Senior Secondary School Chemistry Students' Knowledge of Basic Laboratory Equipment Functions and Chemical Storage Procedures

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Abstract

The study examined the knowledge of basic equipment functions and chemical storage procedures among Senior Secondary School Three (SSS3) chemistry students in the chemistry laboratory. A survey research design was employed to sample three hundred and twenty (320) SS3 chemistry students from eight secondary schools in four Local Government Areas in Oyo State, Nigeria. The instrument used for the study was a structured questionnaire focusing on the functions of basic equipment and chemical storage procedures in a chemistry laboratory. Three science educators validated the instrument for content and construct validation. The validated and reliable instrument was administered to the students during the May/June 2025 West African Secondary School Certificate Examination (WASSCE). The students' responses to the instrument were scored, and the data were analysed using descriptive statistics to answer the research questions and inferential statistics of the independent samples t-test, were also employed to test hypotheses. The results indicated that the students had 44.5% knowledge of basic equipment functions and 25.27% knowledge of chemical storage procedures. There was no statistically significant difference in the students' knowledge of basic equipment functions and chemical storage procedures between male and female students. The students had better knowledge of the basic equipment functions than of chemical storage procedures. Early practical exposure for chemistry students to hands-on activities and adequate training in the use of basic equipment and laboratory practices are crucial for acquiring both theoretical and practical skills, as well as for ensuring safety and efficient work in the chemistry laboratory.

Keywords: Equipment functions, laboratory, storage procedures and students' knowledge.

Introduction

A science laboratory is a specialised area in an educational setting where students can conduct experiments, practice science, and acquire knowledge, skills, and understanding of scientific processes. It is a place where students can handle equipment and tools and follow protocols for safe and successful science activities. It is a place where students align the theoretical concepts to practical activities for better understanding.

Adeoye (2022) identified some basic equipment in a science laboratory. Some of the basic science laboratory equipment includes beakers, pipettes, burettes, test tubes, watch glasses. funnels, clamps and retort stand, tripod stands, conical flasks, volumetric flasks, crucibles, and mortars and pestles. Students must understand the functions of basic laboratory equipment to use them effectively in the laboratory. A lack of awareness of specific rules and regulations governing laboratory operations can lead to laboratory accidents. Some of these rules and regulations includes water should not be added to concentrated acid on its dilution, sodium metal should not be exposed but should be submerged in kerosene or mineral oil like palm oil to prevent its explosion, and students should not handle or operate any laboratory equipment with which they are familiar with their usages. Students are required to wear protective devices, including gloves, laboratory coats, and eye protection. There should be no eating or drinking in the laboratory. Students who adhere to laboratory rules and regulations will promote a healthy working environment free of hazards and accidents.

Literature Review

Piaget (1970) explained learning as the construction of knowledge from experience. According to Vygotsky (1978), learning occurs in a social context through interaction with others and various materials. Lave and Wenger (1991) situated learning theory emphasised that knowledge is constructed in the context where it is applied. These learning theorists' ideas about laboratory practices hold that students acquire scientific knowledge and laboratory skills through active participation and interaction with laboratory materials and personnel.

Students' knowledge of basic laboratory equipment and chemical storage functions is crucial for ensuring safe, effective and meaningful learning in science, especially in chemistry. Alack of understanding of equipment functions and chemical storage procedures can lead to accidents, injuries, or chemical contamination (Occupational Safety and Health Administration, OSHA, 2020). Understanding the functions of basic laboratory equipment improves hands-on skills and enhances students' confidence in practical classes. It enables students to use the appropriate tools for specific tasks, resulting in accurate results in practical work. It prevents time wasted on improper use, making lessons more efficient and effective. Understanding storage procedures helps prevent unwanted chemical reactions, spills, and chemical degradation caused by improper storage conditions. Assessing students' knowledge of equipment functions and chemical storage procedures supports the science curriculum's goals and assessments. It helps teachers tailor lessons to meet curriculum standards and prepare students for assessments. It promotes scientific literacy, lays a foundation for students to become responsible future scientists, and encourages accountability and good laboratory practices, which are essential to academic and scientific professions (Abrahams & Millar, 2008; National Science Teaching Association (NSTA), 2021). In 2011, the National Safety Council (NSC), Ma et al. (2022), and Nasrallah et al. (2022) found that the causes of working accidents included unsafe behaviours, conditions, and a lack of knowledge and skills regarding laboratory equipment.

Restiana and Djukri (2021) found that biology students' knowledge of the functions and procedures for using laboratory equipment was adequate for high school in Yogyakarta, Indonesia. However, the findings revealed that students' knowledge of categorising laboratory materials used in the practices of specific science subjects was poor. Caymaz (2021) found that students had adequate general knowledge of laboratory safety but exhibited deficiencies in laboratory behaviours. The study also reported that the students were unaware of safety symbols in science and demonstrated a lack of competence in laboratory safety.

Aliyo et al. (2023) found that very few students, fewer than the average, practised safety in the laboratory regularly, while others did occasionally, and some never practised safety. It was also found that many students were not inspected for laboratory safety and did not receive training in it. Furthermore, a lack of safety manuals, drainage systems, adequate water flow, and ventilation was observed in the teaching laboratories. Okebukola et al. (2021) investigated chemical safety awareness and practices in Nigeria and found that students in rural schools had lower levels of awareness than those in urban schools. However, urban students breached chemical safety practices more than students in rural schools. The study observed low levels of chemical resources, poor chemical safety training among teachers, inadequate safety equipment, and a lack of enforcement of safety rules and regulations.

Ansah et al. (2024) evaluated the status and availability of safety equipment, as well as the awareness and understanding of safety measures among Ghanaian pre-service science teachers. The study found significant deficiencies in laboratory safety equipment, a lack of essential safety equipment, gaps in safety practices, and low student awareness levels. Mensah et al. (2020) noted that the availability of safety equipment and materials was compromised when they were improperly used due to students' inadequate training.

Ismail and Pernadi (2022) opined that familiarising students with laboratory equipment before the practicum facilitates effective practice. It was recommended that students be familiar with the names and functions of laboratory tools, maintain a safe work area, prevent accidents, and avoid failures in practical experiments to ensure the smooth running of the experiments. Laboratory equipment can be damaged or hazardous if not used according to laboratory procedures.

Iyamuremye et al. (2023) examined students' experiences, engagement, and academic achievement in practical activities and found that engagement positively affected practical work, contributing significantly to academic achievement. However, there was no significant difference in the effect of gender and school types on academic achievement. Musa et al. (2022) also emphasised the importance of chemistry practicals in enhancing the performance of chemistry students in public secondary schools.

Statement of the Problem

Practical laboratory work is crucial for science education, particularly in chemistry. However, laboratory observations indicate that many secondary school students lack an understanding of how basic laboratory equipment functions or the chemical storage procedures required for efficient work and safety in the laboratory. This lack of knowledge makes it difficult for students to conduct experiments correctly and safely, which can lead to serious safety issues. Inappropriate use of laboratory equipment and inadequate knowledge of chemical storage procedures can lead to chemical accidents and contamination and may negatively impact students' learning. To acquire basic theoretical and practical skills in chemistry, to meet society's needs for employment and wealth, and to take advantage of the numerous opportunities that chemistry offers, knowledge of laboratory equipment and practices is crucial for chemistry students (Federal Ministry of Education, 2007). However, there is little evidence to show how well students grasp and apply this knowledge in real laboratory settings. Therefore, it is crucial to explore students' understanding of how laboratory equipment functions and how chemicals are correctly stored in the laboratory. This can help identify learning gaps and create a safer, more effective learning environment for science.

Purpose of the Study

The main objectives of the study were to:

1. Examine the Senior Secondary School Three (SSS3) chemistry students' knowledge of the basic equipment functions in chemistry.
2. Determine Senior Secondary School Three (SSS3) chemistry students' knowledge of chemical storage procedures in chemistry.
3. Investigate the differences in the knowledge of basic equipment functions and chemical storage procedures in chemistry among male and female Senior Secondary School Three (SSS3) students.

Research Questions

The questions raised for the study were:

1. What is the achievement of the Senior Secondary School Three (SSS3) chemistry students in the knowledge of the basic equipment functions in chemistry?
2. What is the achievement of the Senior Secondary School Three (SSS3) chemistry students in the chemical storage procedures in chemistry?
3. What is the difference in achievement of the Senior Secondary School Three (SSS3) chemistry male and female students in the knowledge of the basic equipment functions in chemistry?
4. What is the difference in achievement of the Senior Secondary School Three (SSS3) chemistry male and female students in the chemical storage procedures in chemistry?

Research Hypothesis

The formulated hypotheses at the 0.05 level of significance for the study were:

1. There is no significant difference between the achievement of the Senior Secondary School Three (SSS3) chemistry of male and female students in the knowledge of the basic equipment functions in chemistry.
2. There is no significant difference in the achievement of Senior Secondary School Three (SSS3) chemistry between male and female students in the chemical storage procedures in chemistry.

Methodology

A survey research design was employed to assess students' knowledge of basic equipment functions and chemical storage procedures in the chemistry laboratory. The study population consisted of Senior Secondary School Three (SSS3) chemistry students from four Local Government Areas in Oyo State, Nigeria. Two senior secondary schools were randomly selected from each Local Government Area, for a total of eight schools sampled for the study. Forty (40) students were randomly sampled from each school, and the total sample was three hundred and twenty (320) students. The SS3 students were sampled for this study because the researchers believed they had acquired sufficient knowledge of laboratory practices and the functions of basic chemistry equipment in the chemistry laboratory.

The research instrument consisted of a questionnaire divided into two sections, A and B. Section A consisted of fifteen (15) multiple-choice items with four options. It measured the functions of basic chemical equipment, including a pipette, burette, fume cupboard, test tube, tripod stand, conical flask, measuring cylinder, mortar and pestle, crucible, funnel, watch glass, desiccator, clamp, and retort stand. Section B contained ten (10) multiple-choice items, with four alternatives covering the chemical storage procedures that required students to choose the correct answer. For each option, students were to provide a reason for their choice. ChatGPT (OpenAI, 2023) was used to generate the instrument's content. The contents were modified to construct the research instrument.

Each correct option of the multiple choice attracted one (1) mark, and the reason for the chosen option in Section B attracted two (2) marks to make a total of three (3) marks for each question in the section. The total marks for Sections A and B were fifteen (15) marks and thirty (30) marks, respectively.

The instrument was validated for construct and content validity by three chemistry educators and pilot tested in a secondary school. The internal reliability of Sections A and B using Cronbach's Alpha and Kuder-Richardson Formula 20 (KR-20) were 0.83 and 0.84, respectively.

The validated and reliable research instrument was administered to the sampled SS3 students during the West African Senior School Certificate Examination (WASSCE) in May/June 2025, a few days before the chemistry theory examination. The researchers and the chemistry teachers in the sampled schools administered the questionnaires to the students.

The students' responses were scored, and the data were recorded for analysis. Descriptive statistics were employed to calculate the mean, standard deviation, and standard error, while an inferential statistic, Levene's test for equality of variance and an independent samples T-test, were conducted. The results of the analyses are as presented.

Results

Table 1

The mean, standard error and standard deviation for SS3 students' knowledge of laboratory equipment functions and chemical storage procedures.

Variable	Gender	N	Mean	Standard Deviation	Standard Error
Knowledge of Laboratory equipment functions	Male	140	6.69	3.001	.254
	Female	180	6.67	2.719	.203
Chemical storage procedures	Male	140	3.53	1.980	.167
	Female	180	3.99	2.258	.168

Table 2

The Levene's and the Independent Samples T-test for equality of variance and means of male and female SS3 Students.

Levene's test for equality of variance				Independent samples T-test equality of means			
Variable	Factor	F	Sig.	T	Sig.(2-tailed)	Mean difference	Std. Error
Knowledge of laboratory equipment functions.	Equal variance assumed.	.505	.478	.064	.949	.021	.321
	Equal variance not assumed.			.064	.949	.021	.325
Chemical storage procedures.	Equal variance assumed.	.884	.348	-1.931	.054	- .466	.241
	Equal variance not assumed.			-1.963	.051	-.466	.237

The Levene's test values of F = .505, p = .478 for equal variance assumed for knowledge of equipment functions and F = .884, p = .348 for chemical storage procedures, were not statistically significant. The assumption of equal variances was met to use the independent-samples t-test.

The findings from the analyses based on the research questions as shown in Table 1, are as follows:

1. What is the mean achievement of the Senior Secondary School Three (SSS3) chemistry students' knowledge of the basic equipment functions in chemistry?

   The mean achievement of SSS 3 chemistry students was 6.68, accounting for 44.5% of the total score.

2. What is the mean achievement of the Senior Secondary School Three (SSS3) chemistry students' knowledge of the chemical storage procedures in chemistry?

   The mean achievement of SSS 3 chemistry students in chemical storage procedures was 3.79, accounting for 25.27% of the total score.

3. What is the difference in mean achievement of the Senior Secondary School Three (SSS3) chemistry male and female students' knowledge of the basic equipment functions in chemistry?

   The difference in mean achievement between male and female students regarding their knowledge of basic equipment functions in chemistry was 0.02.

4. What is the difference in mean achievement of the Senior Secondary School Three (SSS3) chemistry male and female students' knowledge of chemical storage procedures in chemistry?

   The difference in the mean achievement of male and female students regarding chemical storage procedures in chemistry was 0.46.

Answer to Research Hypotheses

The findings from the analyses based on the research hypotheses as shown in Table 2, are as follows:

1. There is no significant difference between the achievement of the Senior Secondary School Three (SSS3) chemistry of male and female students' knowledge of the basic equipment functions in chemistry.

   There was no statistically significant difference in the achievement of male and female students in their knowledge of the basic equipment functions in chemistry ($t_{(318)} = .064$, $p > 0.05 = .949$).

2. There is no statistically significant difference in the achievement of Senior Secondary School Three (SSS3) chemistry between male and female students' knowledge of chemicalstorageprocedures.

There was no statistically significant difference between the achievement of male and female students' knowledge of chemical storage procedures ($t_{(318)} = -1.931$, $p > 0.05 = .054$).

Discussion of the Findings

The SSS3 chemistry students demonstrated a fair knowledge of the functions of the basic laboratory. This was because the students had a below-average score on the equipment functions questionnaire. This indicated that students lacked adequate knowledge of the proper usage of some basic equipment in the chemistry laboratory. It was expected that the students, with the three years of learning chemistry in senior secondary school, they would have familiarised themselves with the uses of the basic equipment like beaker, test-tube, pipette, burette, funnel, conical flask, watch glass, evaporating disc, measuring cylinder, watch glass, desiccator, fume cupboard, test-tube, mortar and pestle, crucible, clamp and retort stand that were examined. Properly, the students might have had difficulty identifying the basic equipment, as they cannot adequately determine the appropriate use of some of it. This finding was not supported by Restiana and Djukri (2021), who found that biology students' knowledge of the functions and procedures for using laboratory equipment in Yogyakarta, Indonesia, was adequate.

The study also revealed that SS3 chemistry students demonstrated poor knowledge of chemical storage procedures in the chemistry laboratory. This understanding may pose significant risks to students' safety and health, and limit their effectiveness in laboratory activities, negatively affecting their understanding of scientific concepts and acquisition of skills necessary for manpower development. The findings provide suggestions for targeted interventions in teaching methods, curriculum design, and practical training for both teachers and students on various laboratory practices. This finding suggests that students' failure to identify laboratory tools correctly may lead to an unsafe working environment, an increased risk of accidents, and ineffectiveness in practical activities (Ismail and Pernadi, 2022).

The students also demonstrated a very poor understanding of chemical storage procedures. They possessed little knowledge of storge procedures for silver nitrate, sodium metal, sodium hydroxide pellets, volatile and flammable solvents like ethanol or acetone (2-propanone), concentrated trioxonitrate (V) acid, HNO_3, concentrated ammonia, dilution of concentrated tetraoxosulphate (VI), H_2SO_4. They failed to identify the chemical to be stored in a desiccator among the chemicals provided. These findings imply that the students were neither aware of the laboratory safety procedures nor practised safety measures related to chemicals, as reported by Okebukola et al. (2021).

Improper chemical storage can lead to chemical reactions, e.g., storing a base near an acid can cause a reaction between the base and the acid, producing a salt and water (neutralisation). Explosions and fires can occur when sodium metal is exposed to moisture and air. Toxic gases from chemical reactions, such as ammonia (NH3), carbon (II) oxide (CO2), and sulphur (IV) oxide (SO2), can cause irritation and health issues. Reactions that liberate the poisonous gases should be performed in the fume cupboard, and the laboratory should be well ventilated. Some chemicals are sensitive to light, moisture, temperature, and air, causing their degradation and environmental pollution. Many students not only failed to identify where some chemicals could be stored in the laboratory but also failed to provide adequate reasons for the storage procedures for those chemicals.

The finding also indicated no significant difference in the knowledge of male and female chemistry students in the functions of basic laboratory equipment and chemical storage procedures. That is, both male and female chemistry students had the same level of knowledge in the two variables, equipment functions and storage procedures. This finding implies that both male and female SS3 students had deficiencies in laboratory use and in chemical storage procedures.

Conclusion

The students' achievement was not encouraging. These students' achievements in laboratory practices may reflect their overall achievements in chemistry. Methods of teaching chemistry, students' interest and attitude to chemistry learning, and inadequate laboratory facilities may be reasons for their achievement.

Recommendations

The following are recommended to enhance students' knowledge of laboratory practices and the functions of laboratory equipment.

1. Secondary school chemistry teachers should regularly incorporate laboratory activities into chemistry teaching to allow students to acquire hands-on experience with equipment andchemicalstorageprocedures.
2. Teacher professionalism should be enhanced through training and retraining by organising workshops or seminars, periodically on laboratory safety, equipment identification, usage, and handling chemicals and proper chemicalstoragetechniques.
3. Science curricula should emphasise and implement specific learning outcomes on laboratory safety, laboratory rules and regulations, equipment functions and proper storage practices at all levels of education.
4. Secondary schools should be well-equipped with functional laboratories, complete with laboratory tools, and increase students' access to laboratory resources, not just during examinations,asiscurrentlythepractice.

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