Online and In-person Science Laboratory Instructional Practices: Input to a Science Instructional Guide

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ABSTRACT

This study assessed the teaching practices in the online and in-person science laboratory as input to developing a science instructional guide. It explored the instructional materials used in online and in-person laboratory instruction. It also surveyed the safety measures, pre-lab and in-lab activities implemented by the instructors, teaching methods used, and the challenges the respondents met. The study employed the descriptive method and the developmental research method. A survey questionnaire was used to collect data from 5 science laboratory teachers and 225 students who took science laboratory courses. The findings revealed different teaching approaches and instructional materials were used in in-person and online science laboratory courses. Safety measures in both online and physical laboratories were extensively reviewed. Instructors employed a variety of teaching methods in online and in-person labs. Pictures with captions are dominantly used in the online lab while hands-on activities are mainly implemented for the in-person lab. Students and faculty revealed social presence as a major challenge in online mode while the top-ranked answer for in-person lab is students having different competencies. The data collected were applied to develop an instructional guide recommended to be reviewed before being used accordingly.

Keywords: science laboratory, laboratory instruction, online laboratory, physical laboratory, science teaching

INTRODUCTION

Science laboratory plays a considerably significant role in teaching science (*The Role of Laboratory in Science Teaching | NARST*, n.d.). Laboratory instruction is fundamental since it gives students observation training (George-Williams et al., 2018) and precise information and stimulates their interest. Science teaching and laboratory are intrinsically linked, and practically all teaching techniques include demonstration and laboratory work.

Many studies reveal the relevance of the laboratory in science learning. A study by Antonio (2018) found that teacher education students have a very high interest in laboratory work as it makes them work and discover things on their own, enhances their skills, does not limit their explorations, makes them feel excited and very eager, allow them to discover a lot about things, and create in them a deeper sense of learning whenever they perform. Another study by Sshana, & Abulibdeh (2020) found that practical work in science improved students' academic achievement. It is also reported that a hands-on laboratory component in a chemistry course provides students with a meaningful learning experience (Sadarangani, Serafin, & Chabra, 2024).

Laboratory activities allow students to participate in the process, which improves their teamwork and communication skills (America's Lab Report: Investigations in High School Science' at NAP.edu, n.d.). The performance of laboratory activities that serve the desired purposes is based on the training of teachers qualified to carry out these activities, provided that science lab practices in several studies are not handled correctly, adequately, or effectively (Amolins et al., 2015). The design of pre-laboratory activities strongly influences the critical thinking exhibited by students during their inquiry activities (Brederode et al., 2020).

The values, attitudes, or concepts regarding education that are applied in the classroom collectively constitute a teaching approach. Laboratory instruction can be effective if the teaching approach is appropriate. A student-centered approach is essential for many reasons. It is a method that puts thestudents—rather than the teacher—at the focus of a teaching process (Lathan, 2019). Likewise, this type of teaching puts the learner's interest first. It motivates students to take an active role in their education and act responsibly. Students get the ability to communicate their original thoughts and express themselves. This technique appeals to teachers because it keeps students focused and involved in their work. Higher-order thinking skills are frequently used by students in inquiry-based learning and problem-solving tasks. Students are also allowed to work through their own time.

The teachers face difficulties and challenges in teaching science laboratory courses. A teacher is also a learner. They can impact the students, but this brings a lot of challenges. This study investigated the teachers' laboratory approaches before and after the Covid-19 transition—technological aids for science instruction about productive use of technology in a science lab. The educational institution immediately adopted e-learning as a kind of distance education. Although this technique is effective for delivering content and regulating various procedures, it has limitations in developing practical laboratory skills.

This research developed an instructional guide for science laboratory instruction based on the assessment of science teaching practices and the perception of respondents. Particularly, it investigated the instructional materials used by faculty in teaching both physical and online science laboratory courses. The study also focussed on the aspects that classroom teachers pay attention to in a face-to-face laboratory environment in terms of safety and precautionary measures, pre-laboratory activities, and post-laboratory activities. It also examined the teaching approaches applied in both online and face-to-face science laboratory courses and the challenges faculty and students met.

LITERATURE REVIEW

Students like to be given procedures to follow as well as hands-on lab activities where they strictly observe lab rules and guidelines. They believe a separate laboratory room per Science subject with a laboratory assistant will be conducive to their learning. Concerning faculty, students strongly favor intelligent, buoyant, fair, approachable, and innovative, and act as facilitators during experiments while giving well-planned activities. Statistical correlation tests show there is a correlation between students' grades in Science and the type of laboratory activities. However, their interest in laboratory activities is not correlated to their grades but significantly correlated to their laboratory teacher characteristics.

Fagihi (2018) investigated the awareness of safety measures practiced in school laboratories among the pre-service Science teachers at Najran University. The study also identified the sources of safety measures awareness and whether statistically significant differences occur among the sample responses due to specialization and grade variables. A questionnaire was administered to a sample of (49) students. The findings showed that the pre-service Science teachers have a low awareness level of safety measures. Statistically significant differences were found among the sample responses due to specialization, in favor of

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chemistry, and grade in favor of higher grades. The sources of safety measures awareness include undergraduate courses, faculty members, the laboratory safety manual, and websites.

To determine the effectiveness of using virtual experiments on students' learning in the laboratory, Hamed & Aljanazrah (2020) used the mixed research method wherein an experimental group of 45 students) and a control group of 45 students was used. The results of the study showed that substituting face-to-face theoretical preparation in the general physics lab is at least equally effective as using virtual experiments. Students with virtual components acquired a deeper understanding of concepts and were better prepared for carrying out real experiments. Attending online videos spared students' time and provided them with a more flexible and rich learning environment.

The descriptive-correlational study of Antonio (2018) explored the Science laboratory interests and preferences of pre-service teachers and their implications for Science teaching using a questionnaire. Pre-service revealed a very high interest in laboratory activities. They generally prefer structured and hands-on lab activities using commercial and improvised materials and done collaboratively or by group. They also strictly observe lab rules and guidelines and highly prefer a very good laboratory. They also favor teachers who are highly competent in laboratory instruction. However, pre-service teachers' grades in Science are not significantly correlated with their interest in laboratory activities but is significantly correlated to the type of laboratory activities. Students' interest in laboratory activities significantly correlates to their laboratory teacher characteristics.

Sroczynski (2023) found conducting lab activities in science resulted in students' increased understanding and better learning. Students also enhanced their discourse skills, worked collaboratively with their peers, and were able to connect science concepts to real-life scenarios. Furthermore, laboratory experiments are learner-centered, and they are a tool science teachers can use that results in their students having an increased understanding of abstract science concepts. All these aspects of laboratory experiments result in students having a better understanding of the content and an increased ability to learn science effectively.

The phenomenological study of Duban et al. (2019) explored teachers' practices in science laboratories. The study identified problems such as having no science laboratory in the schools, but some materials were available, which they used in science laboratories. Teachers disclosed they strictly observe safety measures during the laboratory including the use of several tools for safety. Teacher laboratory supervision is enhanced for safety purposes also.

University laboratory courses that were previously hands-on were transformed into remote courses during the COVID-19 pandemic. The mixed-method study of Lee et al. (2023) investigated how 338 public university students in the Republic of Korea perceived their experiences of remote laboratory courses across various disciplines. The researchers also conducted in-depth interviews with 18 students. Statistical tests showed students' perceptions of remote laboratory courses differed significantly by science discipline. Student interviews revealed these differences were due to the different emergent teaching strategies used in each course. The findings led the researchers to suggest that for remote laboratory courses in the post-COVID-19 era, course instructors should set learning objectives, carefully design video experiments, offer collaborative and synchronous online sessions, provide guidance and feedback on lab report writing, and introduce supportive assessments.

Wei et al. (2019) reviewed how interactions have been studied in science education in face-to-face and remote laboratories. The study analyzed 27 articles based on the following themes: the instruments used for measuring interactions, findings on student interactions, and the theoretical frameworks applied. In face-to-face laboratories, instruments for and the characterization of the nature of interactions were prominent. In contrast, remote laboratories lack analysis of direct interactions and are mainly concerned with their practical scope. In addition, it is found that only a limited number of theoretical frameworks have been developed and applied in the research design.

Balta (2025) developed an instructional design model for science laboratory instruction. The study analyzed well-known ID models and used the Dick and Carey model to produce a science laboratory instructional design (SLID) model. To validate the usability of the designed model, 34 high school teachers were surveyed. The survey showed that the mean of the items was extremely high. Statistical analysis of teachers' views about SLID across teachers' gender, subject, and school type showed no significant differences.

RESEARCH METHODS

The study applied descriptive-developmental research. The descriptive procedure of research was used in collecting and analyzing respondents' demographic data, aspects that classroom teachers pay attention to in a laboratory environment, the teaching approaches used in the different science disciplines (biology, chemistry, and physics) laboratory, and the challenges that two groups of respondents met. For the development of the science laboratory instructional guide, the developmental method of research was applied.

The study involved respondents of 5 science laboratory teachers and 225 students from one of the constituent campuses of a state university in the Philippines. Faculty respondents consist of 4 males and 1 female, teaching biology (2), chemistry (2) and physics (2). For the students, 164 or 73% are female and 61 or 27% are male and are enrolled in the following programs: Bachelor of Science in Psychology, Bachelor of Secondary Education Major in Sciences, Bachelor of Science in Criminology, Bachelor of Science in Nursing, Bachelor of Science in Fisheries and Aquatic Sciences, Bachelor of Science in Food Technology, Bachelor of Science in Nutrition and Dietetics.

An identical Likert–type questionnaire was administered to the two groups of respondents of the study. For the survey of instructional materials, a scale of 1-5 was used with 5 – always, 4- very often, 3-often, 2 - sometimes, 1– never. For teaching methods, 5 means very frequently used, 4 means frequently used, 3 is occasionally used, 2 is rarely used and 1 is never used. The responses on challenges were interpreted using 4 as strongly agree, 3 agree, 2 disagree and 1 strongly disagree.

RESULTS AND DISCUSSION

For the instructional materials used in online science laboratory instruction, the investigation indicated that PowerPoint presentations and relevant YouTube videos were predominantly used (3.8 and 3.6 – very often used, ranked first and second). Teachers also revealed that they often (3.2 & 3.0) employ virtual laboratories and simulations Further, a soft copy of the science laboratory manual and workbook were made available to the students and were often (3.2 & 2.8) used to guide them in their activities.

The instructional materials used in online laboratories are also used in face-to-face or physical instruction, with PowerPoint presentations, relevant YouTube, printed laboratory manuals and workbooks cited to be often used. In addition, face-to-face instruction also uses laboratory apparatus, equipment, reagents, and other materials to enrich the students' learning experiences. Bukoye (2019) indicated that the availability of textbooks, proper chalkboards, Mathematics kits, scientific kits, teaching guides, science guides, audio-visual aids, and overhead projectors, among other instructional resources play a significant part in the teaching-learning process.

For the safety and precautionary measures in science laboratories, although it is very seldom that activities are done during the online lab, safety or precautionary measures were presented and reviewed to prepare students for physical activities. Townsend & Goffe (2022) also educated online students in laboratory safety knowing that students will eventually return to in-person laboratory courses. In contrast, physical laboratories require instructors to pay attention to the implementation of safety and precautionary measures. All faculty reported that the necessary measures are implemented in the laboratory to ensure students' safety. The majority of students (92%) observed the availability of protective clothing in the laboratory. Food, drinks, medicine, and cosmetics are not stored or consumed in the laboratory (85%). Students also reported the wearing of proper laboratory attire (95.2%), and the use of gloves (95.2%), which are either cleaned or disposed of after use (99.2%). Students also indicated the practice of handwashing after each laboratory and upon the removal of gloves (99.2%). Works surface and equipment are decontaminated with appropriate disinfectants after any spill or splash (96.8%). Students (94.4%) also reported that access to the laboratory is limited when experiments are in progress. Further, all flammable/combustible chemicals are stored in approved flammable chemical storage cabinets (96%). Likewise, reagent bottles and other materials are property labeled (98.4%).

Teachers conducte different pre-laboratory, in-lab, and post-laboratory activities in both online and in-person labs. In online labs, teachers conduct pre-activity discussions and then the link for the virtual activities will be sent to the students for them to finish the activity within the time allotted given by the instructor. After the completion of the activity follows the post-laboratory discussion.

In the in-person lab, generally, all 5 teachers revealed that they carry out many pre-laboratory activities to facilitate learning and establish safety while the majority of the students acknowledge these efforts of the laboratory instructors. Particularly, before doing physical laboratory activities, students (91.11%) revealed instructors advise them on the preparation they should do before they come to the lab. During the laboratory period, instructors conduct pre-laboratory sessions wherein they disclose the specific learning objectives of the activity to be completed by writing them on the board (72.89%). Efforts are also directed at ensuring students understand the laboratory procedure (91.11%) and they are familiar with the materials and equipment to be used (90.22%). To achieve this objective, teachers are noted to give students a handout highlighting key theoretical, procedural, and safety points (84.88%). They also prepare an outline of the lab activities on the board (70.67%). Instructors also strive to link the lab activities to be done to the counterpart science lecture course (72.45%) to enable them to better understand and appreciate the interdependence of the lecture and laboratory course. Instructors are also keen on giving tips to the students so they can complete the lab successfully within the time allotted (86.22%). A review of the safety considerations (90.22%) is also an essential part of the pre-lab activity. It is also the segment where the criteria to be used in grading the lab reports are disclosed to the students (72.89%).

During ongoing laboratory experiments or activities, science laboratory instructors are also vigilant in monitoring students' safety as they ensure all reagent bottles and other materials are properly labeled – this is as disclosed by 91.2% of the students. Instructors visit each group of students during the lab (69.78%). Concurrently, all teachers demonstrate new techniques to the class or in small groups (77.78%). To avoid confusion, instructors do not hesitate to explain the procedure more than once and they answer questions even though these questions may be considered simple (90.67%). They also ask specific questions to the students to monitor their progress during the lab (81.33%) and provide sample feedback during the lab (79.11%).

Instructors are found to use a variety of teaching methods for both online and in-person laboratories. To teach online science laboratories, instructors employed a variety of methods. Frequently done is using pictures with captions (Students-5.29, instructors-5.00). Another is frequently showing videos or video-recorded demonstrations (Students-5.23, instructors-4.80). Instructors also carry out live demonstrations during online classes (Students-4.56; instructors- 4.80). Activities that can be done at home are required by the teachers to be done by them, which are photographed and included in the report to be submitted (students-4.6; instructors – 4.8). Teachers also employ virtual laboratory software and simulations (Students

– 4.82 frequently and instructors – 4.0 occasionally). The test of significant difference using Mann-Whitney U resulted in a value of 9 at $p < .05$ while the z-test yielded a value of 0.63. Both tests indicate that there is no significant difference between their responses.

For in-person teaching, in particular, students indicated that hands-on activities (3.06), interactive demonstrations (3.02), live discussions (2.96), live instruction (2.96), and just-in-time teaching (3.02) are occasionally done in the laboratory. In contrast, instructors disclosed these methods are done frequently (4.80, 4.60, 4.60, 4.60, 4.60). In summary, students turned in different responses compared to instructors when it came to teaching methods for physical laboratories. This is confirmed by the result of the test for significant differences. The Mann-Whitney U test resulted in a value of 0 at .05 ($p < .05$) indicating a significant difference between the responses of students and faculty. Concurrently, the result of the z-test of -2.51 also confirmed a significant difference at $p < .05$.

Students and faculty meet problems or challenges in online laboratories and in-person laboratories**.** Social presence was regarded as a challenge by both groups (students-3.42, agree; instructors-3.60, SA) with the students rating it the highest among the items. Sadarangani, Serafin and Chabra (2024) study have similar findings as they reveal that the cognitive and the combined cognitive/affective experiences for students in the General Chemistry hybrid and online courses declined.

Equity and accessibility to technology is another challenge with both groups of students and instructors giving almost the same rating (3.39, agree; 3.40, agree). Students and instructors also both disclose that the following are challenges in online laboratories. These are time constraints for covering the lab activity (3.36, Agree; 3.00, Agree), inadequacy of online learning materials (3.25, Agree; 3.00, Agree), lack of training in doing online laboratory (3.11, agree; 3.40, agree), unable to observe student/classmates' contribution to the Laboratory (3.01 agree 3.60 SA), and the negative attitude of students/classmates (2.62 agree; 3.6 SA).

Although it may seem that there is a difference in the mean values of the responses of the two groups, the result of the Mann-Whitney U test of 14 *at* $p < .05$ and the z-test of -1.28 at $p < .05$ indicate that the difference is not statistically significant. This means both students and instructors meet the same challenges in online learning.

Instructors and students agree that the following are the challenges in the in-person science laboratories. The top-ranked answer is students having different levels of competency (3.18, agree; 3.20, agree), which generally affected student learning as they worked in groups. They also unveil that there is insufficient time to study for experiments that require more time (3.00, agree; 3.00, agree). Additionally, both groups require more training on the equipment available in the school laboratory so they can use them optimally (3.00, agree; 3.20 agree). The high student/teacher ratio (2.8, agree; 3.20 agree) is also identified to affect learning adversely and thus a challenge. There are times when there is an inadequacy of tools, devices, and materials to conduct experiments (2.74, agree; 3.00, agree) also surfaced as a challenge. Moreover, students and instructors see it fit to have laboratory assistants (2.75 agree and 3.00 agree). Likewise, the instructor and students' attitude poses a threat to learning. Particularly, instructors treat some science topics to be simple and do not need any experiments to clarify them (2.68 agree and 2.80 agree) while some students have a negative attitude toward doing hand-on activities. (2.62 Agree, 3.60 SA).

The responses of students and instructors were subjected to the Mann-Whitney U test and z-test. Both statistics computed a significant difference with U having a value of 7.5 and z-test with 2.11 at $p < .05$). This value indicates students and instructors have different responses about challenges met in in-person laboratories.

The findings of the study were analyzed and interpreted and then applied to the development of the proposed instructional guide for teaching biology, chemistry, and physics laboratory. The instructional guide contains 7 topics that integrate the findings of the study. Special attention was given to the teaching of the science laboratory, needs assessment in the laboratory, instructional materials required in the science laboratory, frames and tools on how to approach science laboratory instruction, and strategies for teaching science. The researchers tried to manage the challenges revealed in the study in each topic. The output was shown to laboratory instructors for evaluation and comments and the final copy was prepared.

CONCLUSIONS

The study revealed different instructional materials used in both online and in-person science laboratories with PowerPoint presentations, relevant YouTube, printed laboratory manuals, and workbooks cited to be often used in both modes of teaching. Further, different safety and precautionary measures are implemented in physical science laboratories while for online laboratories, although it is very seldom that activities are done, safety or precautionary measures were presented and reviewed to prepare students for physical activities. Faculty and students reveal they carry out different pre-laboratory, in-laboratory and post-laboratory activities. For teaching online science laboratories, instructors and students have the same responses as revealed by Mann-Whitney U value of 9 at $p < .05$ and z-test a value of 0.63. These methods are using pictures with captions, showing videos or video-recorded demonstrations, and live demonstrations. For in-person teaching, students and instructors have different responses – Mann-Whitney U test resulted in a value of 0 at .05 ($p < .05$) and z-test that of -2.51 indicating a significant difference between the responses of students and faculty. In terms of challenges in online and in-person laboratories, Mann-Whitney U test of 14 *at* $p < .05$ and z-test of -1.28 at $p < .05$ indicate there is no significant difference between the students and instructors meet the same challenges in online learning. The data were used in the development of a guide in science laboratory instruction.

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