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Science Laboratory Learning Environment and Students' Practices on Laboratory Safety

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Abstract

This paper aims to identify the significant relationship between the science laboratory learning environment and students' practices on laboratory safety for education students who took at least one subject or course with laboratory unit in face-to-face classes. The data from this study came from 201 education students, collected through an online survey using Google Forms. The non-experimental descriptive correlational design, census approach was used to select the study participants, and standardised questionnaires were also utilised. The weighted mean, standard deviation, Pearson product-moment correlation design, and linear regression analysis were employed as statistical techniques. The study found that the science laboratory learning environment is at a very high level. Meanwhile, the students' practices on laboratory safety, especially emergency response plans, work procedures, and chemical waste management, are at a very high level, while safety equipment and handling of experiments are observed at a high level. The results also showed a significant relationship between the science laboratory learning environment and students' practices on laboratory safety. The domain of science laboratory learning environment that significantly predicts students' practices is the material environment. The result implied that the institution may provide and maintain a conducive laboratory learning environment, which is essential for students to perform laboratory safety, enhance the handling of experiments, and upgrade the safety equipment in the science laboratory.

Keywords: *Education*, *Laboratory Learning environment, Students' practices on laboratory safety, Correlation, Regression*

Introduction

Laboratory safety should come naturally and must become a habit, especially for science teachers and students. Some reasons for compromising safety are overconfidence, ignorance, defiance, carelessness, work stress due to fear of not meeting targets, and poor planning and hygiene (Deepak, 2016). Incidents leading to severe injuries or even fatalities among students and staff occur frequently in university laboratories worldwide (Yang, Reniers, Chen, & Goertlandt, 2019). Meanwhile, laboratory exercises serve as a vital bridge between theory and practical experience in science education, enhancing students' understanding of scientific concepts. For example, the study of Duban, Aydogdu, and Yuksel (2019) demonstrated that laboratory work engagement significantly improved students' comprehension of scientific principles and reduced the likelihood of misconceptions.

The science laboratory provides a unique learning environment where students collaborate to investigate scientific phenomena in a less formal setting, fostering interaction with teachers (Olubu, 2015). Students employ scientific processes to explain phenomena, emphasising the need for well-grounded practical ideas in all science subjects to enhance understanding and academic performance (Oginni, 2016). Correct handling of materials and equipment is crucial in preventing accidents, highlighting the importance of students

knowing the appropriate experimental tools (Ali et al., 2018).

Science teachers need to be clear about the rules and responsibilities of their students, have precise monitoring methods, and always decide what specific procedures will be documented (Mulholland, 2020). Furthermore, Threeton and Walter (2013) stated that students must be prepared for an active safety laboratory model by adhering to safety guidelines and standards in the laboratory learning environment. Safety equipment is typically available in school science laboratories due to the need to interact with various materials, necessitating regular checks and monitoring to ensure student safety (Bakhtiar et al., 2019). Without adequate safety equipment, science laboratory users are at great risk (Ali et al.,2018).

Additionally, safety equipment should be available in or near all laboratories that use hazardous chemicals in clearly labelled, highly visible, and convenient locations (Indiana University, 2019). Improper chemical waste disposal could potentially have a severe consequence for both humans and the environment (Kaufman, 1990, as noted in the study by Ali et al., 2018). Hazardous waste must be controlled from the time it is created inside the lab until it is taken to an off-site facility for treatment or disposal (Environmental Health and Radiation Safety, 2017). Similarly, an emergency response plan involving teacher, lab assistants, and students is crucial to prevent fatalities and minimise injuries during a crisis, encompassing response strategies, drills, equipment readiness, and clear leadership (Muenz, 2017).

It is also important to keep an eye on students' safety practices in the laboratory when conducting experiments. One of the first topics that students encounter when they enter a science laboratory is work procedures. During this time, students are informed of the rules that must be followed when conducting laboratory activities and are given enough information to help them avoid and prevent incidents that may happen if laboratory activities are not carried out carefully (Ali et al., 2018; Mulholland, 2020).

Otherwise, Chinese scientists are also concerned about a lack of control and uniform safety measures, particularly in teaching laboratories, after fatal explosions in university laboratories (Silver, 2021). The use of school science laboratories is hampered by several challenges and issues that prevent their effective activation, such as risks associated with improper use of laboratory tools or equipment, inadequate storage and preservation of some materials, or errors caused by improper handling of materials or the application of some operating procedures (Fagihi, 2018).

In addition, one incident was reported from the chemistry laboratory at the University of Mindanao where a student's careless use of a Bunsen burner resulted in an unexpected, uncontrollable flame that slightly caught her hair and eyelashes (Chem Lab Report, 2020). As reported by the respective laboratory custodians in Chemistry, Biology, and Microbiology at the University of Mindanao, the most common incidents happening during laboratory class were minor breakages and damage to some equipment by students.

The study by Wong and Fraser in 1994 on the Science Laboratory Classroom Environments and Student Attitudes in Chemistry Classes in Singapore marked the beginning of research in science education that focused on the classroom environment because as most attention at the time was focused on learning difficulties related to science achievement, general abilities, the sex of students, and attitudes towards science. As a result of their investigation, they were able to assess the teachers' and students' perceptions of the learning environment in the chemistry laboratory environment. More importantly, they were able to compare their findings conducted in Singapore to the data from Australia, the USA, Canada, Israel, England, and Nigeria, wherein they found out that there are

similarities and differences in the science laboratory classroom environment between Singapore and those countries.

In the same manner, the results of this study can be used as a basis to further explore this area of research and to give importance to the safety of students in the laboratory. The results can also be used to further improve the safety guidelines and policies of schools to ensure the effectiveness of the science laboratory learning environment and to ensure laboratory safety practices for students. In addition, they can also be the gauge for comparing the data from other schools should they wish to explore this area or research. This study was based on the proposition of Hinderson, Fischer, and Fraser (1998) that learning environment factors are particularly important influences on student outcomes, even when other factors are controlled.

Assessing the relationship between the science laboratory learning environment and students' safety practices is essential to understand how the environment influences behaviour, improves safety standards, informs policy development, enhances science education, and ensures student well-being. Researchers are encouraged to examine this study because no research has been conducted to determine the significant relationship and influence of the science laboratory learning environment on students' practices on laboratory safety at the University of Mindanao. As mentioned above, the incident also pushed the researchers to pursue the study since they discovered the necessity of conducting the study.

Furthermore, the findings of this study can be used as valuable information for expanding knowledge about the importance of science laboratory learning environments on the students' practices on laboratory safety. By placing a greater emphasis on hands-on experiences that foster problem-solving abilities and critical thinking, a science laboratory learning environment significantly promotes advanced learning at all levels of education. When supported by investments in hands-on experiences, this environment encourages students to pursue higher education and equips them with the skills that high-tech employers value (American Chemical Society, 2017).

This study has four aims: (1) To determine the level of science laboratory learning environment in terms of rule clarity, integration, indoor air quality, learning space, and material environment; (2) To describe the level of students' practices in laboratory safety in terms of work procedures, safety equipment, handling of experiments, chemical waste management, and emergency response plan; (3) To identify the relationship between the science laboratory learning environment and students' practices in laboratory safety as well as to determine which domain of science laboratory learning environment predicts the students' practices in laboratory safety of all education students who experienced laboratory classes at the university through multiple linear regression analysis; (4) The researchers hypothesise that there is a significant relationship between the science laboratory learning environment and students' practices on laboratory safety, and there is a domain in the science laboratory learning environment that predicts the students' practices on laboratory safety.

Methodology

Study Participants

The respondents of this study were second to fourth-year students from the College of Teacher Education (CTE) of the University of Mindanao–who took at least one subject or course with at least one laboratory unit in face-to-face classes. However, only 201 out of the 268 total population were qualified to take the survey. The study was conducted from September to November of the school year 2021-2022. Considering the current situation, some of the respondents could not take the online survey due to poor internet connectivity and their hectic academic priorities. According to Raosoft computation, based on the total population, the

recommended sample size is 159; subsequently, the 201 participants were highly acceptable (corresponding to a 75% respondent rate) since it exceeded the recommended sample size. The researchers used a census approach where all members are enumerated (Surbhi, 2017).

Materials/Instruments

In congruence with the quantitative research design, the researchers adopted research questionnaires. To determine the Science Laboratory Learning Environment of CTE students, the adopted and merged questionnaires from the study of Fraser and Lee (2009) and Ahmad and Halim (2014) were used. This study focused on five indicators: rule clarity, integration, indoor air quality, learning space, and material environment. The rule clarity, integration, and material environment contained seven items, while the indoor air quality and learning space had four and five items.

On the other hand, the second part of the instrument was a 5-point statement scale corresponds to Very True (5); True (4); Somewhat True (3); Not True (2); and Not at All True (1). It focused on the students' practices on laboratory safety which was the dependent variable of the study. This part of the research tool was extracted from the study of Ali et al. (2018). The study contained five indicators that assessed the knowledge of the students in terms of their practices in laboratory safety, which included work procedures, safety equipment, handling experiments, chemical waste management, and emergency response plans. The first two indicators mentioned above contained seven statements each. The handling experiments and emergency response plan indicators included six statements, while the chemical waste management indicator had four statements. The standardised questionnaire did not undergo validation since it was adopted from a source. The researchers used this scale adopted from Alipio's (2020) study with the following interpretations: 1.00-1.79 as very low, 1.80-2.59 as low, 2.60-3.39 as

moderate, 3.40-4.19 as high, and 4.20-5.0 as very high.

Design and Procedure

This paper employed the quantitative descriptive correlation design, collecting data from surveys using standardised questionnaires (Pal, 2017). The descriptive correlation research design was employed to describe the present and subsequent phenomena (Atmowardoyo, 2018). As stated by Creswell (2003), quantitative research uses strategies of inquiry using predetermined instruments to collect statistical data through experiments and surveys. The non-experimental quantitative research aligned with the present investigation, for it seeks to determine the influence of laboratory learning environment on students' practices on laboratory safety.

Furthermore, with the approval of the study conduction, the survey was done virtually using Google Forms. The researchers reached the respondents through social media, then sent the questionnaires privately to individuals, verified their email based on the generated data from Google Forms, and forwarded it to the statistician. The weighted mean was utilised to determine the level of the science laboratory learning environment and students' practices on laboratory safety. Pearson product-moment correlation was applied to determine the relationship between the science laboratory learning environment and students' practices on laboratory safety. Furthermore, linear regression analysis was employed to identify which science laboratory learning environment domain predicts students' laboratory safety practices at the University of Mindanao. In addition, SPSS 19.0 was used for all statistical tools.

Result and Discussion

Level of Science Laboratory Learning Environment

Table 1 shows the mean score for the scientific laboratory learning environment indicators. The highest rating given by the respondents, which indicated that the science laboratory learning environment was consistently observed, had an overall mean of 4.48. Rule clarity had the highest mean of 4.60 of all the factors categorised as very high, as presented below, showing that students always adhered to the teacher's rules and directives inside the lab. On the other hand, while indoor air quality received the lowest mean of 4.40; it is considered very high. In fact, the students always observed suitable-temperatures with adequate working fans and exhaust fans for efficient airflow, which allowed the learning process to take place comfortably.

The very high level of the science laboratory learning environment aligned with the viewpoint of Kwok (2015), that the science laboratory is specially designed and equipped for science experiments and investigations. It was also comparable to Sharma's (2014) idea, which evaluated the emphasis on creating and adhering to a clear set of rules and on learners' acknowledgement of how far the teacher will go when a student defies the rules. The set of rules is essential to ensure safety in the laboratory. As pointed out by Allanas (2021), the lack of rules might raise the danger of an accident, that is why teachers typically follow safety standards very strictly to prevent lab accidents. It is further justified that having clear regulations will prevent any administrative or physical accidents. Consequently, rules are used to establish safe conditions in laboratories.

Table 1. Science Laboratory Learning Environment

Indicators	Mean	Std. Deviation
Rule Clarity	4.60	0.502
Integration	4.50	0.557
Indoor Air Quality	4.40	0.624
Learning Space	4.41	0.564
Material Environment	4.46	0.571
Overall	**4.48**	**0.494**

Level of Students' Practices on Laboratory Safety

Table 2 shows the mean scores for the indicators of students' practices on laboratory safety. The highest rating given by respondents had a mean score of 4.48, indicating that students' practices on laboratory safety were consistently evident.

The emergency response plan obtained the highest mean score of 4.44 out of the six indications, showing that respondents consistently demonstrated the set of written procedures for handling emergencies.

Table 2. Students' Practices on Laboratory Safety

Indicators	Mean	Std. Deviation
Work Procedure	4.30	0.474
Safety Equipment	4.11	1.076
Handling Experiment	4.07	1.112
Chemical Waste Management	4.25	1.061
Emergency Response Plan	4.44	0.837
Overall	**4.48**	**0.484**

The very high level of students' practice on laboratory safety was affirmed by the notion of Duban, Aydogdu, and Yuksel (2019) saying that to bridge the gap between theory and practice, laboratory practices are crucial, and their applications have been shown to assist students in defining scientific concepts in a more thorough and relevant way. Furthermore, it agreed with the study of Muenz (2017) that the essential things to consider in developing an emergency plan are creating responses to various incidents, conducting drills, having equipment in the proper place, and having a clear leadership structure and sets of priorities. Ali et al., (2018) also emphasised that students must be aware of what to do during an incident.

The emergency response plan must be thorough and guarantee that everyone involved, including the students, is familiar with how to use it in an emergency.

Correlation Between Science Laboratory Learning Environment and Students' Practices on Laboratory Safety

Table 3 illustrates the significant relationship between the two variables, the science laboratory learning environment and students' practices on laboratory safety.

Additionally, the determined R-value for the association between the general standard of the scientific laboratory learning environment and the students' practices on laboratory safety was .863, with a p-value of .000 and a significance level significantly lower than 0.05. Consequently, the null hypothesis is rejected.

As a result, this study found a substantial link between the learning environment in scientific laboratories and students' safety procedures in the lab. While the survey by Hofstein and Naaman (2007) showed that school science labs aid students in gaining experience through interactions with various tools and materials and improving their ability to understand the natural world, Akinbobola (2015) pointed out that students should also be made aware of the safety guidelines and regulations governing laboratory activities and procedures.

Influence of Science Laboratory Learning Environment on the Students' Practices on Laboratory Safety

The linear regression analysis of the science laboratory learning environment and students' practices on laboratory safety are analysed and interpreted to determine which among the rule clarity, integration, indoor air quality, learning space and material

environment significantly predicts the student's practices of laboratory safety. Reflected in Table 4 is the linear regression analysis of the science laboratory learning environment and with R^2 value of .772 and p-value of .000 lower than level of significance.

Table 3. Correlation between Science Laboratory Learning Environment and Students' Practices on Laboratory Safety

Science Laboratory Learning Environment	Students' Practices on Laboratory Safety					
	Work Procedure	Safety Equipment	Handling Experiment	Chemical Waste Management	Emergency Response Plan	**Overall**
Rule Clarity	.629** (.000)	.416** (.000)	.684** (.000)	.670** (.000)	.630** (.000)	**.696** (.000)**
Integration	.644** (.000)	.469** (.000)	.699** (.000)	.679** (.000)	.663** (.000)	**.719** (.000)**
Indoor Air Quality	.688** (.008)	.646** (.010)	.651** (.000)	.710** (.000)	.706** (.000)	**.785** (.000)**
Learning Space	.681 (.229)	.602 (.090)	.652** (.002)	.682** (.000)	.729** (.000)	**.770** (.000)**
Material Environment	.749** (.000)	.673** (.005)	.716** (.000)	.737** (.000)	.782** (.000)	**.843** (.000)**
Overall	**.767** (.000)**	**.639** (.000)**	**.767** (.000)**	**.786** (.000)**	**.802** (.000)**	**.863** (.000)**

*p < .05 is significant (two-tailed)

Table 4. Influence of Science Laboratory Learning Environment on the Students' Practices on Laboratory Safety

Indicators	Study Behavior			
	B	**β**	**t**	**Sig.**
Rule Clarity	.069	.072	1.194	.234
Integration	.045	.052	.823	.412
Indoor Air Quality	.139	.180	2.813	.005
Learning Space	.176	.206	3.494	.001
Material Environment	.387	.457	6.993	.000
R	.878			
R^2	.772			
F	131.821			
ρ	.000			

Thus, it could be stated that the science laboratory learning environment influences students' practices on laboratory safety. Moreover, the science laboratory learning environment influences students' practices on laboratory safety by 77.2 per cent. Among the indicators, the material environment best predicts the students' practices on laboratory safety given its highest beta coefficient. The difference of 22.8 per cent is characterised by other components not included in the study. Furthermore, the science laboratory learning environment and students' practices on laboratory safety were reflected in the results of the study conducted by Ali (2018). This study indicated a medium-high to high level of students' awareness on laboratory safety, but with the lowest score on safety equipment, which can be attributed to low resource allocation for the purchase of safety equipment like laboratory coats and safety goggles. The results of this study reinforce the importance of providing the students who are conducting laboratory activities with a conducive science laboratory learning environment. Since the study suggests that there is a significant relationship between the two variables, this amplifies the idea that students' practices on laboratory safety are greatly influenced by their learning environment. The study might be limited to education students only who were able to experience laboratory activities, but this is an effective way of assessing the status of the university's laboratory environment and can be replicated by other courses to further improve both the science laboratory learning environment and student's practices laboratory safety.

Conclusion

Based on the results of the study, it is concluded that the learning environment in the scientific lab, as shown in the scores, was high on all fronts, including rule clarity, integration, indoor air quality, learning space,

and learning environment. Second, the level of students' practices on laboratory safety is very high. In particular, the emergency response plan, the work procedure, and the chemical waste management were also very high; however, the work equipment and handling experiment obtained a descriptive level of high. Third, a significant relationship exists between the science laboratory learning environment and students' laboratory safety practices. Lastly, material environment significantly predicts the student's practices on laboratory safety. As a result, this study on science laboratory learning environment and students' practices on laboratory safety confirms the proposition of Hinderson, Fischer, and Fraser (1998) that learning environment factors were found to be particularly important influences on student outcomes, even when other factors were controlled.

Recommendation

It can be noted that two indicators in students' practices on laboratory safety gained only a high descriptive value; thus, it is recommended that more emphasis be placed on safety equipment and handling experiments. Nonetheless, this can be further explored since the findings of the study are only limited to a few laboratories in the institution where this study was conducted.

Other researchers can explore this study by looking into other types of laboratories, such as biology laboratory, physics laboratory, microbiology laboratory, or even laboratories in other courses, such as those in Hotel and Restaurant Management or Engineering courses. In addition, researchers can also use the data from this study to be able to compare it with other colleges or universities to determine the similarities and differences, thereby improving the conduct of laboratory activities through the refinement of the science laboratory learning environment and better improving the students' practices on laboratory safety. Lastly, to help future researchers that may find other factors that influence the students' practices on laboratory safety not involved in this study with a broader scope of participants.

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