International Journal of Educational Management and Development Studies
Volume 6 Issue 2 June 2025
DOI: https://doi.org/10.53378/ijemds.353210

An exploration on applied experiments in natural science education

Benkosi Madlela

Abstract

The study explored the application of experiments in natural science education. An interpretivist research philosophy guided the data collection process and it allowed the researcher to use a qualitative research approach. This approach made it possible for the researcher to go to schools and understood the phenomenon from the participants' point of view and experiences. Participants had detailed information as they were the ones who applied experiments on a daily basis as they conducted their duties. The case study design enabled the researcher to focus on five schools and studied them in-depth to generate rich information for the study. Findings showed that experiments are an effective instructional method that motivated learners and enhanced their understanding of scientific concepts. They improved learners' participation and attitudes towards learning science. Findings also showed that the application of experiments in NS faced challenges such as shortage of laboratories, apparatus, equipment, materials and chemicals. Other challenges included large classes and less time allocation for science in the time table. The study recommended that the Ministry of Basic Education, schools and stakeholders should build adequate laboratories and fully equip them with necessary resources. If there are no materials teachers should improvise with resources available in their local environments to conduct experiments. Schools in collaboration with the Ministry should train science teachers and equip them with skills and knowledge of designing and implementing experiments or improvising if there are shortages of resources. Schools should use educational technologies in the application of experiments in natural science subjects.

Keywords: *experiments, education, applied, science*

Article History:

Received: *September 23, 2024* ***Revised***: *November 18, 2024*
Accepted: *May 20, 2025* ***Published online***: *June 5, 2025*

Suggested Citation:
Madlela, B. (2025). An exploration on applied experiments in natural science education. *International Journal of Educational Management and Development Studies*, 6(2), 188-209. https://doi.org/10.53378/ijemds.353210

About the author:
Dr Benkosi Madlela is Postdoctoral Research Fellow at the University of Johannesburg. Email: benkosimadlela@gmail.com

1. Introduction

Experiments are one of the key methods of instructional delivery in Natural Science (NS) and other science subjects. Bouzit et al. (2023) view scientific experiments as contributing to the development of a set of learners' cognitive, psychomotor and methodological skills. Experimental practice in the science class represent a break from theoretical pedagogies, as it provides learners with active learning and promotes their comprehension of concepts and development of technical and methodological skills. Laboratory activities increase students' curiosity and positive attitudes toward science (Bretz et al., 2013). Improving the teaching and learning of NS through the use of experiments aligns with sustainable development goal number 4 that advocates for quality education. The United Nations General Assembly in 2015 adopted the 2030 Agenda for Sustainable Development where for the first the role of science, technology and innovation was explicitly recognised as a vital driver of sustainability. Sustainability depends on the capacity of states to put science at the heart of their national development strategies. To achieve this, science should be strengthened at grassroots school level through employing effective instructional methods like experiments.

Kotsis (2024) notes that experiments are crucial in inquiry based science since they provide learners with practical experiences that develop their critical thinking abilities and enhance their comprehension of scientific concepts. They allow learners to formulate and test hypotheses, access data and make conclusions based on supportive evidence. Learners who participate actively in science learn more about science and gain valuable skills that are necessary for success in the 21st Century. The NS curriculum aims to enable learners to complete investigations, analyse problems and use practical processes and skills in evaluating solutions. This encourages learners to ask questions that could lead to further research and investigation (Department of Basic Education – DBE, 2012). Investigations enable learners to develop scientific process skills that are used by scientists to find out about the world and to solve problems. The DBE (2012) advises NS teachers to use practical experiments in class to enable learners to identify problems and develop questions, formulate hypotheses and design an experiment that will help them to test the hypotheses, observe and record their observations. At the end of the investigation process learners should communicate their findings. This improves learners' attitudes, motivation and interests in the NS subject (DBE, (2012).

Based on this background the study explored how experiments are applied by NS teachers in class, and generated strategies for the effective application of experiments in the teaching and learning of NS. The study was conducted to assess the applied experiments in the teaching and learning of NS and the strategies that can be used to promote effective use of experiments.

2. Literature Review

2.1. Theoretical Framework

The study is grounded on Gardner's multiple intelligence theory. This psychological and educational theory was proposed in 1983 by Dr. Howard Gardner, a Professor at Harvard University (Prakash, 2022). Gardner believes that intelligence is not a single entity, but different types of intelligences exist in the human mind. Prakash (2022) argues that Gardenr initially identified seven core intelligences in his book entitled "Frames of Mind," and he later added two types of intelligence to the theory in his book entitled "Intelligence Reframed." Sener and Cokcaliskan (2018) assert that Gardner's multiple intelligence theory helps educators to distinguish different learning styles among students. Each learner applies the material taught in the classroom according to his or her dominant intelligence and learning style with which the learner learns most effectively. According to this theory, combining learning styles with dominant intelligences enhances learning processes among the learners (Sener & Cokcaliskan, 2018).

Gardner's categories of intelligences are identified by Prakash (2022) as verbal-linguistic intelligence, logical-mathematical intelligence, visual-spatial intelligence, bodily-kinaesthetic intelligence, musical-rhythmic intelligence, interpersonal intelligence, intrapersonal intelligence, naturalistic intelligence and existential-spiritual intelligence. Aina (2018) encourages physics teachers to adopt multiple intelligences theory to enable all categories of learners to benefit from teaching. Different challenges that learners encountered in the learning of Physics are attributed to the teachers' inability to understand and apply multiple intelligences.

Unlike other instructional methods such as the teacher centred lecture method, experiments if used properly are capable of promoting the application of Gardner's multiple intelligence theory in the science class. Experiments appeal to learners' multiple intelligences and senses. In the study conducted by Madlela and Umesh (2024), science teachers said that experiments cater for textile and visual learners and those who learn better by doing. This means that learners have different intelligences, as a result, teachers should use instructional methods such as experiments that appeal to learners' different intelligences. Alsalhi (2020) found that the intelligences represented in the science textbook were mostly verbal/linguistic, visual/spatial, and logical/mathematical intelligence, with a combined percentage of 73.3%. The other 26.7% was distributed between interpersonal intelligence, intrapersonal intelligence, bodily/kinesthetic intelligence, natural intelligence, and musical intelligence. Proper use of experiments in class covers almost all these intelligences since conducting of experiments requires logic, psychomotor, linguistic, visual and interpersonal skills.

Morgan (2021) argues that Gardner in a 1997 interview about his theory said whatever learners learn at school is likely forgotten unless they play an active role. To be active requires them to ask questions, participate in hands-on activities, and recreate and transform information as needed. Gardner argued that learners can perform well in examinations by memorising information which they will likely forget after a few years. In contrast, learners who make a prediction, conduct an experiment, analyse data, and see the results develop skills and knowledge likely to last for a much longer period (Edutopia, 2009). The DBE's (2012) National Curriculum Statement Grades R-12 aims to produce learners who are able to work effectively as individuals and with others as members of a team, collect, analyse, organise and critically evaluate information, communicate effectively using visual, symbolic and/or language skills in various modes. Experiments provide a realistic platform for the achievement of all these aims that are aligned with different intelligences of Gardner's theory. The DBE (2012) further states that inclusivity should be prioritised in teaching and learning in schools where teachers should plan for diversity. Different intelligences in Gardner's theory and experiments address learners' diverse learning needs. They cover learners' different abilities of learning such as learning through listening, learning through involvement and doing and learning through visual observation. This fosters inclusivity and accommodates diversity in a science class.

2.2. Importance of Experiments in Science

Wei and Chen (2020) assert that the term experiment is used in different ways to mean different things in school science. Hofstein et al. (2013) note that the three terms, experiment, practical work and laboratory work are often interchangeably used and they generally refer to experiences in which students engage in various hands-on activities or investigations involving scientific equipment or apparatus. In Shamsudina et al. (2013) view, experiment is the core of doing investigation in the science classroom. Learners get opportunities to manipulate objects, test hypothesis, and work together to solve a problem or prove something exciting. This enables learners to learn through multiple senses leading to better understanding of concepts.

Research has proven that experiments are effective in the teaching and learning of science. Dhanapal and Shan's (2014) mixed study examined the effectiveness of hands-on experiments in the learning of science indicated that most learners got better results as they learnt and remembered better through hands-on experiments. The level of participation and motivation increased as learners learnt through hands-on experiments (Dhanapal & Shan, 2014). Similarly, Sshana and Abulibdeh (2020) found a positive correlation between practical work and the academic attainment of most learners in science. While Abdi (2014) emphasises that learners who were instructed through inquiry-based learning achieved higher scores than the ones who were instructed through traditional methods, Raymond and Wong (2018) found classroom experiments can improve student learning outcomes when conducted before the relevant concepts are covered. Experiment participation has a positive influence on learners' performance in the examination questions related to the classroom experiment. Learners not only gained valuable learning experience and knowledge in the topic but their interest in the subject content was stimulated.

Kotsis (2024) argues that experiments are essential in inquiry-based science education because they give learners practical experiences that enhance their comprehension of scientific concepts. Carrying out experiments enable learners to use scientific methods to record data, make observations, and develop conclusions supported by evidence. This assists learners to understand scientific methods better and develop critical thinking abilities. Experiments create a more memorable educational experience by allowing learners to interact directly with the subject matter. This shows that experiments are effective in science education, creating a dynamic and engaging learning environment that encourages scientific literacy, curiosity, exploration and deeper learning.

2.3. Challenges of Using Experiments in Science

Research indicates that the implementation of experiments in science education faces numerous challenges that require urgent attention. Aydogdu (2015) highlights several issues associated with laboratory work, despite its essential role in science learning. These include a lack of necessary materials, insufficient information and techniques for conducting experiments, inadequate knowledge about laboratory equipment and chemicals, and limited understanding of safety procedures and accident protocols. Similarly, Bouzit et al. (2023) identify the absence or insufficiency of materials and deficits in laboratory infrastructure and equipment as key obstacles. Madlela and Umesh (2024) further emphasize that overcrowded classrooms lead to the recycling of apparatus, where disposable equipment is reused due to shortages. The high learner-to-teacher ratio, as noted by Bouzit et al. (2023), makes it difficult for teachers to manage experiments effectively, reducing the opportunity to provide individual support. This problem is compounded by the lack of laboratory assistants in 80% of schools, making experimental work even more challenging (Bouzit et al., 2023).

In addition to material and infrastructural challenges, a significant barrier to effective science experimentation is the lack of teacher training and expertise. Bouzit et al. (2023) argue that insufficient training in experimental teaching hinders teachers' ability to conduct meaningful experiments in the classroom. Madlela and Umesh (2024) point out that some primary school teachers are unqualified to teach NS and lack familiarity with inquiry-based methods such as experiments. This results in learning gaps when students transition to higher grades, as they are unaccustomed to practical scientific inquiry. Iyer and Kalyandurgmath (2021) reinforce this concern, reporting that many teachers lack the knowledge, skills, and technological proficiency to conduct experiments, whether physically or through simulations. These deficits significantly reduce the use and effectiveness of experiments in science instruction, ultimately undermining the development of learners’ scientific skills and understanding.

2.4. Strategies that Foster Effective use of Experiments

Research has identified several strategies that can enhance the effective use of experiments in science classrooms, especially in contexts facing resource and infrastructural limitations. Anto et al. (2023) suggest that collaborative experimentation among learners, the use of alternative materials, and digitized activities can promote more engaging and accessible practical science experiences. Similarly, Hamed and Aljanazrah (2020) emphasize the value of flexible and interactive virtual experiments. They argue that virtual experiments offer comparable learning outcomes to traditional laboratory experiments while saving time and cost. These digital approaches allow students to acquire practical and scientific inquiry skills remotely, creating a learning environment that transcends time and space constraints (Hamed & Aljanazrah, 2020; Tabuena & Pentang, 2021). This flexibility is especially beneficial in addressing challenges such as overcrowded classrooms, lack of laboratory resources, and limited access to equipment in disadvantaged schools. In the same vein, Madlela and Umesh (2024) advocate for using simulations, educational videos, and YouTube-based experiments when physical laboratories and materials are unavailable.

The flexibility and accessibility offered by virtual experiments also play a motivational role in science learning. According to Hamed and Aljanazrah (2020), learners appreciate the ability to engage with experiments anytime and from various locations—including homes, computer labs, and libraries—using laptops or smartphones. This creates a more conducive and personalized learning environment for both learners and educators. Moreover, recorded virtual experiments can serve as valuable revision tools, allowing students to revisit content at their convenience—an option that is often more feasible than scheduling consultations with overburdened teachers. However, while digital tools offer effective alternatives, systemic support remains critical. Bouzit et al. (2023) argue that the Ministry of Education must play an active role in equipping science laboratories with essential resources such as materials, water, gas, and electricity, as well as ensuring that equipment meets the demands of large class sizes. Teacher preparation is equally important. Bouzit et al. (2023) emphasize the need for training teachers to handle laboratory tools and conduct experiments effectively. Supporting this, UNESCO (2014) highlights the direct link between teacher quality and overall education quality. Continuous professional development, particularly in experimental science education, is essential to equip teachers with the skills needed to design and implement effective scientific investigations (Senayah et al., 2016).

3. Methodology

The data collection process was guided by interpretivism research philosophy which made it possible to use a qualitative research approach (Creswell, 2014). Interpretivism argues that truth and knowledge are culturally and historically situated based on people's experiences and their understanding of them (Ryan, 2018). It aims to include richness in the insights gathered rather than attempting to provide definite and universal laws that can be generalised and applicable to everyone regardless of some key variables and factors (Saunders et al., 2012).

Interpretivism enabled the researcher to generate information from participants' points of view based on their daily experiences in the teaching and learning of NS using experiments (Kivunja & Kuyini, 2017). The adopted qualitative approach made it possible for the researcher to go to Johannesburg East schools to collect rich information about the application of experiments in science education (Haradhan, 2018; Tichapondwa, 2013). A case study design allowed the researcher to study five selected schools in detail and generated comprehensive information from them about the phenomenon using different data collection methods (McMillan & Schumacher, 2014; Creswell, 2014).

Twelve NS teachers were purposively selected to take part in the study based on their in-depth knowledge and experiences in the teaching of NS; eight participated in focus group discussions, two participated in lesson observations, and two participated in face to face interviews. McMillan and Schumacher (2014) state that interviews and focus group discussions generate detailed information from participants. During interviews and focus group discussions participants gave in-depth information in the comfort of their offices and staffrooms. Observations enabled the researcher to use an observation guide to record how teachers applied experiments in the teaching and learning of NS. Through observing lessons being conducted in class, the researcher gathered detailed information (Muianga et al., 2018).

Data was analysed and presented in a narrative and verbatim way (McMillan & Schumacher, 2014). Trustworthiness of findings was ensured through triangulation of data from interviews, focus group discussions and lesson observations, and through sharing the research report with participants to check whether it reflected their views. Research ethics were abided through non-disclosure of participants' names and the names of their schools. Participation in the study was voluntary and through informed consent. Participants signed consent forms before taking part in the study. Permission to conduct the study was given by the Department of Basic Education Gauteng Province.

4. Findings

Data analysis and interpretation gave rise to the following themes, importance of experiments, application of experiments in NS and strategies for effective application of experiments in NS. Some of the participants' contributions have been presented verbatim. Schools were coded as school A, school B up to school D. Participants were coded as participant 1 from school A up to participant 2 from school D.

4.1. Importance of Experiments

During interviews and focus group discussions participants indicated that experiments play an essential role in the teaching and learning of NS in schools.

> *The use of experiments in the teaching of science makes learners pay attention. In most cases learners do not pay attention when they are taught theory. Experiments capture the attention of learners in class and motivate them to participate during the lesson.* (**Participant 1 school A**)
>
> *I use experiments because, experiments promote active learning, and allow learners to explore and relate theory to practice. As they explore and engage in hands-on activities their analytic and problem solving skills develop.*
>
> *When learners are taught through experiments their understanding and performance improves than when they are taught scientific concepts in theory.*
> *(***Participant 1 school E***)*

Dhanapal and Shan (2014) also found that most learners achieved better results, as they learned and retained information more effectively through hands-on experiments. Hands-on experiments also increased learners' motivation and participation. During lesson observations, it became evident that experiments captured learners' attention and enhanced their motivation and engagement. Raymond and Wong (2018) note that classroom experiments can improve learning outcomes in examination-related questions. They also stimulate learners' interest in the subject and enhance their understanding of the subject matter. Participants stated that experiments give learners the opportunity to explore. This aligns with the DBE (2012), which encourages learners to explore and develop their science process skills.

Participants stated that experiments enable learners to see, do, record and communicate during the lesson.

> *During experiments learners play an active role in preparing for the experiment, conducting the experiment, making observations, recording and communicating results. This keeps them more involved and engaged unlike in a theory lesson where they sit and passively listen to the teacher most of the times*. (**Participant 2 school C)**

Learners learn better when they actively participate than when they play a passive listening role while the teacher dominates the lesson. Bretz et al. (2013) argue that experimental practice in science classes represents a break from theoretical pedagogies, as it provides learners with active learning opportunities and promotes their comprehension of concepts. It also increases students' curiosity and fosters positive attitudes toward science (Bretz et al., 2013). Similarly, experiments allow learners to engage multiple senses and intelligences, as they can learn through touching, smelling, doing, and seeing. Gardner's theory of multiple intelligences notes that learners possess different types of intelligence; some learn better through doing, while others learn better through seeing. Teachers should therefore accommodate learners' diverse learning styles, as combining these styles with dominant intelligences enhances the learning process (Cokcaliskan, 2018; Sener & Cokcaliskan, 2018). Experiments are inclusive because they cater to learners' various intelligences.

As the DBE (2012) advises teachers to use inclusive instructional methods that address learners' diverse needs in the classroom, experiments serve as an effective method of promoting inclusivity and diversity.

Participants stated that conducting experiments helps learners to practically see and use apparatus, and to observe chemical reactions, rather than just learning theoretical content from teachers and textbooks.

Experiments give learners an opportunity to see scientific apparatus and chemicals practically in the laboratories. Learners who had not yet seen these things get excited to see them for the first time and tend to appreciate how they look like. Learners learn better when they see than when they are told about things that they can't see. **(Participant 3 from school B)**

> *Children learn better when they see and do than when they are taught theory. Experiments help them to see how certain chemicals react when they are mixed together or how water changes into different states. Seeing things practically happening during experiments help learners to understand the topic better and become motivated to learn the subject.* **(Participant 1 school D)**

Participants' assertions are supported by Kotsis (2024) who argues that experiments are essential in inquiry-based science education, because they give learners practical experiences that enhance their comprehension of scientific concepts. Practical involvement in experiments allows learners to interact directly with the subject matter (Kotsis, 2024) as they manipulate apparatus and mix chemicals, observe and record reactions. This creates a dynamic and engaging learning environment that encourages scientific literacy, curiosity, exploration and deeper learning.

4.2. Application of Experiments in Natural Science

Though during interviews and focus group discussions participants expressed how they applied experiments in class, practical information with regard to this was generated through lesson observations. Participants stated how they applied experiments in NS.

> *There are some simple experiments that we conduct in class, but there are those that we conduct in the laboratories because they need lab equipment. The major challenge though is that labs are not fully equipped. There is shortage and lack of proper apparatus and chemicals. We end up improvising due to these shortages.* **(Participant 2 school C)**

Though it is common practice for experiments to be conducted in laboratories, some can also be carried out in classrooms. During lesson observations, it was noted that certain schools conducted experiments in classrooms, where teachers improvised due to a lack of proper apparatus and chemicals. Improvisation by teachers is beneficial, as it provides learners with opportunities to gain experimental experience in environments where there are inadequate resources for conducting experiments.

The study of George (2017) revealed that most students reported laboratories lacked adequate basic infrastructure and were dysfunctional for carrying out experiments. Udosen and Ekukinam (2014) suggest that, since most science laboratory equipment is very expensive, it may be substituted by creating inexpensive materials locally that suit the conditions of the local environment. Kizito (2021) also supports participants' strategy of improvisation during experiments. His study provides a step-by-step demonstration of how to create and use inexpensive, repurposed materials from the local environment in science lessons. It further provides examples of improvised science materials and demonstrates their effectiveness.

Some participants stated that they provided learners with opportunities to conduct experiments, while others explained that, due to precautionary and safety measures, experiments were conducted only by the teacher.

> *When we conduct experiments both the teacher and learners get involved. Sometimes the teacher conducts the experiments while learners observe, but*

sometimes learners prepare and conduct experiments themselves under the guidance of the teacher. **(Participants 2 school A)**

Whether the experiment is conducted by the teacher or learners depends on the type of that experiment. If the experiment is safe, then learners are given an opportunity to carry it out, but if the experiment is dangerous and involves chemicals such as sulphuric or nitric acids it is conducted by the teacher for safety precautions. **(Participant 1 school C)**

Experiments are conducted by teachers while learners observe the process. Learners are not allowed to conduct them for safety reasons. Some learners lack discipline, as a result it would be dangerous to allow them to conduct dangerous experiments because they might end up injuring themselves or others. **(Participant 1 school C)**

In a learner-centred approach, it is advisable that learners conduct experiments themselves, with the teacher acting as a facilitator by demonstrating and giving instructions. Anto et al. (2023) argue that experiments can be used effectively by promoting collaborative experimentation among learners. This suggests that experiments should be conducted by learners through teamwork. If experiments are conducted only by the teacher, with learners playing a passive role, they are deprived of the opportunity for active participation.

Kotsis (2024) views learners' active participation as essential for acquiring valuable skills necessary for success in the 21st century. The DBE (2012) advises NS teachers to use practical experiments in class to help learners identify problems, develop questions, formulate hypotheses, and design and conduct experiments to test those hypotheses. Experiments, therefore, are most effective when conducted by the learners themselves. Hu et al. (2024) argue that learners can follow laboratory safety measures if they are properly oriented with safety instructions and awareness.

4.3. Practical Application of Experiments

Lesson observations afforded the researcher an opportunity to see how NS teachers applied experiments in class. Teachers were observed conducting experiments during their lessons. For example, Participant 2 at School E was observed performing an experiment in class. He wanted learners to observe what happens when salt, milk, and washing powder are added to different containers of water. He poured the same quantity of water into three different beakers using a measuring cylinder. He then added salt, milk, and washing powder into three separate beakers—each substance into its own container. The teacher used a tablespoon to stir the water in each beaker and asked learners to state what they observed after stirring. Learners responded, and the teacher acknowledged the correct answers. Typically, in laboratory settings, stirring is done using a spatula, not a tablespoon. However, as Kizito (2021) recommends, teachers are encouraged to improvise with available local resources when there are shortages of materials and apparatus. In this case, the teacher explained to learners that a spatula is normally used, but a tablespoon was used instead due to its unavailability.

Learners' responses to the teacher's questions indicated that they understood the experiment better by visually observing the changes. Most learners accurately described what they observed when salt, milk, and washing powder were added to water and stirred. However, the experiment could have been more effective and engaging if learners had conducted it themselves, rather than watching the teacher do it for them.

Olugbenga (2021) argues that adopting learner-centred methods transforms the teacher's role into that of a facilitator and guide. Active learner participation and hands-on experience during experiments are encouraged to avoid situations where the teacher does everything while learners remain passive. The experiment could have been structured around group work—one group using salt, another milk, and another washing powder. Under the teacher's guidance, groups could prepare for the experiments, formulate hypotheses, conduct the tests, record their findings, and share results with the whole class through group presentations (DBE, 2012; Le Roux, 2010). Anto et al. (2023) also emphasize the effectiveness of promoting collaborative experimentation among learners.

Participant 1 at School D was observed conducting an experiment in the laboratory. He began the lesson by asking learners questions that linked to the previous topic—acid reacting with a base. He used a slide projector to display the topic of the day and key points from the previous lesson. This approach is supported by Arifin and Arifin (2019), who argue that prior knowledge has a positive effect on science learning outcomes. They highlight that prior knowledge can be reinforced by connecting learners' existing knowledge and past experiences before introducing new content. After the introduction, the teacher developed the lesson by conducting experiments. The main objective was to help learners observe what happens when various items and substances are added to an acid. However, the experiments were conducted solely by the teacher while learners observed. Afterward, the teacher asked learners questions, most of which were answered correctly, though a few students struggled to respond.

According to Le Roux (2010), before conducting an experiment, the teacher should engage learners in discussion and preparation rather than doing everything alone. Learners are supposed to help gather chemicals, apparatus, and recording materials. Similarly, Olugbenga (2021) advises that the teacher should act as a facilitator and allow learners to take an active role. The teacher could have provided learners the opportunity to prepare, conduct the experiment, and communicate the results themselves. Nonetheless, it was evident during the lesson that the use of experiments helped sustain learner motivation throughout. Dhanapal and Shan (2014) found that the use of experiments in science enhances learner participation and motivation.

4.4. Strategies for Effective Application of Experiments in Natural Science

Participants suggested some ways that could be used to improve the application of experiments in NS.

> *If experiments are to be effectively used, schools should equip laboratories with necessary chemicals and apparatus. It is difficult to carry out experiments without necessary resources.*

Participants argued that since most laboratories were not well-equipped, schools were supposed to make lab resources available so that teachers could effectively carry out experiments. This is supported by Bouzit et al. (2023) who urge the Ministry of Education to equip science laboratories with necessary resources if science experiments are to be effectively conducted in schools.

Some participants advocated for the construction of enough laboratories in schools capable of accommodating large numbers of learners.

> *Schools should build enough laboratories and equip them. In most schools, learner enrolment is high and laboratories are small and incapable of accommodating all learners. With enough laboratories and equipment, experiments can be effectively carried out in schools.* **(Participant 2 school E)**

Mokoro (2020) argues that the shortage or absence of required laboratory facilities makes learning more theoretical than practical. It also leads to congestion during practical sessions, which may result in poor learner performance in examinations. Mokoro recommends that the government, in collaboration with other educational stakeholders, should build the necessary laboratory facilities in schools.

Some participants expressed the view that, in the absence of laboratory equipment and chemicals, it is advisable for teachers to improvise and conduct experiments rather than not conducting them at all.

> *Instead of failing to conduct experiments due to the shortage of equipment and materials, teachers should improvise. They can bring some of the needed things or ask learners to bring them. For example, teachers can bring ice blocks and the electric kettle for boiling water to demonstrate different states of water. If there is no Bunsen burner at school fire can be used.* **(Participant 1 school A)**

Due to the paucity of resources, especially in disadvantaged schools, it is advisable for teachers to improvise in order to mitigate these challenges. Osei-Himah et al. (2018) recommend that when schools lack original instructional materials, improvisation can enhance the teaching and learning of science. Their study found that improvised instructional materials convey the same meaning as the original ones. Their analysis revealed no significant difference between improvised and originally produced instructional materials when used in science teaching and learning. This suggests that, in the absence of original materials, teachers can achieve the same or nearly the same outcomes through improvisation.

Participants also stated that the teacher–learner ratio should be reduced to enable teachers to give adequate attention to all learners during experiments. They further advocated for the employment of sufficient laboratory assistants and for more time to be allocated to experiments in the timetable.

> *Some classes have high numbers of learners, and this makes it difficult for all of them to participate during experiments. It is also difficult for the teacher to pay attention to all of them when experiments are being conducted. If the teacher learner ratio can be reduced by the Department of Basic Education and schools, then experiments can be effectively carried out at school. A small or average number of learners would allow all of them to have a chance to participate. It would also allow the teacher to pay attention to each and every learner during the experiment process. Hiring enough laboratory technicians and assistants can also help to relieve the pressure of high numbers of learners.* **(Participant 1 school D)**
>
> *Experiments should be given more time in the time table. Sometimes teachers do not do experiments because they need more time than the one allocated in the time*

> *table. Due to limited time, instead of using experiments which are time consuming teachers end up using theory which is less time consuming so that they could finish the syllabus before examination time. To avoid this, more time should be allocated in the timetable so that teachers can be encouraged to carry out experiments in an effective way that will benefit learners.* **(Participant 1 school C)**

Gudyanga and Jita's (2019) study revealed that teachers faced challenges such as time constraints and heavy workloads, hindering the effective implementation of practical activities. Participants' suggestion to employ laboratory assistants is supported by Gudyanga and Jita (2019), who recommended that laboratory assistants be provided in schools to help reduce teachers' workloads. An adequate number of laboratory assistants would relieve pressure on NS teachers during laboratory activities. These assistants could work alongside teachers to monitor, guide, and support learners during experiments, thereby enhancing the effectiveness of practical work, even in large classes.

Participants also believed that training and professional development for teachers could improve the implementation of experiments in NS.

> *For continuous improvement, schools should have workshops for teachers to train them about inquiry based teaching methods including experiments. Training teachers on these methods will equip them with skills and knowledge of conducting experiments in science better.* **(Participant 3 school B)**

Participants' assertions about teacher training align with Bouzit et al. (2023), who state that to ensure the effective implementation of experiments, teachers should be trained in conducting experiments and using laboratory tools. Ndihokubwayo (2017) also urges those responsible for teacher training to equip both pre-service and in-service teachers through workshops focused on improving laboratory teaching skills. Such training aims to make teachers confident, competent, and skillful, even when facing a scarcity of teaching materials. UNESCO (2014) argues that, since the quality of an education system is closely linked to the quality of its teachers, it is essential to support teacher training to facilitate quality learning. Training is strategic, as it equips science teachers with the professional skills needed for the design and implementation of scientific experiments (Senayah et al., 2016).

During interviews and focus group discussions, participants did not mention the use of educational technologies such as simulations, videos, or virtual experiments in the implementation of experiments in NS. Madlela and Umesh (2024) regard simulations and YouTube experiment videos as valuable tools in science classrooms, especially when there is a shortage of laboratory equipment and materials. Moreover, Hamed and Aljanazrah (2020) argue that introducing interactive virtual experiments can diversify and strengthen the use of experimentation in science education. These virtual experiments can yield student performance and achievement levels comparable to those of traditional laboratory experiments. Moreover, they are capable of overcoming barriers related to time, resources, and space.

5. Conclusions and Recommendations

Based on the findings of the study and the literature review, it was concluded that experiments as an instructional method increase learner engagement and motivation, resulting in improved learner performance and achievement. It was also concluded that some teachers conduct experiments themselves while also providing learners with opportunities to conduct experiments. However, some teachers prefer to conduct experiments alone, denying learners the opportunity to do so due to concerns that safety measures and precautions might be compromised if learners conduct the experiments. The DBE (2012), through the CAPS curriculum documents, clearly states that learners should be allowed to form hypotheses, prepare for experiments, conduct experiments, and test the hypotheses. It was further concluded that large class sizes, as well as shortages or lack of laboratories, apparatus, materials, and equipment, negatively affect the effective application of experiments in science.

The study recommends schools, in collaboration with the government and other stakeholders, build adequate laboratories and equip them with the necessary equipment, materials, apparatus, and chemicals. In cases where apparatus and chemicals are not available, teachers should improvise using locally available resources that are relevant to their contexts.

Schools should use workshops to provide continuous training for teachers on how to design and implement scientific experiments, including how to improvise when there is a shortage of equipment and materials.

The Department of Basic Education and schools should reduce the learner-teacher ratio to avoid overloading teachers with too many learners. Experiments require a reasonable number of learners per teacher to enable effective involvement and attention for all learners. The Department of Basic Education and schools should employ enough laboratory assistants to help teachers prepare for experiments, as well as monitor and guide learners during experiments.

Schools should utilize educational technologies in the application of experiments in science. Technology would enable the use of simulations, virtual experiments, and YouTube experiment videos, thereby reducing material and space costs as well as time constraints.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was not supported by any funding.

Institutional Review Board Statement

This study was conducted in accordance with the ethical guidelines set by the University of Johannesburg. The conduct of this study has been approved and given relative clearance(s) by the Department of Basic Education.

ORCID

Benkosi Madlela - https://orcid.org/0000-0002-0720-5549

References

Abdi, A. (2014). The effect of inquiry-based learning method on students' academic achievement in science course. *Universal Journal of Educational Research, 2*(1), 37–41. https://doi.org/10.13189/ujer.2014.020104

Aina, J. K. (2018). Physics learning and the application of multiple intelligences. *Revista Brasileira de Gestão Ambiental e Sustentabilidade, 5*(9), 381–391. https://doi.org/10.21438/rbgas.050926

Alsalhi, N. R. I. (2020). The representation of multiple intelligences in the science textbook and the extent of awareness of science teachers at the intermediate stage of this theory. *Thinking Skills and Creativity*, *38*, 100706. https://doi.org/10.1016/j.tsc.2020.100706

Anto, I. J. C., Buagas, I. R. A., Ong, P. M. V. J., Naparan, G. B., & Villaver, A. V. (2023). Challenges and coping strategies of science teachers. *Canadian Journal of Educational and Social Studies, 3*(4), 148–166. https://doi.org/10.53103/cjess.v3i4.168

Arifin, I. I. N., & Arifin, I. N. (2019). The effect of prior knowledge on students' learning outcomes on the subject of basic science concepts. In *5th International Conference on Education and Technology (ICET 2019)* (pp. 158–160). Atlantis Press.

Aydogdu, C. (2015). Science and technology teachers' views about the causes of laboratory accidents. *International Journal of Progressive Education, 11*(3), 106–120.

Bretz, S., Fay, M., Bruck, L. B., & Towns, M. H. (2013). What faculty interviews reveal about meaningful learning in the undergraduate laboratory. *Journal of Chemical Education, 90*(3), 5–7. https://doi.org/10.1021/ed300384r

Bouzit, S., Alami, A., Selmaoui, S., & Rakibi, Y. (2023). Scientific experiments in Moroccan high schools life science courses: Constraints and solutions. *European Journal of Educational Research, 12*(2), 957–966. https://doi.org/10.12973/eu-jer.12.2.957

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches.* SAGE.

Dhanapal, S., & Shan, E. W. Z. (2014). A study on the effectiveness of hands-on experiments in learning science among year 4 students. *International Online Journal of Primary Education, 3*(1), 20–31.

Department of Basic Education (2012). *Natural Science curriculum and policy statement documents.* Pretoria.

Edutopia (2009). *Howard Gardner on multiple intelligences*. https://www.edutopia.org/video/howard-gardner-multiple-intelligences

George, M. J. (2017). Assessing the level of laboratory resources for teaching and learning of chemistry at advanced level in Lesotho secondary schools. *South African Journal of Chemistry*, *70*, 154–162. https://doi.org/10.17159/0379-4350/2017/v70a22

Gudyanga, R., & Jita, L. C. (2019). Teachers' implementation of laboratory practicals in the South African physical sciences curriculum. *Issues in Educational Research, 29*(3), 715–731. http://scholar.ufs.ac.za:8080/xmlui/bitstream/handle/11660/6528/

Hamed, G., & Aljanazrah, A. (2020). The effectiveness of using virtual experiments on students' learning in the general physics lab. *Journal of Information Technology Education: Research*, *19*, 976–995. https://doi.org/10.28945/4668

Haradhan, M. (2018). Qualitative research methodology in social sciences and related subjects. *Journal of Economic Development, Environment and People, 7*(1), 23–48.

Hofstein, A., Kipnis, M., & Abrahams, I. (2013). How to learn in and from the chemistry laboratory. In *Teaching chemistry–A studybook* (pp. 153–182). Brill.

Hu, X., Wan, J., Zheng, B., Ren, H., Chen, J., Ying, Q., & Bai, X. (2024). Effective practices of enhancing students' safety awareness in teaching laboratories in the new era. *Frontiers in Educational Research, 7*(5). https://doi.org/10.25236/FER.2024.070504

Iyer, G., & Kalyandurgmath, K. (2021). The study of methods and challenges faced by science teachers while conducting practical (lab) online in Mumbai region due to COVID-19. *International Journal of Creative Research Thoughts*, 9(7), 75-90.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education, 6*(5), 26–41.

Kizito, N. (2021). Step by step guidelines on improvising laboratory experiment materials. *Voice of Research*, 10(2).

Kotsis, K. T. (2024). The significance of experiments in inquiry-based science teaching. *European Journal of Education and Pedagogy, 5*(2), 86–92. https://doi.org/10.24018/ejedu.2024.5.2.8

Le Roux, C. S. (2010). *Teaching science environment and society.* University of South Africa.

Madlela, B., & Umesh, R. (2024). Utilising educational technologies to support inquiry-based learning in natural science. *International Journal of Educational Management and Development Studies*, *5*(3), 172–197. https://doi.org/10.53378/ijemds.353093

McMillan, J. H., & Schumacher, S. (2014). *Research in education.* Pearson Education.

Mokoro, D. K. (2020). Adequacy of laboratory facilities for effective implementation of competence-based curriculum in public secondary schools in Arumeru District, Tanzania. *East African Journal of Education and Social Sciences (EAJESS), 1*(2), 141–149. https://doi.org/10.46606/eajess2020v01i02.0029

Morgan, H. (2021). Howard Gardner's multiple intelligences theory and his ideas on promoting creativity. In F. Reisman (Ed.), *Celebrating giants and trailblazers: A-Z of who's who in creativity research and related fields* (pp. 124–141). KIE Publications.

Muianga, X., Klomsri, T., Tedre, M., & Mutimucuio, I. (2018). From teacher-oriented to student-centred learning: Developing an ICT-supported learning approach at the

Eduardo Mondlane University, Mozambique. *TOJET: The Turkish Online Journal of Educational Technology, 17*(2), 46–54.

Ndihokubwayo, K. (2017). Investigating the status and barriers of science laboratory activities in Rwandan teacher training colleges towards improvisation practice. *Rwandan Journal of Education, 4*(1), 47–54.

Olugbenga, M. (2021). The learner-centered method and their needs in teaching. *International Journal of Multidisciplinary Research and Explorer, 1*(9), 64–69.

Osei-Himah, V., Parker, J., & Asare, I. (2018). The effects of improvised materials on the study of science in basic schools in Aowin Municipality-Ghana. *Research on Humanities and Social Sciences, 8,* 20–23.

Prakash, S. (2022). Multiple intelligence theory as a pedagogical process and its relevance in new education policy, *IJNRD*, 7(8).

Raymond, L. I., & Wong, T. (2018). Teaching them before we teach: The effectiveness of conducting classroom experiments before teaching the underlying theory. *IAFOR Journal of Education, 6*(3), 79–92. https://doi.org/10.22492/ije.6.3.05

Ryan, G. (2018). Introduction to positivism, interpretivism and critical theory. *Nurse Researcher, 25*(4), 41–49. https://doi.org/10.7748/nr.2018.e1466

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students* (6th ed.). Pearson Education Limited.

Senayah, K. E., Tchagnaou, A., Djagnikpo, O. E., & Devi, M. K. (2016). The role of teacher training in the acquisition of skills by secondary 1 students in Togo. *African Education Development Issues, 7,* 139–153.

Sener, S., & Çokçaliskan, A. (2018). An investigation between multiple intelligences and learning styles. *Journal of Education and Training Studies, 6*(2), 125–132.

Shamsudina, N. M., Abdullah, N., & Yaamatc, N. (2013). Strategies of teaching science using an inquiry based science education (IBSE) by novice chemistry teachers. *Procedia - Social and Behavioral Sciences, 90,* 583–592. https://doi.org/10.1016/j.sbspro.2013.07.129

Sshana, Z. J., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education, 10*(2), 199–215. https://doi.org/10.3926/jotse.888

Tabuena, A. C., & Pentang, J. T. (2021). Learning motivation and utilization of virtual media in learning mathematics. *Asia-Africa Journal of Recent Scientific Research, 1*, 65–75. https://doi.org/10.2139/ssrn.3969549

Tichapondwa, S. M. (2013). *Preparing your dissertation at a distance: A research guide*. Virtual University for Small States of the Commonwealth.

Udosen, I. N., & Ekukinam, T. U. (2014). Improvisation of technological instructional media and students' performance in primary science in Nigerian schools. *World Conference on Science and Technology Education*.

United Nations Educational, Scientific and Cultural Organization. (2014). Teaching and learning: Achieving quality for all. https://bit.ly/3L191XS

Wei, B., & Chen, Y. (2020). The meaning of 'experiment' in the intended chemistry curriculum in China: The changes over the period from 1952 to 2018. *International Journal of Science Education, 42*(4), 656–674. https://doi.org/10.1080/09500693.2020.1723181

Wei, B., & Li, X. (2017). Exploring science teachers' perceptions of experimentation: Implications for restructuring school practical work. *International Journal of Science Education, 39*(13), 1775–1794. https://doi.org/10.1080/09500693.2017.1351650