International Conference NEW PERSPECTIVES in SCIENCE EDUCATION

Investigating the Laboratory Experiences of Chemistry Teachers

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Abstract

The science laboratory is a distinct feature of science education. And laboratory or practical activities plays an important role in implementing the chemistry curriculum for students' understanding of the material world. Achieving the objectives of practical activities in the school curriculum depends on several factors that include teachers' goals, expectations, experiences and their pedagogical content knowledge. In this paper, we explored chemistry teachers' laboratory experiences in implementing laboratory activities. Specifically, features of laboratory-based activities that characterize teachers' practices, and factors that influence their choices to implement laboratory activities were examined. We adapted an online survey instrument to investigate chemistry teachers' laboratory experiences. A paper and pencil form of the instrument was administered to a sample of 155 chemistry teachers, but only 100 participants returned their questionnaires completed. These were coded and analysed. Findings revealed that the mean scores for student-generated research questions and the procedure to guide laboratory-based activities were lower compared to other features. While the frequency of teachers' use of laboratory activities was significantly high, the mean score of factors that teachers identified to have impacted on their choice or decision to implement laboratory-based activities was higher for the availability of chemicals, safety facilities, and laboratory glasswares. The implications of our findings for laboratory inquiry and recommendations are discussed.

Keywords: *Teachers' experiences, Laboratory-based activities, Chemistry.*

1. Introduction

The science laboratory has long been described as a distinct feature of science education [1] [2]. It plays a central role in implementing science curricula for learners' understanding of the material world [3] [4]. And practical activities within the laboratory provide learners with first-hand demonstration of phenomena and *beginner-experience* of what it means to engage in scientific investigations [5] [6].

The relevance of laboratory activities underscores the attention it has continued to receive in several science standards, and recently in the *Framework for K-12 Science Education* [7], and the *Next Generation Science Standards* [8]. For instance, the NGSS document emphasized the need to engage students in scientific practices that include "asking questions, planning and carrying out investigations, analysing and interpreting data" in science learning [8] [9]. While these scientific practices may not necessarily take place within the science laboratory, the laboratory remains central to science learning; as activities therein can provide students with conceptual understanding and motivation to learn science [3]. In this study, laboratory activities are considered as tasks in which students are provided with hands-on experience as they observe, interact or manipulate real objects/materials to understand the material world [3].

2. Literature Review

Researchers have studied the barriers of teachers' beliefs [10] [11], science teacher knowledge [12], and the "impact of expense" on teachers' choices of laboratory activities [9], with an overarching goal to understand and reduce their impact for effective laboratory inquiry [13].

While there are barriers to effective implementation of laboratory activities, some teachers have continued to conduct laboratory inquiry, though, in form of "cookbook" experiments/structured or guided and open inquiry. This is possibly in their recognition of the fact that laboratory activities ought to take place in order to measure its impact on students' learning of science [9] [13].

Regarding barriers that influence teachers' choices to implement laboratory activities, Boesdorfer and Livermore [9] position links up well with the recommendations of the NRC's *Inquiry and National*

Science Education Standards that teachers need necessary support to integrate laboratory inquiry in their instructional practices [14]. Research on teachers' beliefs and practices, their access to curriculum and instructional materials (laboratory apparatuses, glasswares, equipment, chemicals and consumables) that constitute barriers for implementing laboratory inquiry are well-documented [15] [16] [17]. However, studies that draw on teachers' laboratory experiences are not widespread. Advancing support for teachers' need requires research to understand how the availability of instructional materials influence their use of laboratory activities to promote students' learning. Therefore, we explored chemistry teachers' laboratory experiences in implementing laboratory-based activities that can help students develop conceptual understanding of chemical phenomena.

Research questions raised to guide the study are: 1. What features of laboratory-based activities are implemented by chemistry teachers in their instructional practices? 2. What factors influence chemistry teachers' choices of laboratory-based activities? 3. What alternative laboratory-based activities does chemistry teachers use in their classroom practices, and the reasons they use them?

3. Method

A total of 155 chemistry teachers drawn from public and private-owned schools in Ilorin, Kwara State. Ilorin is the State Capital of Kwara–one of the States in the North Central geopolitical zones in Nigeria. Of the 155 chemistry teachers who took part in the study, 74% were females and 26% were males. Only 100 participants returned their questionnaires filled. The teachers taught chemistry to senior school (SS 1 – 3) students. SS 1 – 3 are comparable to Grade 10 – 12 in countries that use grade system.

An online survey instrument developed by Boesdorfer and Livermore [9] to measure teachers' use of laboratory activities in their teaching practices was adapted and administered to the chemistry in a paper and pencil form. The original instrument was designed to have multiple items, Likert-scale, tick all that apply, and open-ended questions. However, we adapted the instrument to align with the context of study, and to ensure that teachers understand the survey items and can respond appropriately.

The instrument elicited teachers' response on the features of laboratory activities they implement in their instructional practices, factors that can possibly influence their choices of laboratory activities and the reasons for what they do during laboratory activities (for the original instrument, see [9]). To ensure the validity of the instrument, two science educators reviewed and provided feedback used to improve the instrument. The quantitative data collected for this study were teachers' self-report of laboratory experiences in implementing laboratory activities. The instrument was administered directly and retrieved from the teachers. Each teacher took about 15 minutes to complete the questionnaire. Upon completion, questionnaires were coded in Excel and export to SPSS v. 25 for analysis.

4. Results and Discussion

The results of the analysis and discussion of each of the three research questions are presented in the following sections.

Table 1 presents the mean scores and standard deviation of the features of laboratory-based activities chemistry teachers implement in their instructional practices. From the result of our analysis, higher mean scores indicate the activities students are engaged with *more often*. The results revealed that students engaged in laboratory activities where they work with chemicals, laboratory glass wares and apparatuses, follow a set of given instructions, take measurements and make observations. The teachers further indicate that students answer post-lab questions (M = 3.89) and are required to wear safety equipment (M = 3.73), discuss findings as a class. However, students are provided with research questions and required to support their conclusions with evidence more often than they make predictions (M = 3.34), generate research questions (M = 3.12) and develop or create a procedure to guide a lab-based activity (M = 2.96). The teachers' responses to these items indicate that students carry out laboratory activities that require these skills only sometimes, but not often.

Table 1. *Mean Score and Standard Deviation of Laboratory-based Activities Implemented by the Chemistry Teachers*

Statement	**Mean (N = 100)**	***SD***
Students work with chemical substances (e.g., HCl, NaOH).	4.20	0.817
Students work with laboratory glasswares and apparatuses.	4.24	0.854
Students are required to wear safety equipment.	3.73	1.120

Students discuss findings as a class.	3.73	0.983
Students follow a set of given instructions.	4.16	0.992
Students make predictions.	3.34	1.139
Students take measurements.	4.07	1.008
Students make observations.	4.07	0.913
Students generate research questions.	3.12	1.216
Students create a procedure.	2.96	1.127
Students are provided with questions to guide investigations.	3.66	1.291
Students are required to support conclusions with evidence.	3.66	1.148
Students answer post-lab questions.	3.89	1.145

The features of lab-based activities with higher mean scores shows that teachers engage their students with regular hands-on experience of chemical phenomena. The extent to which these hands-on experiences align with current best practices as articulated in science reform standards and the NGSS document remains unclear [8] [14]. Classroom observations as further probes of how teachers enact lab-based activities would have provided a deeper insight. However, we will assume that these activities are not the traditional laboratory activities. This result is consistent with the report of Boesdorfer and Livermore [9] where majority of the chemistry teachers engage their students with laboratory experiments. The lower mean scores for students-generated research questions and developing a procedure to guide an experiment further queries our assumption that the laboratory activities teachers claim to enact may as well be traditional in nature. However, researchers have maintained that engaging students to ask investigable questions are the real drivers of scientific investigations [18], but majority of the chemistry teachers admitted that students are provided with research questions in laboratory activities.

To answer research question 2, Table 2 present factors that teachers considered to influence their choices of laboratory-based activities in their instructional practices. Teachers indicated the availability of chemicals or substances as a factor that impacted their decisions the most. Others include laboratory glasswares (e.g., beakers, graduated cylinders), safety equipment, available procedural instructions and comfort in laboratory setting. Factors with lower mean scores such as funds for waste removal and for materials are reported to rarely affect the teachers' choices to implement laboratory-based activities. For other factors with mean score > 2.5, it suggests that such factors influenced teachers' choices of the laboratory-based activities to implement.

Table 2. *Mean Scores and Standard Deviation of Factors that Influence Chemistry Teachers' Choices to Implement Laboratory-based Activities*

Factor	**Mean (*N* = 100)**	***SD***
Safety equipment	3.19	.896
Available chemical substances	3.41	0.754
Laboratory equipment (e.g., pH metre, analytical balance).	2.98	0899
Laboratory space	2.92	1.002
Laboratory glasswares (e.g., beakers, conical flasks, graduated cylinders)	3.21	0.891
Available laboratory procedural instructions	3.11	0.90
Adequate preparation time	2.99	0.847
Class time	2.99	0.916
Available safety warnings	2.94	0.930
Available materials that can be borrowed	2.50	1.020
Available waste removal instructions	2.37	0.895
Funds for waste removal	2.34	0.945
Funds for materials	2.71	0.913
Comfort in laboratory setting	3.08	0.992
Others (if any)	2.90	0.992

Teachers' indications of availability of chemicals or consumables, glasswares, safety facilities and the comfort of the laboratory settings as factors that influence their choices of lab-based activities suggest that where these are not readily available, laboratory activities may not likely to take place. The implementation of lab activities, to a large extent, depends on the availability of materials. The nature of these factors require that school administrators provide teachers with necessary and consistent support in terms of supplies of consumables and equipment, and of course, professional development in its different forms [14]. since teachers indicated procedural instructions as barrier to laboratory activities, we may infer that the initial teacher education may not have given adequate attention to teachers' preparation in terms of designing and enacting laboratory activities.

To answer research question 3, Table 3 presents the mean scores and standard deviation of alternatives to laboratory-based activities that chemistry teachers engage their students with. A higher mean score for teacher demonstration shows is an indication that it is the most frequently used alternative to laboratory-based activities that chemistry teachers revert for non-availability of laboratory facilities and consumables. The frequency of teachers' demonstration is reported to be more than three times *per* term (*M* = 3.24). They also engage their students 2-3 times in the analysis of provided data (*M* = 2.61). Other alternatives such as film experiments (*M* = 2.27), simulated laboratory experiment (*M* = 2.45) and other videos are not usually carried out up to three times *per* term.

Table 3. *Mean Scores and Standard Deviation of the Alternative Activities Implemented by Teachers*

Non-laboratory-based activities	**Mean (*N* = 100)**	***SD***
Filmed experiments	2.27	0.633
Analysis of provided data	2.61	0.723
Simulated laboratory experiments	2.45	0.642
Teacher demonstration	3.24	0.818
Other videos	2.40	0.735

Table 4 provide reasons why teachers implement alternatives to laboratory-based activities. The chemistry teachers indicated that they conduct non-laboratory-based activities to complement for students' learning if the activities require lesser materials, considered more valuable and for the financial implications. However, less than 50% of the teachers choose these non-laboratory-based activities for preference or time factors, safety restrictions and easy of assess to relevant materials.

Table 4. *Percentage Distribution of Reasons for Implementing Non-laboratory-based Activities*

Reason	***Percentage**
I use them because they are more valuable to students' learning	42.00
I use them because I prefer them	24.00
I use them because they save time	12.00
I use them because they require fewer materials	71.00
I use them because they save money	63.00
I use them because there are no safety restrictions	4.00
I use them because it is easier to access necessary materials	3.00
I use them to supplement my other classroom activities and lessons	69.00

Note. *Percentages do not total 100 since the participants selected as many reasons as possible.

Our definition of laboratory-based activities suggests activities that gives priority to student-centred learning of science. However, the indicated alternatives to laboratory-based activities that chemistry teachers often revert to cannot be considered to reflect this idea for students' understanding of the material world. The result in Table 4 invoke a reason to question whether the hands-on experiences that students are engaged in during practical work are not traditional or laboratory inquiry or reform-based [8] [14]. While chemistry teachers indicated that their choices of alternatives to laboratory-based activities was because such activities require fewer materials and as supplemental for learning, more than 50% of the teacher opted for these alternatives during their instructional practices for the reason of material cost. This result contradicts the findings of Boesdorfer and Livermore's [9] study, where monetary reason has less impact on teachers' choices of non-laboratory activities. We assume that what accounted for this difference is that not much funding is provided in the government's yearly budget for education.

5. Conclusion

The study explored the laboratory experiences of chemistry teachers in order to understand the nature of activities that characterize their laboratory activities during instruction and factors that often informs their choices of laboratory-based activities. Although teachers claim to engage students in laboratory-based activities, these activities seem to have a semblance of guided inquiry or traditional laboratory activities for the fact that teachers provide students with research questions to guide their experiments. While we may not completely label these experiments as "cookbook," we can as well conclude that the laboratory activities implemented for students' learning of chemistry does not seem to reflect the development of skills and practices advocated for in science reform documents [8] [14]. The barrier of funds for laboratory materials often influence teachers' choices to revert to alternatives of teacher-led demonstration and analysis of provided data. While we may not have explored the impact of teachers' training on laboratory use, the evidence that teachers require procedural instructions to implement laboratory-based activities is a deficit in teachers' knowledge that requires support through professional development programmes.

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