STRATEGIES OF PHYSICS LABORATORY SAFETY FOR UNDERGRADUATE PROGRAMS

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ABSTRACT: Good laboratory practices (GLP) in tertiary institutions is a must to ensure safety among laboratory tenants. The implementation of GLP however varies according to discipline with most studies focusing on chemical safety and no specific literature discussed how Physics laboratory safety be implemented. To address this gap this study was conducted descriptively to provide example of strategies of implementing GLP in Physics laboratory. The study considered the case of the University of Science and Technology of Southern Philippines (USTP) Physics laboratories. Overall, strategies of USTP Physics laboratories were observed to present best practices evidenced by improved laboratory safety protocols. These strategies were implemented by (i) improving laboratory facilities; (ii) incorporating GLP in the preliminary discussions in the laboratory manuals; (iii) upgrading instruments and apparatuses with safety data sheets; (iv) training of faculty and laboratory technician on GLP and related activities; (v) scheduling of laboratory classes mainly during the daytime; and (vi) improving the faculty-student ratio in the laboratory. While present study may provide policy strategies to other higher educational institutions (HEIs'), however much work needs to be considered in centralizing GLP in all allied sciences laboratory units.

Keywords: *Physics laboratory; laboratory safety; good laboratory practices (GLP)*

1. INTRODUCTION

Good laboratory practices (GLP) in universities must be implemented to ensure occupational safety among faculty, students, researchers, and laboratory technicians. Studies on GLP and safety awareness in the Philippines among higher educational institutions (HEIs') showed lack of facilities to ensure safety [1] [2]. These were commonly evidenced by the: (i) absence of material safety data sheets (MSDS) of chemicals and apparatuses [1]; (ii) absence of complete personal protective equipment (PPE) [2]; and (iii) use of makeshift cabinets for chemicals and apparatuses [3]. These findings were essential to consider in developing safety and hazard awareness in HEIs'. Much attention is needed considering that laboratory resources can be outsourced to develop explosives and others.

While past literature focused on chemical safety, there are no existing studies dealing on other allied sciences like Physics. Advanced and material science Physics laboratories similarly utilize chemicals, apparatuses, and instruments to conduct experiments and research. The protocol of safety in Physics laboratories is often neglected, which brings a serious concern in HEIs' offering Physics laboratory courses as general education units to undergraduate programs. The likelihood of hazard exposure to undergraduate students and faculty is high if GLP measures are not operationalized, creating the need for evaluating strategies appropriate for Physics laboratory safety.

Other studies similarly suggest that awareness alone is irrelevant if no specific training be introduced on laboratory safety. A study on undergraduate students showed deficiency in the areas of hazard identification and emergency response despite being aware of laboratory safety [4]. Similarly, undergraduate students' awareness on laboratory safety was found to be very low particularly when conducting experiments at night [5]. This in return establishes the need for training intervention to improve safety awareness [6]. Overall, these gaps are essential to be considered in developing strategies for Physics laboratory safety.

Extrapolating from present literature, this study was conducted to establish key strategies needed in Physics laboratory to improve safety awareness. Emphasis of the present study were on qualitatively evaluating existing facilities, manuals, instruments/apparatuses, faculty and laboratory technician trainings, laboratory schedules, and faculty-student ratio. These parameters to evaluate strategies were anchored from past literature on laboratory safety [1] [2] [3] [4] [5] [6]. The case of the University of Science and Technology of Southern Philippines (USTP)-Physics laboratory served as reference guide.

2. MATERIALS AND METHODS

2.1 Research design and framework

This study is mainly descriptive, drawing audit on safety protocols observed in USTP Physics laboratory (see Figure 1). Data on faculty-student ratio for four consecutive semesters (2015-2017; excluding summer classes) served as sample size.

Figure 1. Framework of the study

Figure 2. a) Laboratory safety bulletin; b) Fire extinguisher outside and inside the laboratories; c) two exit doors

Figure 3. a) Gas exhausts vents outside the laboratories; b) Clutter free hallways; c) Emergency water sprinklers

Figure 4. a) Wider spaces in the laboratories; b) Laboratory apparatuses shelves separating electronics/electrical

Laboratory manuals, instruments/apparatuses safety guides, laboratory schedules, faculty/laboratory technician trainings, and faculty-student ratio were similarly considered to deduce key strategies implemented for laboratory safety. Figure 1 presents the framework of the study.

2.2 Study site

The study was conducted in USTP, identified as science and technology university with service Physics courses to undergraduate programs. Four Physics laboratories were assessed on safety protocols. Pre-selected interviews were conducted among Physics faculty to corroborate with existing practices.

2.3 Data analysis

All results were expressed inferentially using descriptive statistics. Summary of results were presented in frequency, mean and percentage.

3. RESULTS AND DISCUSSIONS

3.1 Facilities

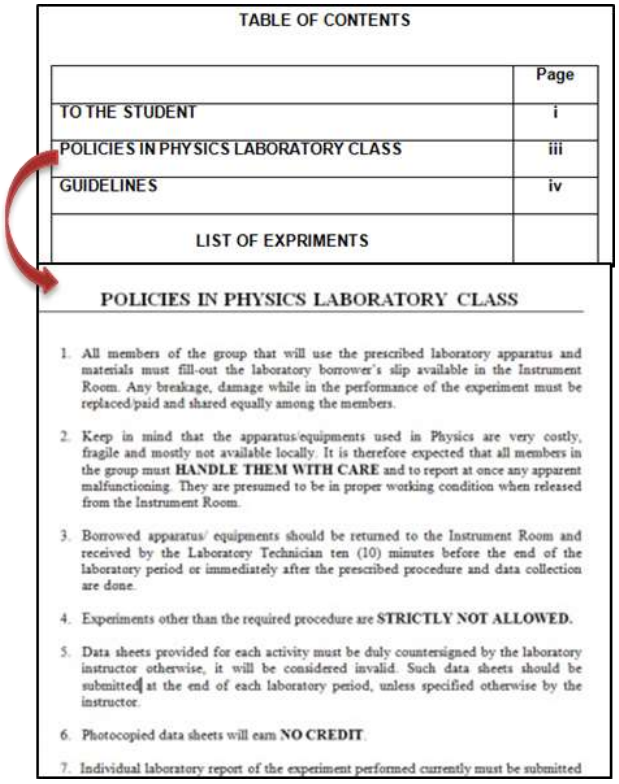
USTP-Physics laboratory safety was introduced through identified key facilities. Laboratory safety bulletin, fire extinguishers, and exit doors (see Figure 2) were strategically accessible by laboratory tenants. Similarly, hallways outside the laboratory were free from clutter (see Figure 3) allowing accessible emergency exits. Water sprinklers and gas exhaust were noticeable to reduce fire risks due to explosives and flammables (see Figure 3). This was viewed as positive motivation to improve safety awareness [7]. Laboratory shelves and cabinets were available separating electronics or electrical equipment. (see Figure 4). Glassware's were contained below the desks with enclosure or in the hanging cabinets with makeshift lips to avoid fall off due to shaking and others. This practice was introduced in the past to properly store chemicals [2]. Wide spaces between laboratory tables were in placed to allow mobility of students conducting experiments (see Figure 4). Similarly, surveillance camera were in placed in the laboratory lobby to provide security visibility. Overall, these GLP features are essential to ensure safety and reduce risk hazards [1].

3.2 Manuals

Laboratory manuals contain basic GLP protocol embedded in the section "policies in Physics laboratory" prior to experiment conduct in all undergraduate courses (see Figure 5). Most of the students enrolled in Physics laboratory have chemistry units both laboratory courses reinforced GLP through discussion on laboratory safety every start of the semester. GLP integration in the laboratory manuals provides safety considerations to students by communicating specific hazards prior to the start of an experiment [4].

3.3 Instruments and apparatuses

Newly acquired apparatuses and instruments have appropriate safety data sheets. Availability of these materials to students may reinforce safety awareness [1]. The overall control of dispensing apparatuses/instruments for experiments was relied on the laboratory technician and faculty in charge.



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POLICIES IN PHYSICS LABORATORY CLASS

1. All members of the group that will use the prescribed laboratory apparatus and materials must fill-out the laboratory borrower's slip available in the Instrument Room. Any breakage, damage while in the performance of the experiment must be replaced/paid and shared equally among the members.
2. Keep in mind that the apparatus/equipments used in Physics are very costly, fragile and mostly not available locally. It is therefore expected that all members in the group must **HANDLE THEM WITH CARE** and to report at once any apparent malfunctioning. They are presumed to be in proper working condition when released from the Instrument Room.
3. Borrowed apparatus/ equipments should be returned to the Instrument Room and received by the Laboratory Technician ten (10) minutes before the end of the laboratory period or immediately after the prescribed procedure and data collection are done.
4. Experiments other than the required procedure are **STRICTLY NOT ALLOWED.**
5. Data sheets provided for each activity must be duly countersigned by the laboratory instructor otherwise, it will be considered invalid. Such data sheets should be submitted at the end of each laboratory period, unless specified otherwise by the instructor.
6. Photocopied data sheets will earn **NO CREDIT**.
7. Individual laboratory report of the experiment performed currently must be submitted

Figure 5. Physics laboratory manual with basic GLP protocol

Figure 6. Apparatuses/instruments of Physics 10 (Mechanics and Heat) with safety protocols).

Figure 7. Apparatuses/instruments of Physics 11 (Electricity and Magnetism) with safety protocols

However, due to the nature of using students to operate the Physics laboratories, the turnover of operating personnel is frequent, and the sharing of process safety knowledge during a formal handover often does not exist [8].

3.4 Faculty and laboratory technician training

Training on GLP and laboratory safety intervention was found to improve safety awareness [6] as tool for educational initiative [9]. This was one of the strategies that USTP-Department of Physics have been practicing. For the past three years the laboratory technician attended trainings to enhance mastery of GLP protocols, motivating exercise for improving the laboratory safety measures [10].

Table 1. Trainings on GLP participated by faculty/lab technician

Training	Date	No of faculty/lab technician
Working safely with biological safety cabinet and user training	March 8, 2017	2
Safe handling of all reagents as an environmental support	September 15. 2016	1
Physics upgrading laboratory seminar	April 21, 2016	13

3.5 Laboratory schedules

Overall, there were about 155 Physics laboratory classes in USTP (see Table 2). Mainly these classes were categorized to time schedules. About 111 classes were observed from 7:30 AM-4:30 AM while 44 classes were hold 4:30 PM-9:00 PM. This scheduling strategy was viewed favorable to improve students' safety awareness. Findings of reference [5] showed very low safety awareness among students conducting experiments at night.

Table 2. Number of Physics laboratory classes by schedule for the past two academic years (A.Y.)

Class Schedule	A.Y. 2015-2016		A.Y. 2016-2017		Total
	Physics 10	Physics 11	Physics 10	Physics 11	
7:30 AM-10:30 AM	6	12	10	5	33
10:30AM-1:30 PM	11	8	16	8	43
1:30 PM-4:30 PM	16	5	11	3	35
4:30 PM-7:30 PM	9	8	8	10	35
6:00 PM-9:00 PM	0	0	3	6	9
Total	42	33	48	32	155

3.6 Faculty-student ratio

Most of the students enrolled in Physics laboratory courses were from the College of Engineering and Architecture (CEA) followed by students from the College of Technology (CT), College of Information Technology and Computing (CITC), College of Science and Mathematics (CSM), and College of Science and Technology Education (CSTE) (see Figure 8 and 9). On the other hand, the overall ratio of faculty-students varies dependently on the academic year and the type of Physics laboratory courses (see Table 3). Mean ratio of faculty-student in Physics 10 laboratory was 1:122 whereas 1:101 for Physics 11. The overall ratio of faculty-student was 1:223 with three contact hours per week.

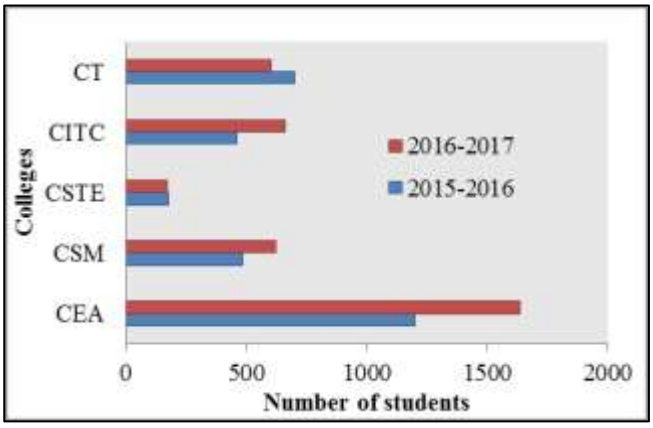

Figure 8. Total number of students per colleges every academic year

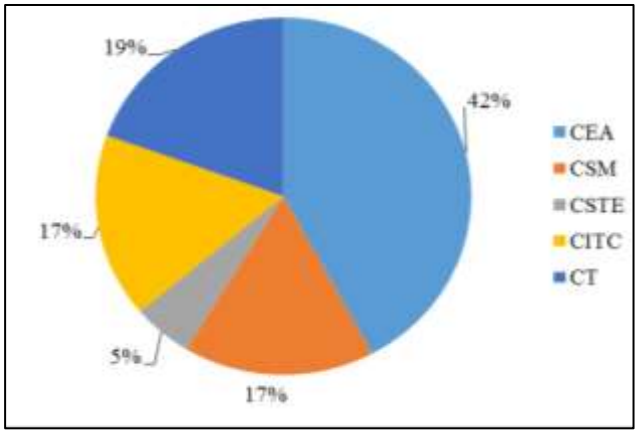

Figure 9, Total percentage of students per colleges for the two academic year

Table 3. Faculty-student ratio in USTP Physics laboratory

Academic year	Number of students		Faculty
	Physics 10	Physics 11	
2015-2016	1811	1213	14
2016-2017	1855	1849	17
Mean	1833	1523	15
SD	31.11	449.72	2.12
Faculty-student ratio	~1:122	~1:101	NA
Overall ratio	~1:223		

This disproportionate laboratory ratio for faculty-student may result to inadequacy to monitor laboratory safety. The

strategies implemented to reduce hazard risk were by: (i) installation of television monitors in the laboratory aiding the experiments (see Figure 10); (ii) wide spaces in the laboratory; and (iii) the assistance of the laboratory technician.

Figure 10. Installations of television monitor to aid Physics laboratory experiments

4. CONCLUSIONS

Overall, strategies of USTP Physics laboratory were viewed as best practices in improving laboratory safety. Faculty and students were practicing GLP protocol to reduce risk hazard and provide better learning environment. These strategies were implemented by (i) improving laboratory facilities; (ii) incorporating GLP in the preliminary discussions in the manuals; (iii) upgrading instruments and apparatuses with safety data sheets; (iv) training of faculty and laboratory technician on GLP and related activities; (v) scheduling of laboratory classes mainly during the daytime; and (vi) improving the faculty-student ratio in the laboratory. While present study can provide policy strategies to other HEIs' to implement GLP in Physics laboratory, however much work needs to be considered in centralizing GLP in all allied sciences laboratory units.

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