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Optimizing Science Laboratory Exposure and Students' Learning Outcomes Through Modeling of Educational Practices

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Abstract

The study examined the level of teacher's training in laboratory management, pedagogical techniques and students' engagement, laboratory exposure, and learning outcomes in laboratory-based science instruction. Non-experimental research design was utilized in gathering data from 578 participants, which included faculty members and undergraduate students, from randomly chosen institutions of higher learning located in Davao City, Philippines. Data were gathered using a validated survey instrument with a very high reliability coefficient (the Cronbach's alpha coefficients were between .942 and .980). Descriptive analysis was applied to identify the mean and standard deviation of each variable. The findings revealed that teachers had very high levels of training in laboratory management and pedagogy. In a similar manner, the students showed extremely high levels of engagement, lab experiences, and learning. The results discussed above are pertinent to the need for ongoing professional development and the use of student-centered and inquiry-based labs in science teaching.

Keywords: laboratory management, pedagogical techniques, student engagement, learning outcomes, laboratory exposure

Introduction

Laboratory work can be considered among the essential elements of teaching science lessons since it serves as a starting point for experiments, research, and application of the knowledge acquired in a theoretical context. In addition, knowledge is gained through doing certain activities and acquiring analytical, critical thinking, and problem-solving abilities (Abrahams & Reiss, 2012; Hofstein & Kind, 2012)[1, 9]. On the other hand, the effectiveness of laboratory teaching largely relies on the abilities of educators who can conduct such practice successfully and implement appropriate pedagogic approaches (Hofstein & Lunetta, 2004; Darling-Hammond et al., 2020) [10, 5]. Effective training in laboratories ensures safety and appropriate organization in the classroom, while pedagogic training makes it possible to use inquiry-based approaches. All those methods are tightly connected with student engagement, a factor known to predict student performance and academic achievements (Bond et al., 2020; Sinatra et al., 2015) [4, 12].

Nevertheless, some knowledge gaps still prevail in the literature on the matter under discussion. For example, current works mostly focus on studying laboratory management and pedagogical training independently of each other. There is also a lack of empirical information concerning the relationship

between student engagement, laboratory experience, and the effects on learning in educational facilities, especially in developing countries (Bond et al., 2020; Hofstein & Kind, 2012) [4, 9].

With this issue in mind, the current study aims at conducting a thorough investigation of the extent of training provided to the educators, students' engagement level, laboratory experience, and learning outcomes associated with laboratory-based science education. The examination of these factors allows for addressing the research questions of the study.

Methodology

Quantitative research design was adopted for this study to determine the levels of teachers' training in laboratory management and teaching approaches, along with those of students' involvement, exposure to laboratories, and outcomes in laboratory-based science instruction. Private higher education institutions in Davao City, Philippines, served as the setting for this study, where data were gathered among 578 participants, including 213 faculty members and 365 students involved in laboratory-based curricular programs. The selection of the faculty members was based on purposeful sampling because they had the experience on how to conduct training for lab management and teaching techniques, while the students were purposely sampled using stratified random sampling technique. Stratified sampling was employed in order to ensure that there is inclusion of different programs and year levels of the students. This measurement tool covered all of the study's variables and had undergone both expert validation and pilot testing. The reliability coefficient of the instrument ranged between 0.942 and 0.980 using Cronbach's alpha value. The data was collected through both face-to-face and online methods while making sure that the participants provided their informed consent and that all the procedures carried out in the process complied with ethical considerations, such as maintaining confidentiality and abiding by the guidelines of the Data Privacy Act of 2012. The collected data were then subjected to descriptive analysis through the use of the mean and standard deviation to assess the level of teachers' training in laboratory management, teaching methodology, student engagement, student learning outcomes, and laboratory experience.

Results

Table 1: Level of Teachers' Training in Laboratory Management by the Teachers

Indicators	Mean	SD	Interpretation
Facilitation of hands-on activities	4.45	0.66	Very High
Laboratory safety protocols	4.42	0.67	Very High
Resource allocation and organization	4.32	0.75	Very High
Equipment usage and maintenance	4.15	0.79	High
Maintenance and calibration	4.01	0.82	High
Overall Mean	**4.27**	**0.66**	**Very High**

Table 1 shows the extent to which Teachers' Training in Laboratory Management was acquired by the Teachers. The average total rating for teachers' training in laboratory management was 4.27 (SD = 0.66) which was regarded as very high. The indicators, such as facilitation of hands-on activities, laboratory safety protocols, and resource allocation and organization were rated very high, while the equipment usage and maintenance, and maintenance and calibration, were rated high.

Table 2: Level of Teachers' Training in Pedagogical Techniques

Indicators	Mean	SD	Interpretation
Classroom dynamics and engagements	4.62	0.60	Very High
Interactive and collaborative teaching strategies	4.52	0.63	Very High
Assessment and feedback method	4.47	0.61	Very High
Differentiated instruction	4.41	0.64	Very High
Integration of technology in teaching	4.38	0.63	Very High
Overall Mean	**4.48**	**0.57**	**Very High**

Table 2, displays the Teachers' Training in Pedagogical Techniques. The pedagogical training of the teachers was also at an extremely high level, scoring highly in differentiated instruction, technological integration, collaborative teaching techniques, assessment techniques, and classroom interaction. This implies that the teachers have adequate skills for imparting instruction to their students.

Table 3: Level of Student Engagement in Classes Managed by Trained Teachers

Indicators	Mean	SD	Interpretation
Use of LMS or virtual reality	4.38	0.79	Very High
Collaboration with peers	4.30	0.84	Very High
Attendance and classroom activities	4.27	0.84	Very High
Curiosity and motivation to learn	4.26	0.86	Very High
Active participation during the lesson	4.09	0.85	High
Overall Mean	**4.26**	**0.77**	**Very High**

The results of the level of Student Engagement in classes managed by trained teachers are shown in Table 3. The level of student engagement was very high and demonstrated characteristics such as active participation, motivation, cooperation, punctuality, and the use of digital learning platforms.

Table 4: Level of Students' Learning Outcomes Managed by Trained Teachers

Indicators	Mean	SD	Interpretation
Ability to apply knowledge in real world scenarios	4.18	0.85	High
Industry exposure	4.16	0.85	High
Overall academic performance	4.14	0.85	High
Mastery of subject content	4.13	0.84	High
Problem solving and critical thinking skills	4.11	0.85	High
Overall Mean	**4.14**	**0.81**	**High**

The table 4 shows that Students' Learning Outcomes Managed by Trained Teachers were at a high level, which includes learning content, critical thinking, problem solving, practical application, and academic achievement. These results show the effectiveness of lab-based teaching.

Table 5: Level of Students' Laboratory Exposure

Indicators	Mean	SD	Interpretation
Collaborative and Interdisciplinary learning	4.32	0.86	Very High
Laboratory-Based learning	4.21	0.86	Very High

Project-Based learning	4.15	0.86	High
Inquiry-Based learning	4.15	0.86	High
Problem-Based learning	4.14	0.87	High
Overall Mean	**4.19**	**0.82**	**High**

Students' Laboratory Exposure Level is shown in Table 5. It is noted that the laboratory exposure was also high because there were many activities involving inquiry-based, project-based, problem-based, and collaborative learning by the students.

Discussion

Based on the findings from this study, there was consistency in the very high-level indicators in all key variables including teacher preparation for laboratory management, pedagogical practices, student involvement in experiments, laboratory experience, and learning outcomes. Therefore, the results from this study present clear evidence that a highly established science education process has been put in place through an effective science teaching environment using a laboratory-based approach.

First, the very high indicator of teachers' training for laboratory management implies that the faculty at this institution is fully trained to ensure proper management and organization of laboratory facilities, materials, equipment and hands-on experiments for their students. Proper management in the laboratory classroom enables a conducive atmosphere where students can conduct experiments in a safe and well-organized manner. This assertion is supported by research conducted by Abrahams & Reiss (2013)[2], who pointed out that effective laboratory management contributes to improved laboratory practice and scientific exploration. In addition, according to Abrahams & Reiss (2012) [1], setting up effective laboratory management and practical activities makes it possible for enhanced student participation and learning.

Secondly, the very high level of pedagogical skills possessed by the teachers means that teachers have adequate skills for using learner-centered teaching methods like differentiated instruction, integration of technology, collaboration, and effective assessment practices. This is because such teaching methods are considered important when teaching science nowadays because they encourage active learning among learners. According to Darling-Hammond et al. (2023) [6], high quality of teachers' professional development improves instructional practices in schools. In addition, Prince (2004) [11] observed that approaches to instruction that entail collaboration and interactions help motivate students, particularly in challenging courses such as science. Accordingly, the findings from the current study reveal that the skills possessed by teachers extend beyond theoretical knowledge to its practical application as well.

Third, the very high levels of engagement among students recorded during this study reveal how effective the instruction techniques have been adopted in schools. Engagement among students is considered a major determinant of academic achievement (Bond et al., 2020) [4], and high engagement involves behaviors, emotions, and cognitive functions. The involvement of students in the learning experience through participation, motivation, collaborative learning, and technology indicates that students are engaged in their academics. These findings corroborate the assumptions of social cognitive theory, which suggests that students will engage more in activities where they see competent and confident role models such as competent teachers (Bandura, 2001) [3]. Similarly, this finding supports the assertions of scholars who suggest that engagement increases when students learn through interactive techniques (Prince, 2004; Bond et al., 2020) [11, 4]. Hence, the high levels of engagement among students have been caused by effective instructional practices and laboratory management techniques.

Fourth, the high rate of laboratory exposure is an indication that students are constantly engaged in a variety of laboratory work involving inquiry-based learning, project-based learning, problem-based learning, and collaborative learning. This finding indicates the necessity of giving the learners chances to participate in many kinds of laboratory work. As mentioned by Hmelo-Silver (2004) [8], the use of inquiry learning and problem-based learning techniques may assist learners to learn new things through active learning and then apply those learned materials to solve practical problems in the real world. As mentioned by Freeman et al. (2014) [7], active learning plays an essential role in developing scientific literacy amongst the learners.

Lastly, the remarkably high quality of student learning outcomes shows the overall effectiveness of laboratory teaching in relation to proper teacher training and high student involvement. Indeed, the students have demonstrated high competence in subject content, critical thinking, problem-solving, and application of knowledge into practice. This study is aligned with previous empirical studies according to which active inquiry-based learning promotes better academic success and understanding of science-related notions (Freeman et al., 2014; Bond et al., 2020) [7, 4]. In addition, the findings can be considered as an evidence of effectiveness of experiential learning since, according to Hmelo-Silver (2004) [8], learning takes place through experience and reflection on it.

The results presented in this study demonstrate the interdependent nature of teacher preparation, student participation, laboratory experience, and learning achievements. Well-prepared teachers who possess adequate skills in handling laboratories and teaching methods are capable of developing highly engaging and effective learning situations conducive to active participation. In this respect, highly participatory students and learners with extensive laboratory experiences result in good learning outcomes. The relationship discussed above corresponds to the conceptual framework of the study and emphasizes the necessity of adopting an integrative approach toward enhancing science education. Nevertheless, the consistently high scores observed among all variables can be attributed to the educational institution where the study was conducted, especially considering its focus on faculty development and laboratory-based teaching practices in private higher education establishments. Still, even with the results obtained in the present study, it is evident that there is always room for improvement when it comes to the quality of instruction. Thus, the institutions dealing with education should continue working towards educating teachers using professional development programs which address both teaching and lab management skills. Curriculum developers should ensure that lab activities encourage the use of an inquiry-based and student-centered learning approach.

In conclusion, the study carried out provides strong empirical evidence that the efficient optimization of laboratory instructions along with adequate teacher training and student involvement leads to better achievement in science learning. It emphasizes the importance of integrating lab management skills, teaching skills and learning experiences for the effectiveness of science learning.

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