, fungi, and viruses based on their morphological, biochemical, and genetic characteristics. Learning how to differentiate between species, aiding in disease diagnosis and epidemiological studies.

Parasitology, parasites are remarkable organisms that thrive at the expense of their hosts. In this part of the manual, it explores various parasitic organisms, including protozoa, helminths, and arthropods. Understanding their life cycles, transmission routes, and the diseases they cause is crucial for effective diagnosis, treatment, and prevention. Research Projects and Case Studies which will reinforce your understanding and critical thinking skills, we present research projects and case studies related to microbiology and parasitology. These practical exercises offer hands-on experience in designing experiments, analyzing data, and drawing meaningful conclusions.

The created manual is titled Exploring The Microcosm: A Laboratory Manual To Microbiology And Parasitology For Science Education Program focusing and adherence to the CHED-CMO 75 series of 2017, a policies, standards and guidelines for Bachelor of Secondary Education (BSEd) in the Philippine tertiary education.

Table 1. Components and Themes of the Laboratory Manual in Microbiology and Parasitology

Components	Themes
Laboratory 1 : Drawing of Essential Laboratory Apparatuses	-Focus on the most commonly used equipment (these are given in the manual like: beakers, test tubes, flasks, Bunsen burner). -Arrange the apparatuses in a realistic lab setting. -Draw equipment used for accurate measurements -Include detailed labels showcasing measurement scales.
Laboratory 2 : Hay Infusion Laboratory	-Identification of bacteria, protozoa, and fungi in hay infusion - Succession of microbial communities over time -Effects of nutrient availability on microbial growth -Competition and symbiosis among microorganisms
Laboratory 3 : Bread Molds Laboratory	-Identifying and classifying different types of molds that grow on bread (e.g., *Rhizopus stolonifer*, *Penicillium*, *Aspergillus*). -Investigating how temperature, humidity, light, and storage conditions influence mold development. -Examining the stages of mold growth from spore germination to mycelium formation.
Labotarory 4 : Bacterial Growth in Nutrient Agar	- Influence of temperature, pH, and incubation time -Nutrient composition and availability -Oxygen requirements (aerobic vs. anaerobic growth) - Moisture and environmental conditions
Laboratory 5 : Bacterial Isolation Technique	-Comparison of Different Bacterial Isolation Techniques (e.g., Streak Plate, Spread Plate, Pour Plate) -Optimization of Culture Media for Efficient Bacterial Isolation - Innovations in Bacterial Isolation Techniques for Fastidious Microorganisms

Components	Themes
Laboratory 6 : Special Topic in Parasitology	- Enhancing Laboratory Skills Through Hands-On Bacterial Isolation -Advances in molecular diagnostics for parasitic infections -Genetic diversity and evolution of parasites - Socioeconomic impacts of parasitic diseases -Parasitic infections in marginalized and developing regions -Global initiatives and policies for parasitic disease control
Laboratory 7 : Case Study Presentation	-Presentation of the case study for publication

3.2 Content validity of the manual for microbiology and parasitology for science education

Content validity in this study refers to the degree to which an instrument, in this case the laboratory manual, accurately represents the subject matter and includes all necessary topics and skills relevant to the field. For the "Microbiology and Parasitology Laboratory Manual for Science Education," content validity ensures that the manual aligns with the required competencies and learning outcomes outlined in the Commission on Higher Education (CHED) CMO No. 75 series of 2017. To establish content validity, the manual underwent a rigorous development and evaluation process. First, the content was carefully curated based on the prescribed curriculum standards and best practices in microbiology and parasitology education. Each laboratory activity was designed to reflect essential concepts, techniques, and analytical skills necessary for science education students. Furthermore, the manual was cross-referenced with relevant textbooks, peer-reviewed journals, and established laboratory protocols to ensure comprehensiveness and accuracy. A panel of subject matter experts (SMEs) in microbiology, parasitology, and science education was consulted to review the manual. These experts evaluated the alignment of the content with the CHED standards, the clarity of instructions, the appropriateness of laboratory exercises, and the relevance of assessment tools. Their feedback was instrumental in refining the manual to address gaps, improve clarity, and enhance the overall instructional quality.

The content validity process also included pilot testing the manual with a group of science education students. This allowed for the assessment of practical implementation, student engagement, and the manual's effectiveness in achieving learning outcomes. Data collected from the pilot study, including student feedback and performance, provided empirical support for the manual's validity and usability. The results of the expert evaluation and pilot testing indicated a high degree of content validity. The manual effectively covers key areas in microbiology and parasitology, including laboratory safety, specimen handling, microbial identification, and parasitological analysis. It also emphasizes critical thinking, scientific inquiry, and procedural accuracy, which are vital for future educators.

Table 2. Key Indicators of Content Validity for a Laboratory Manual

Indicators	Concentration
Alignment with Curriculum Standards	-Consistency with CHED CMO 75 series of 2017 and other regulatory frameworks. -Inclusion of essential topics and competencies outlined in the curriculum.
Coverage of Learning Objectives	-Clear alignment between manual content and specific course learning outcomes. -Each experiment or activity addresses defined educational goals.
Accuracy and Scientific Rigor	- Use of correct terminologies, processes, and concepts.
Clarity and Comprehensibility	- Clear, concise, and understandable instructions. - Logical sequence of experiments, with step-by-step procedures.
Depth and Breadth of Content	-Sufficient scope to cover fundamental and advanced topics. -Balanced inclusion of theoretical background and practical applications.
Assessment and Evaluation Components	-Inclusion of formative (e.g., questions after each experiment) and summative assessments. -Clear rubrics for grading laboratory outputs and performance.
Safety and Ethical Considerations	-Clear guidelines on laboratory safety protocols. -Ethical use of specimens and responsible handling of

Indicators	Concentration
	materials. -Input from subject-matter experts to ensure accuracy.
Expert Review and Validation	-Pilot testing with students to identify gaps or areas for improvement.

3.3 Context validity of the manual for microbiology and parasitology for science education

Context validity in this study refers to the degree to which the content of an educational material aligns with the intended curriculum, learning outcomes, and the real-world application of knowledge and skills. In the development of the *Microbiology and Parasitology Laboratory Manual for Science Education*, ensuring context validity is crucial to provide students with a learning resource that reflects both academic standards and practical competencies. The manual was meticulously designed in alignment with the Commission on Higher Education (CHED) Memorandum Order (CMO) No. 75, series of 2017, which outlines the policies, standards, and guidelines for microbiology and parasitology courses. This alignment ensures that the content covers the required topics, including the fundamental principles of microbiology and parasitology, laboratory techniques, and the proper handling of biological specimens. Adhering to these guidelines, the manual supports the achievement of the prescribed learning outcomes and competencies for science education students.

To establish context validity, the manual was subjected to a rigorous validation process involving subject matter experts, including microbiologists, parasitologists, and science education faculty members. Their expertise ensured that the manual accurately reflects current scientific knowledge, laboratory practices, and pedagogical approaches. Feedback from these experts resulted in refinements to the manual, enhancing the clarity of instructions, the accuracy of scientific information, and the appropriateness of laboratory exercises. In addition to expert validation, the manual underwent pilot testing with a sample of science education students. This phase provided valuable insights into the manual's usability, comprehensibility, and relevance to real-world laboratory applications. Student feedback highlighted areas for improvement, such as the need for clearer procedural steps and additional contextual explanations, which were subsequently addressed to ensure alignment with their learning needs.

The manual incorporates practical scenarios and problem-based learning activities that bridge theoretical knowledge with hands-on experience. This approach enhances students' ability to apply microbiological and parasitological concepts in real-world contexts, such as public health and environmental monitoring. Including case studies and inquiry-based experiments reinforces critical thinking and problem-solving skills, which are essential for future educators and researchers.

3.4 Usability of the manual for microbiology and parasitology for science education

The usability of the developed Microbiology and Parasitology laboratory manual is a critical aspect in ensuring its effectiveness in facilitating learning and enhancing student engagement in a teacher education institution in the Philippines. This section discusses the manual's practicality, ease of use, alignment with learning outcomes, and its contribution to science education. Abayomi, Michael, and Nwadioha, published works in medical microbiology and parasitology which highlights the safety and specimens, and microscopy to control and provides the scientific and administrative direction of a clinical microbiology [26]. For this study, it focuses on science education core program outcomes which assures that the manual must be in adherence with the policies, standards, and guidelines set forth for the program by CHED.

The usability of a laboratory manual in microbiology and parasitology is critical to enhancing student learning, engagement, and competency in science education. A well-structured manual provides clear instructions, aligns with curricular goals, and supports active, inquiry-based learning, which facilitates deeper understanding of complex biological processes [27]. In the context of science education, manuals that are user-friendly and pedagogically sound have been shown to improve students' practical skills, laboratory safety awareness, and confidence in conducting experiments [28]. Furthermore, the integration of visual aids, formative assessments, and contextualized laboratory activities tailored to learners' backgrounds enhances accessibility and effectiveness [29].Usability also encompasses the manual's adaptability to various instructional settings and its alignment with competency-based outcomes outlined in national frameworks such as CHED CMO 75, series of 2017 in the Philippines.

3.4.1 Practicality and Accessibility

The laboratory manual was designed with consideration for the available resources and laboratory settings in educational institutions. It provides clear instructions, readily available materials, and step-by-step procedures that are feasible within the typical laboratory environment. This approach ensures that the manual is adaptable to varying levels of institutional resources. Additionally, the manual incorporates alternative procedures when specific laboratory equipment is unavailable, enhancing its accessibility across diverse educational contexts.

The University of Toronto, through the teaching assistants' training program revealed that the University of Toronto has a stated commitment to "fostering academic community in which the learning and scholarship of every member may flourish, with vigilant protection for individual human rights, and a resolute commitment to the principles of equal opportunity, equity and justice [30], [31].

3.4.2 Ease of Use and User-Friendliness

The manual follows a structured and consistent format, including learning objectives, materials needed, safety guidelines, detailed procedures, and assessment questions. This systematic approach aids both students and instructors by providing a clear and organized workflow. The use of diagrams and images enhances comprehension of complex processes, while concise language ensures clarity. Feedback from pilot implementation indicates that students found the manual easy to navigate and understand, minimizing the need for extensive instructor intervention. The ease of use and user-friendliness of a science manual are critical to enhancing student engagement and learning outcomes, particularly in laboratory settings where clarity and accessibility directly impact task execution and comprehension. A well-designed manual should feature clear instructions, logically sequenced procedures, and visual aids that support independent learning and reduce cognitive overload [32]. Studies have shown that user-friendly educational materials contribute to improved student confidence and accuracy in performing laboratory tasks, especially when aligned with students' cognitive and experiential levels [29]. Moreover, incorporating inquiry-based and interactive elements within the manual further supports student-centered learning and knowledge retention (Banchi & Bell, 2008), making the manual not just a guide, but a learning tool in itself.

Tukiainen, Saqr, and Deriba, revealed that accessing the accessibility of the lab environment is essential to make sure all students are served equally. Their ability to offer superior practical learning experiences compared to traditional laboratory [33]-[35]. In this part, all users must be able to understand and easily utilized the manual and the operations on how it should be use.

3.4.3 Alignment with Learning Outcomes

The manual aligns closely with the competencies outlined in CHED CMO 75 series of 2017, ensuring that students acquire the necessary theoretical knowledge and practical skills in Microbiology and Parasitology. Each laboratory exercise is designed to reinforce key concepts through hands-on practice, bridging the gap between theoretical lectures and practical applications. The integration of inquiry-based activities promotes critical thinking and scientific inquiry, fostering a deeper understanding of microbial and parasitological processes.

According to teaching excellence and innovation report of the Wilfrid Laurier University, courses do not exist in isolation and considering your course's outcomes and assessment from a programmatic perspective is very beneficial in ensuring that students progress appropriately through the program and achieve the skills and knowledge that are necessary in the appropriate sequence [37]. The University of New South Wales on their teaching reports, they have mentioned that learning outcomes are framed well in advance of detailed assessment plans – for example, to accord with professional-accreditation requirements [38]. Then, when the assessment plan is being developed, it becomes clear that the approved learning outcomes were framed poorly, it is too late to change the outcomes, and uncomfortable compromises have to be made.

3.4.5 Effectiveness in Enhancing Learning

The manual's design emphasizes active learning through experiential activities. Preliminary evaluations and user feedback highlight improved student engagement and better comprehension of complex microbiological and parasitological principles. Students reported increased confidence in conducting laboratory procedures and analyzing results. Instructors noted a reduction in preparation time due to the manual's comprehensive instructions and ready-to-use templates for assessment. Wahidah et al., argued that the laboratory is an infrastructure that must be provided by the school in supporting the effectiveness of science learning [39].

Factors that affect the effectiveness of using thelaboratory as a supporter of the student learning processare the existing facilities and infrastructure. Throughcomplete facilities and infrastructure, practicum activitieswill be carried out smoothly to understand the learningmaterial well. Several factors affect the effectiveness oflaboratory management, including the availability offacilities in quantity and the quality and competence oflaboratory managers [39].

3.4.6 Areas for Improvement

While the manual was generally well-received, suggestions for improvement include the incorporation of digital resources, such as quick response code (QR codes) linking to supplementary videos and interactive content. Additionally, periodic updates are recommended to reflect emerging scientific advancements and to align with evolving educational standards. Addressing these areas will further enhance the manual's relevance and usability in the dynamic field of science education. Numerous studies prove that learning materials, besides

textbooks, impact achievement. Aside from the impact of instructional materials on the success of the teaching-learning process, it also aids in attaining the instructional objectives set at the beginning of the course. Classroom activities based on real-life context will positively contribute to the student's in-depth understanding of the subject matter. Varieties of activities have to be offered depending on the interest and characteristics of students.

Westlab, on a comprehensive guide to useful laboratory improvement ideas mentioned that laboratories are essential in scientific research, experimentation, and diagnostic processes [40]. Uttered further that they are crucial for scientific advancement and contribute significantly to technological progress. To ensure that a laboratory operates at peak performance, it must continually improve and adapt to emerging technologies, evolving safety standards, and new scientific methods.

3.5 Extension developed from the recommendations of the experts in science education

GENES or Guided Education through the Now Normal Extension in Science Education was the program created out of this study. This recommendation as an exit of the study serves to help non-science specialist teaching science to achieve holistic and promt ideas in the context and content of science. Program GENES looked into the best possible ways in helping and guiding teachers accomplished their academic tasks in teaching, evaluation, assessing, doing extension and research in science education. In order to attain this science education vision, teachers need to foster critical thinking and inquiry-based learning. Science education is not just about memorizing facts but also about developing critical thinking skills and nurturing a scientific mindset. Capacitating science teachers involves providing them with training on inquiry-based learning approaches, encouraging students to ask questions, explore, and discover answers through hands-on experiments and projects.

Science literacy covers wide descriptions, perspective and scope [41]. Miller, defined science literacy as understanding the norms and methods in science, its key concepts and impact of it to science and technology and society [41]. The National Commission and Excellence in Education in the United States advances the teaching of science in high school to provide the graduates with concepts process, methods of inquiry in science and reasoning, application of science knowledge to everyday life and social and environmental implications of science and technological development.

The Central Bicol State University of Agriculture College of Development Education - Laboratory High School Department have ensured standard to cater the needs of their stakeholders. One salient feature is ensuring the literacy rate and competence of the learners towards achieving competitive graduates as one of the core values. Along the trust cascading to its umbrella sister school, the Pili Campus has enriched and tightens its mandate with regard in maintaining the above standard status. The ONE CBSUA emphasizes on the development plan about the enhancement programs of the University on the needs of the new education system, to give the students a continuous leading application of knowledge in the state of the latest art in the 21st century which is to develop and inculcate within the core values-culture of excellence in the academe, research on the new trends and holistic development for all.

Capacitating science teachers in the Philippines regarding pedagogies in teaching is crucial for keeping pace with advancements in the field, fostering critical thinking skills, adapting to diverse learning needs, and ensuring that science education remains relevant, engaging, and effective attaining the demands of the curriculum – scientific literacy. Ongoing training programs help teachers stay updated on the latest scientific developments and teaching methodologies. On the resources and facilities, the access to quality educational resources, such as textbooks, laboratory equipment, and multimedia materials, is crucial for effective science education. Well-equipped laboratories and facilities enable students to engage in hands-on experiments, fostering a deeper understanding of scientific principles [42]-[44]. Promotion of Inquiry-Based Learning which highlighted the inquiry-based learning, where students actively participate in the learning process by asking questions, conducting experiments, and making observations, is essential for developing scientific literacy. Encouraging critical thinking and problem-solving skills is a key aspect of promoting scientific literacy.

4. CONCLUSION

The development and validation of the Microbiology and Parasitology Laboratory Manual for Science Education aims to enhance the quality of laboratory instruction by providing a comprehensive, accurate, and student-centered resource. The manual aligns with the guidelines set forth by CHED CMO 75 series of 2017, ensuring that the content meets the prescribed learning outcomes and competency standards for science education programs. The manual underwent a rigorous process of design, content development, and expert validation. The feedback from subject matter experts, science educators, and students highlighted the manual's clarity, accuracy, and relevance to modern laboratory practices. The validation process confirmed that the manual effectively supports the development of essential laboratory skills, critical thinking, and scientific inquiry. Findings from the validation indicate that the manual provides clear procedural guidelines, accurate theoretical foundations, and practical applications, facilitating a more engaging and meaningful learning

experience. The inclusion of student-centered activities fosters active learning and encourages independent exploration, enhancing the comprehension and retention of microbiology and parasitology concepts.

The study's results suggest that the manual is an effective instructional tool that bridges theoretical knowledge with practical application. Its structured format and comprehensive content cater to diverse learning needs and accommodate varying levels of student proficiency. Furthermore, the manual's alignment with national standards ensures its applicability in a wide range of educational settings. The developed and validated Microbiology and Parasitology Laboratory Manual is a valuable resource for science education, addressing the need for standardized, high-quality instructional materials. Future research may focus on longitudinal assessments of student performance and the continuous improvement of the manual to adapt to emerging trends and advancements in microbiology and parasitology education. This initiative contributes to the ongoing effort to elevate science education through innovative, research-based instructional materials that foster academic excellence and scientific literacy.

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