Transitioning from High School to University in Lesotho: The Views and Experiences of First-Year Students on Chemistry Practical Work

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ABSTRACT

Practical work is a critical component of science education, fostering conceptual understanding, skills development, and scientific literacy. However, challenges like limited resources, time constraints, and poorly structured activities often hinder its effectiveness in high schools, particularly in the resource-constrained settings found in most Lesotho high schools. Employing a mixed methods approach, this study sought to explore students' pre-university and first year university experiences with chemistry practical work and their preparedness for university level practical work. A Google Docs questionnaire, containing both closed and open-ended questions, was uploaded to the learning management system, which then distributed email notifications to first-year science students at the National University of Lesotho. In total, 107 students completed the questionnaires. Quantitative and qualitative data were analysed through descriptive statistics and content analysis respectively. The findings revealed significant disparities in students' exposure to practical work during high school, with 16% reporting no practical work experience and 52% having conducted fewer than five practicals. Lack of functional laboratories, apparatus, and consumables as well as the prevalence of teacher demonstrations limit students' engagement with practicals. Digital tools are rarely used to supplement practical work due to lack of access to the internet and electricity, as well as some restrictive school policies. Students faced challenging practical work at university, with many of them feeling unprepared due to inadequate high school training, highlighting the need for improved infrastructure and teacher training. The study suggests priority issues to be addressed to improve chemistry practical work in high schools in Lesotho.

KEYWORDS

Chemistry education, Practical work, High school to university transition, Student preparedness, LGCSE curriculum

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INTRODUCTION

The goals of teaching science may be broadly categorized into learning about science, learning science, and doing science.[1,2] Learning about science involves developing an understanding of the nature of science. For instance, when students are learning about science, they focus on issues such as developing conceptions around the history, nature, and philosophy of science, its practices, and knowledge.[2] Learning science engages students in building theoretical and conceptual scientific knowledge while doing science involves activities that mirror or approximate what scientists do in real-life settings.[2,3] These broad goals are complex and challenging to achieve through a single teaching and learning approach.[2] Consequently, multiple teaching approaches should be adopted and tailored to ensure that teaching and learning experiences are carefully structured and aligned with clearly stated learning objectives. Moreover, school science should cater both to students aiming for scientific literacy and those aspiring to pursue science-related careers.[1] Among various teaching and learning methods, active student engagement is advocated, with practical work in its various forms offering promising experiences for meaningful science learning.[1]

Practical work encompasses a variety of activities, such as experiments in and outside laboratories, hands-on activities, and more, each with its strengths and limitations. These activities can promote a balance between learning science and learning about science.[1] Practical work is defined as "…any teaching and learning activity which at some point involves the students in observing or manipulating the objects and materials they are studying" (p. 2).[1] Experiments, for example, are activities performed under defined conditions to test or explore a hypothesis.[4] Each of these activities play a crucial role in promoting meaningful learning in science, and care should be taken to ensure that activities align with objectives.[4] Practical work activities have potential to assist students to develop 21st century skills and competencies so that they are better adapted to contribute to their societies. This adaptation is possible as they acquire essential skills like "...creativity, critical thinking, communication, and collaboration" (p. 20),[5] problem solving, productivity as well as work related competencies.[6]

Despite the essential role of practical work in science education, several challenges exist. One major challenge is the narrow understanding of the different versions of practical work, their potential, and their limitations, which hinders the formulation of effective learning activities.[4] For instance, Hodson[4] highlights that some science curricula reflect a narrow understanding by failing "… to recognize that not all practical work is carried out in a laboratory, and that not all laboratory work comprises experiments" (p. 53). Furthermore, realities in schools, such as time constraints and poorly structured activities, affect the extent to which students benefit from practical work.[1] The lack of necessary resources and selective teaching practices has been identified in many research studies as among factors negatively impacting practical activities.[7] Additionally, limited time allocated for practical activities affects their quality and impact.[7,8] Practical work requires substantial time for both preparation and execution. However, most schools in Lesotho do not allocate sufficient time specifically for practical work, which leads some teachers to focus on theory and to neglect practical activities.[8] This practice of selective teaching is also coupled with chalk and talk teaching approaches[9] despite a persistent decline in academic performance of students in science.

Furthermore, in the context of Lesotho, a small country landlocked by South Africa, these challenges are more pronounced due to low

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budgets to support schools and limited assistance for teachers in understanding and applying policy reforms.[10,11] In addition, reports from the Examinations Council of Lesotho (ECoL) have for many years raised concerns about poor performance of students on examination questions related to practicals.[12] Local research studies corroborated the concern of ECoL namely that secondary students are exposed to very minimal or no practical work.[7,8] Despite the reported challenges, the Ministry of Education changed the 5-yr Lesotho General Certificate of Secondary Education (LGCSE) to a 4-yr program thus placing more burden on both teachers and students to cover the same content within a reduced timeframe. It is not clear how schools handle practical work within the four-year period, which was already challenging in the five-year LGCSE program.

It is against this background that the current study sought to explore students' pre-university and first year university experiences with chemistry practical work and their preparedness for university level practical work. By combining quantitative and qualitative approaches, this exploratory study captures both the breadth and depth of students' experiences with practical work during high school and their first year at university. The study offers valuable insights into the links and gaps between high school and first-year university chemistry practical work experiences, as well as the challenges and opportunities for improving chemistry and science practical work in high schools in Lesotho. The findings could have important implications for policymakers, educators, and stakeholders seeking to enhance the quality of practical work and better prepare students for university-level chemistry education. The study addresses the following primary research question:

> How do first-year Bachelor of Science students describe their pre-university and first-year university experiences with chemistry practical work, and their preparedness for university-level practical work?

LITERATURE REVIEW

Practical work in science and how it is practiced in high schools

Practical work is widely acknowledged as essential in science education including chemistry, providing students with opportunities to make meaningful links between observations and ideas. This key aim is likely to be achieved when practical activities maintain a balance between manipulation of objects and critically applying ideas to the tasks.[13] A great deal of chemistry is based on abstract concepts invisible to the naked eye, which students have to understand and connect to the visible and tangible phenomena.[14] It follows that in chemistry specifically, practicals have a major role to play to help students connect abstract concepts to observable phenomena in order to experience meaningful learning.[15] Experimental work becomes essential considering Johnstone's triplet conception that chemistry exists at three levels, namely "…(a) macro and tangible: what can be seen, touched and smelt; (b) sub micro: atoms, molecules, ions and structures; and (c) representational: symbols, formulae, equations, molarity, mathematical manipulation and graphs" (p. 11).[16] It is therefore critical that students make meanings about the three levels and their relationships. Practical work further fosters students' development of the essential skills and competencies applicable in the fields of science and beyond.[17]

Duggan and Gott[18] describe classifications of practical work based on their primary goals in education, namely, "… illustration or enquiry, skills, observation and investigation" (p. 142). Enquiry practicals are designed to help students 'discover' concepts through engaging in hands-on activities, based on the assumption that independent exploration leads to meaningful learning. These practicals did, however, not achieve their intended aims as they were found to be overly planned to provide correct results rather than representing reality and allowing students to engage in exploration. Moreover, the activities categorised as enquiry were abstract, challenging and disconnected from students' experiences. As a result, illustration practicals were adopted with the aim to assist students to reach expected results through teacher support and a series of structured activities. Illustrations like enquiry, still received some critique for being too prescriptive. Skills-focused practical works allow students to carry out specified tasks aimed at fostering skills development and acquisition while observation-oriented practical provides opportunities for students to observe phenomena in a scientific way. In a similar dimension, investigations emphasize "…students using and developing skills, concepts and procedural understanding in finding the solution to a problem" (p. 144). In a study by Lewthwaite[19] teachers outlined different types of practicals they engage students in and their justifications for their choices. For instance, teacher demonstrations which were safe and economical, focused on development of pre-requisite skills for experimentation and investigations. The Lewthwaite[19] study also engaged students in "prescriptive experiments" (p.40) where they acquire skills on scientific procedures and knowledge on handling apparatus. Another type of practical work identified was investigations which demand a lot of resources. Investigations are more cognitively and physically demanding for students as they have to demonstrate competencies in planning and execution of tasks with minimal teacher support.[19,20] Generally, the categorization of practical work does not illustrate explicit activities but only emphasizes the key focus. Specific focus is essential in practical work to avoid designing complex activities for students where learning may be highly challenged.[1] There is a need to engage students in several types of practical work coupled with other strategies so that they can acquire extensive knowledge, competencies and skills embedded in various practical work activities.[1]

Earlier work by Duggan and Gott[18] further highlighted that each category of practical work plays a primary role in achieving certain objectives and therefore, the type of practical work has to be matched with lesson objectives. Misunderstanding of the primary objectives of different types of practical work has the potential to create challenges that may lead to failure to achieve objectives. For instance, in a study by Abrahams and Millar,[13] teachers' reliance on confirmatory practical activities did not develop students conceptual understanding on heart rate. In the same study, it was established that students are not likely to discover scientific ideas and interpret concepts merely from observations. In order for a practical session to be effective, it has to be based on relevant prior ideas and competencies of students so that there will be interplay between 'hands-on' and 'minds-on' during the practical session.[21] Opportunities for students to make justifications are likely to promote effective learning during practicals.[22]

However, if students are deficient in ideas relevant to the practical, they are not likely to benefit much from a practical work session.[13] Millar[1] emphasizes that nothing should be left to chance, students need to understand the objectives of the tasks, possess adequate prior knowledge and competencies to carry out intended tasks. Paterson[23] echoes similar sentiments to Millar by emphasizing the need to assist students to develop pre-requisite competencies before they engage in practical activities which require integration of knowledge, skills and proficiency. Moreover, practical tasks should, to a large extent, not be crowded with too many objectives which may potentially overwhelm students. In a similar dimension, students should be freed from unnecessarily complex instructions which overload their thinking capacity. This will allow students to focus on tasks, and experience meaningful learning with sustained interest.[23] Ramnarain's[24] study provides some evidence for the importance of engaging students in clearly articulated activities, involving them in all stages of practical work so that they are physically and cognitively engaged. Students are able to engage in high order thinking while performing physical activities for meaningful learning which ultimately contribute to good academic performance.[20,25]

Student experiences with high school practical work

Positive and negative issues have been highlighted in research literature in relation to students' experiences with high school practical work. For instance, in a study by George and Kolobe[7] respondents reported that practical work such as experiments allow students to understand abstract concepts, improve motivation, interest and perseverance in activities while also developing essential skills. The study by Hyde et al.[22] found that high school practical work activities are very simplified, group-based and guided thus, students have limited engagement which may not prepare them adequately for challenging tasks. Since teachers take most of the lead in activities, students are less stressed to think about the progression of the practical exercise, they worry less about safety issues and reporting of practical session outcomes among others.[22] These findings provide evidence that high schools seem to be engaging students in limited opportunities or no practical work.[8,20,22] In some practical sessions, such as experiments, students are provided with, readily prepared solutions used during titrations.[22] Academic writing, safety and records keeping are essential in scientific work, but there is evidence that high school chemistry practical work neglects these aspects.[20,22]

Hofstein and Lunetta[26] provide further limitations of high school practical work by pointing out that they are typically structured and restrictive experiments with limited scope for independent inquiry and are characteristic of the "cookbook" type (p. 47). This mode of practical work is critiqued for denying students to apply critical thinking,[26] and exercise autonomy[24] as they engage in activities. Hofstein and Lunetta[26] further outline that lack of authentic assessment procedures makes practical work boring for students. Moreover, deficient conceptions of practical work in schools contribute to its failure to promote intended objectives which affect students' affective attitudes towards practical work.

In many educational settings some critical impediments to practical work have been reported. These include timetable constraints, classroom overcrowding, an examination-driven curriculum, limited access to laboratory facilities, materials and equipment.[8,26] These barriers have a negative impact on the preparedness of students for higher education. Consequently, first-year university science students may face an adjustment period challenges as they transition from teacher-led, resource poor environment to more autonomous, and rigorous practical work.[22]

Transition from high school to university-level practical work

For many first-year university students, the transition to university marks a shift in expectations, experiences and academic rigor.[27] The transition is characterized by instances of difficulties and excitement.[22,27] Students encounter a new environment where they individually need to embrace many responsibilities such as independent learning, managing socializing habits, becoming accustomed to increased workloads and seeking support from others.[28] Other personal issues such as being away from family and friends further add to the complexity of transition from high school to university.[27]

More specifically, students enrolled in science programs have been found to experience daunting issues. For instance, the study by Lowe and Cook,[27] established that science students experienced some difficulties like coping with the amount of work in a given time with little support from staff. University chemistry practicals may involve open-ended investigations, requiring students to demonstrate competencies in designing experiments, executing procedures, and analysing large and sometimes complex data independently or in small groups. These increased levels of autonomy and responsibility can be challenging for students who have no experience or are accustomed to structured and restrictive, "cookbook" versions of practical work.[22] Additionally, students may find university practical work activities more daunting due to the increased technical complexity, and the need for sophisticated skills to operate instruments and manipulate apparatus. Furthermore, students are expected to uphold strict safety protocols, collaborate, keep systematic practical records, communicate scientific findings and produce scientific reports.[22] Students often feel very unprepared to meet these demands within a short space of time.[22,29]

In many cases, high school practical work activities are done in large groups while at university level, small groups, pairs or individual sessions are common. The university arrangements allow every student to be fully engaged and demonstrate some competencies in planning and carrying out practical activities in a more focused way. Students accustomed to large-group demonstrations often find the university environment demanding, as it requires them to demonstrate a range of skills that were not well developed during high school.[22]

Sometimes university chemistry practical work activities do not seamlessly connect to theoretical ideas learnt in lectures.[30] Reid and Shah[31] noted that in some instances, there is "…too much emphasis on the experiments to be performed and not enough emphasis on what the students should be gaining" (p. 177). This statement by Reid and Shah[31] mirrors findings with high school practicals where students are mainly exposed to manipulation of objects and observations with little to no engagement of critical thinking and communication to make links with scientific ideas. Consequently, delinking physical activities from cognitive activities and assuming that students will acquire underlying scientific ideas contribute to inefficiency of practical work. One study established that lecturers still engage students in 'cookbook' type of practical work. This is due to a packed curriculum and limited time allocated for practical activities. As a result, students are negatively affected, as they have limited time to engage in activities. Furthermore, the practicals fail to place emphasis on real-life experiences.[32] In addition, a disconnection between practical activities and theoretical knowledge was reported as a challenge for students to find benefits of practical work.

However, Mahaffy[33] reports that to alleviate anxiety and cultivate motivation and perseverance in learning chemistry,

> "*…we need to situate chemical concepts, symbolic representations, and chemical substances and processes in the authentic contexts of the human beings who create substances, the culture that uses them, and the students who try to understand them*" (p.51).

Thus, practical work which connects to students' real-life experiences has more potential to promote acquisition of essential knowledge competencies and skills in chemistry.

METHODOLOGY

This study employed a mixed-methods approach[34] to explore the experiences of first-year university students with practical work in chemistry in Lesotho, comparing their pre-university (high school) and university-level experiences. The methods adopted were found suitable to achieve the purpose of the study guided by the research question:

> How do first-year Bachelor of Science students describe their pre-university and first-year university experiences with chemistry practical work, and their preparedness for university-level practical work?

Study context and sample

The study was conducted at the National University of Lesotho (NUL), focusing on purposively selected first-year students enrolled in the Bachelor of Science (BSc) program. These students had completed the Lesotho General Certificate of Secondary Education (LGCSE), which includes physical science (a combination of chemistry and physics) and or biology as part of their high school curriculum. The LGCSE curriculum emphasizes practical work as an essential component of science education, with the expectation that students develop skills in planning investigations, making observations, interpreting data, and evaluating methods. Even though the LGCSE curriculum does not prescribe a specific number of practical work activities, almost all topics include terms such as 'perform experiment,' 'investigate,' 'test,' and 'carry out, etc' which are embedded in the envisaged learning outcomes and can be interpreted as indicators of the need for a practical work session.

At the university level, first-year BSc students engage in practical work sessions across chemistry, biology, and physics courses in two semesters. A semester lasts 12 weeks, with practicals running for 10 weeks. Students typically attend one 3-hour practical per week or on alternate weeks, alongside tutorials, resulting in 5 to 10 practicals (15 to 30 hours of practical work) per semester and 10 to 20 practicals per academic year. Students work in groups of three, occasionally four, in slightly larger cohorts which average more than 60 students per session. The primary objective of these sessions is to reinforce theoretical concepts and develop practical work skills, including the ability to conduct experiments independently, record observations and results, analyse and interpret data, and present results in scientific reports.

Data collection

Data were collected through an online questionnaire distributed to first-year BSc students at NUL. The questionnaire was designed to gather both quantitative and qualitative data on students' experiences with practical work at the high school and university levels. It included the following sections:

- **Biographical information**: Questions on gender, high school name and district or location, and whether students completed the 4-year or 5-year LGCSE program.
- **High school practical work experiences**: Questions on the availability of laboratory facilities, the physical building, apparatus and reagents, the number of practical work activities conducted, the types of practical activities engaged in (e.g., experiments, demonstrations), how students experienced practical work and the use of digital tools to supplement practical work.
- **University practical work experiences**: Questions on students' perceptions of their preparedness for university-level practical work with reference to their high school experience, the challenges they faced, and their reflections on the transition from high school to university.
- **Suggestions for improvement**: Students were ultimately asked to provide detailed suggestions (if any) for improving practical work in high schools. Example of questions from the questionnaire relevant to this study are presented in Figure 1.

The questionnaire was distributed to 240 first year students enrolled in the BSc program in the 2023/2024 academic year. The questionnaire was distributed online as a Google Doc via the university Learning Management System. A total of 107 students completed the questionnaire.

Data analysis

The data were analysed using a combination of quantitative and qualitative methods. Quantitative data, such as the number of practical work activities conducted and students' self-reported preparedness, were analysed using descriptive statistics (e.g., frequencies and percentages) to identify patterns which were later triangulated with the qualitative data findings to offer a richer understanding.

The qualitative part of the data from open-ended questions were analysed through content analysis.[35] Content analysis was adopted in order to achieve an in-depth and rich understanding of the data collected without undue influence caused by preconceived ideas. The analysis of the qualitative data, which drew guidelines largely from the work of Hsieh and Shannon[35] and Mayring[36] began with the organization of the data by separating it from the quantitative part. Having organized the data, authors met to discuss the analysis procedure in relation to the adopted conception of practical work and the research question. The guiding conception of practical work was adopted from Millar,[1] who defined practical work as "… any teaching and learning activity which at some point involves the students in observing or manipulating the objects and materials they are studying"(p.2). Due to the focus of the study, some of the possible categories were conceived prior to the analysis such as, classification of practical work, pre-university experience, first year university experience and preparedness with university level practical work. Additionally, authors were aware of a possibility of missing some issues if only pre-conceived preliminary codes were used in the analysis. Furthermore, the study was not testing any theory with clearly specified concepts.[35] Therefore, both deductive and inductive content analysis[37] were found to be more suitable to address the research question focus. After the analysis process was discussed and agreed upon, authors took a sample of data, independently read the sample data to gain an initial impression of how students describe their pre-university and first university experiences with practical work as well as their preparedness to engage in university practical work in chemistry. Having familiarised themselves with the data, authors convened several times to analyse the sampled data together, formulated a table with prior-codes as headings and placed segments of data under each code. More codes were added as they emerged during the analysis of the sampled data until no more new codes could be identified. Thereafter, the first author carried out the analysis of all data capturing it in the table. To establish trustworthiness of the findings several meetings with the second author were held to discuss the analysis to ensure that the data under each code was placed in the appropriate category. Ultimately, some codes were collapsed to produce final categories with corresponding frequencies.[36,38]

Due to the large sample size of participants (N = 107) and the fact that some students came from one school, students from one school were grouped together so that their data could be analysed separately to remove duplications of entries on issues that relate to their schools (for instance, availability of laboratories) before undertaking the overall analysis. The same method was used to assess the validity

High school practical work experiences

7. Are you satisfied with the number of chemistry practicals you did throughout your secondary/ high school learning? Please explain?
8. Mention any reasons for not doing any or more practicals. Provide as much details as possible.
9. In the case where practicals were done, how were they carried out? (e.g. by students or watching or observing teachers?) Please explain your response.
10. Did you have access to digital means like video, simulations, animations etc. of any practical works? Please provide some examples and reasons for using or not using them.

University practical work experiences

11. How many chemistry practicals have you done in the university Year 1 Chemistry so far?
12. From your university Year 1 experience regarding practicals, how adequately has high school prepared you for Year 1 chemistry practical work?
    a) Choose the most applicable: completely unprepared, somewhat unprepared, neutral, somewhat prepared, completely prepared.
    b) Explain your answer with sufficient details and supporting examples.

Suggestions for improvement

13. If you were to go back to your former high school, what advice would you give to chemistry teachers about practical work? Please provide details to justify your answer.

Figure 1: Questions posed to students about the transition from high school to university practical work

of the responses as the similarity of the responses would afford a measure of validity.

Ethical considerations

The study adhered to ethical research practices, including obtaining informed consent from participants, ensuring confidentiality, and using data solely for research purposes. Participants were informed of their right to withdraw from the study at any time without penalty. They were also assured that their responses which would remain anonymous in any reporting and would not affect their academic performance. Anonymity was ensured by replacing students' names with coded references. (For instance, ST-1 for student number one).

Limitations

While the study provides valuable insights into students' experiences with practical work, there are some limitations. First, the reliance on self-reported data may introduce bias, as students' recollections of their high school experiences may not always be accurate. Second, the study focused on first-year students at one university, which may limit the generalizability of the findings to other contexts. Future research could address these limitations by incorporating observational data and expanding the sample to include multiple institutions of higher learning.

FINDINGS

Biographical information of participants.

Biographical information of the participants who responded to the questionnaire shows that 58% of the respondents are females with males making up 42%. This categorization is important given the global initiatives of promoting inclusive enrolment of males and females in the science, technology, engineering and mathematics (STEM) subjects. Much as this is a very important statistic, it does not necessarily reflect the actual enrolment. The actual enrolment statistics could not be obtained at the time of submission of this manuscript, thus the proportion of females to males in this study may not represent the first-year cohort in chemistry.

Distribution of schools by proprietor

Most schools in Lesotho can be classified as being under the proprietorship of the government, community, private or church affiliated. The churches affiliated schools represented in this study sample include the Roman Catholic Church (RCC), Lesotho Evangelical Church in Southern Africa (LECSA), Anglican Church of Lesotho (ACL), Methodist and Assemblies. Figure 2 shows detailed information on schools' representation in terms of proprietors.

Figure 2 shows the distribution in proprietor of schools where church affiliated schools has the highest representation (66%). Other schools, government (20%), community (10%) and private (4%) had lower representations in the sample. The high representation of church schools is not surprising due to their being widespread across the country.

Students' distribution by location

Schools differ from each other in many ways among them is the geographic location. Consequently, the study categorized the respondents by district to gain a broader perspective as some of the districts are more rural than others. Figure 3 shows the categorisation of the respondents' schools by geographic location.

Figure 3 shows that only four districts had representation of ten or more students with schools in Mohale's Hoek and Qachas's Nek providing all the students from those districts. The remaining districts reflect a low number of schools and students who proceed to tertiary studies. These findings may indicate that some schools struggle to prepare students who qualify for programs in the Faculty of Science and Technology. Interestingly, none of the schools represented in Figure 3 was a former junior secondary (those schools which used to offer only a junior certificate). It may be inferred that that such schools are still struggling to keep up with the demands of the LGCSE hence their students are not able to join advanced university programs.

Schools: Physical facilities, apparatus and consumables

Since the main objective of the study was to investigate the practical work experience, Figure 4 presents the respondents' assessment of their former schools in terms of the availability of laboratories (facilities) and the appropriate apparatus including reagents and chemicals. Students were grouped into schools they attended in order to extract data for this part. A total of 49 schools was recorded. Five schools in South Africa are excluded in this section and rest of the analysis as the study focussed on the transition from high school to university in Lesotho.

Despite the reported availability of physical facilities and consumables in Figure 4, further analysis of qualitative data lead to identification of two categories, providing more insights as described below.

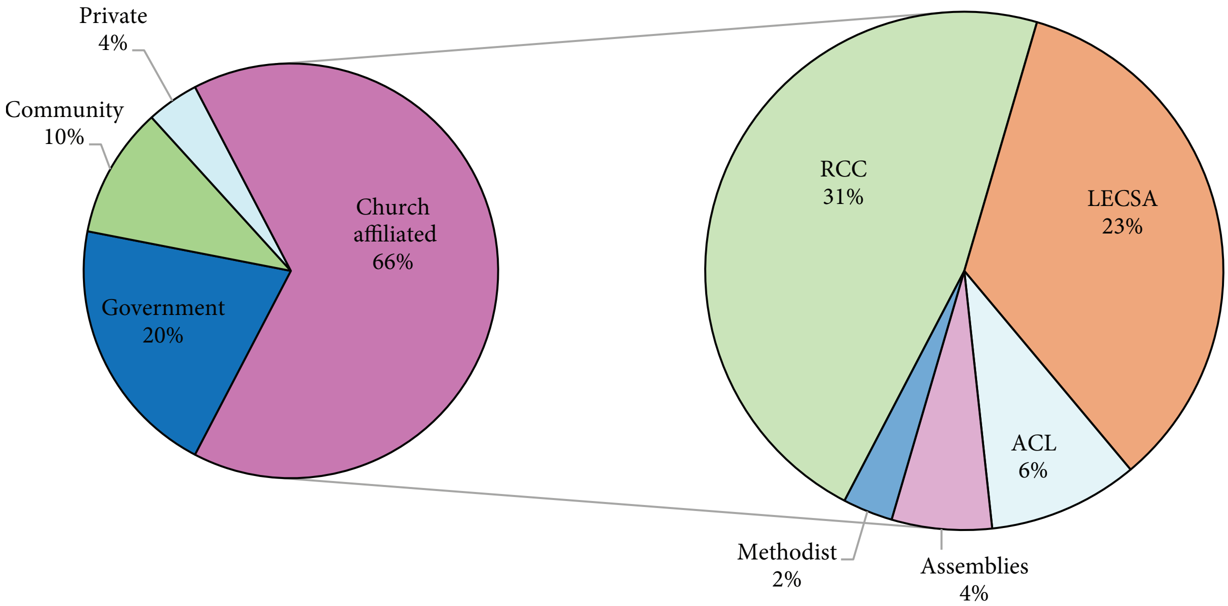

Figure 2: Distribution of schools where the respondents attended high school

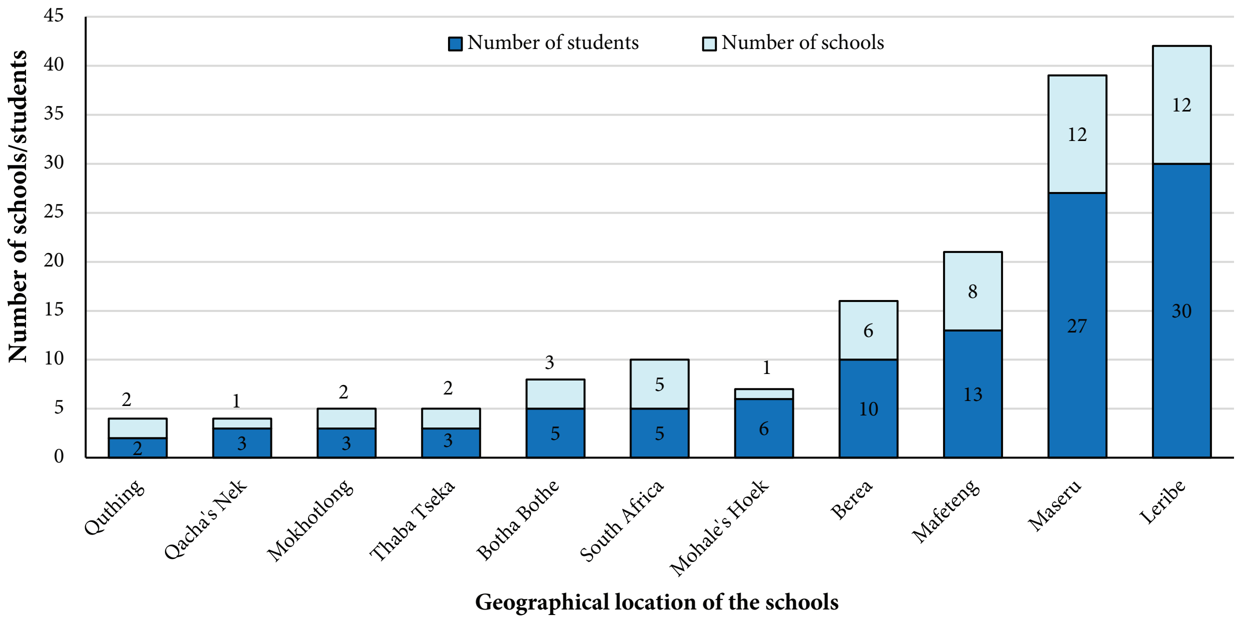

Figure 3: Number of schools and students per geographical location

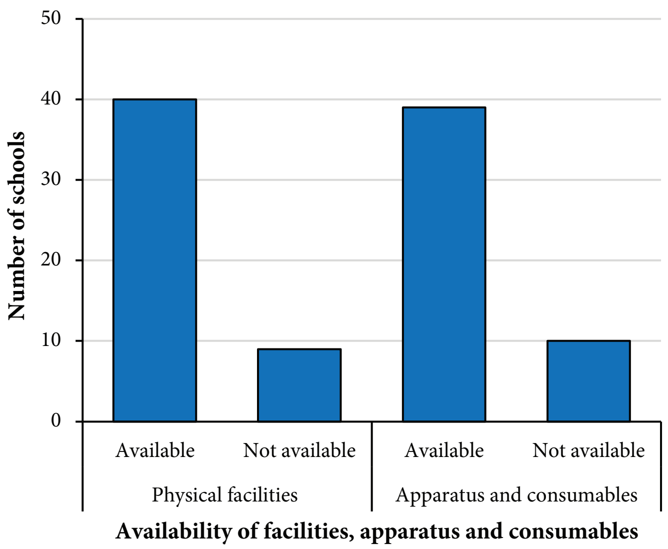

Figure 4: Availability of physical facilities and apparatus for practical work in different schools

Condition of physical infrastructure, apparatus and equipment

This category refers to the overall state and usability of the physical laboratory building(s), including the presence or absence of basic facilities and apparatus. Within this category, many participants (62%) stated that most physical facilities were old, dysfunctional and not fit for chemistry practical work – see the excerpts from some participants:

> *"The laboratories were there but with damaged apparatus."* **ST-62**
> *"It [School] had laboratory facilities but they were very poor so I might as well just say it didn't have one."* **ST-81**
> *"Yes, but they were few, some of the apparatus were not there."* **ST-90**

State and usability of chemicals and reagents

This category focuses on the state and suitability of chemical substances available for use in practical work activities, specifically focusing on issues related to their shelf-life. Similar issues to infrastructure, apparatus and equipment were raised by many students (77%) regarding the available consumables, namely that they were available in limited quantities, had expired and were no longer in a usable state:

> *"Yes, they were there but chemicals had expired therefore we were unable to perform experiments involving chemicals."* **ST-44**

These students' remarks are consistent with the findings of prior studies on the availability of resources in Lesotho schools.[7,8] The findings are not new, but demonstrate a dire situation which has not improved in more than ten years since George and Kolobe[8] reported their findings. This suggests that schools critically need significant investments geared towards physical laboratory building, maintenance, purchase of equipment and procurement of usable consumables.

Schools with no physical facilities, apparatus and consumables

Within this category, insights of what happens in schools where there are no physical facilities and consumable are provided. Some schools lack facilities (18%), apparatus and consumables (20%) and as a result, their students are mostly exposed to the theoretical aspects of chemistry as some students indicated. For instance, one student asserted:

> *"No, there were no laboratories in my former school, we were just taught without doing any experiments."* **ST-95**

Another student mentioned that, details of practical work were done theoretically by writing.

> *"…we were taught theory as the backbone of chemistry...we did experiments in terms of writing not doing them physically."* **ST-79.**

This statement by **ST-79** possibly points to situations where practical work procedures, envisaged results and conclusions are discussed and noted so that students memorize them. While the LGCSE curriculum emphasises the importance of practical work, the findings shows that a lot of work still needs to be done for high school students to do practical work with few or no constraints.

Proportion of students and the estimated number of practicals done in high school

Given the statements that most of the existing laboratories were not in a functional state, with limited or expired chemicals, it was important to estimate the number of practical work activities carried out under these contextual constraints as reported by students. These practical work activities include those done by students as well as demonstrations by teachers (see Figure 5).

From Figure 5, about 47% of respondents stated having done a bare minimum of practical work activities in the range of 1-5, 25% and

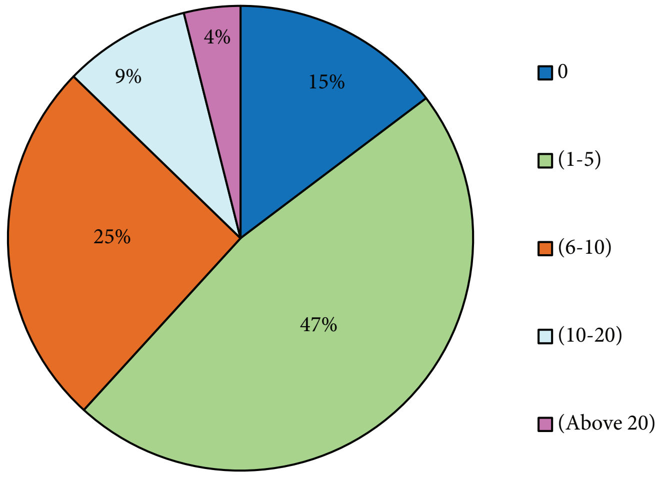

Figure 5: The estimated number of practical work activities carried out by different respondents at LGCSE

9% of students did roughly 6-10 and 10-20 practical work activities, respectively. A very small percentage of students (4%) carried out more than 20 practicals. Notably, 15% of students had no experience of practical work in chemistry during their high school education.

The use of supplementary digital means to facilitate practical work in chemistry

There are few research reports exploring the use of ICT tools, such as videos and virtual experiments to support and complement physical experimentation in schools in Lesotho.[12,39] Furthermore, some teachers still believe science should be taught through physical experiences; hence they do not support the use of digital demonstrations and simulations.[40] It is against this background that the students were asked to provide details of any other means (for instance, digital videos) that were used to supplement or substitute the physical practical work. Two categories emerged from the analysis of responses of the students.

Use of digital audio-visual tools

This category encompasses the use of digital audio-visual tools such as video, animations, and simulations which teachers could use to supplement practical work activities or use as substitutes where physical engagement in practical work is not possible. Some students reported that videos from YouTube as well as animations were used to support practical work. However, the frequency of use was low (25%). One responded (ST-65) highlighted:

> *"Yes, videos were provided to us by teachers. Examples are a few YouTube videos showcasing the experiment being carried out."* **ST-65**

The rest of the students (75%) who attempted the question on audio-visual tools mentioned that they had no experience of any digital means to support practical work in chemistry.

> *"No, we did not have such because of lack of devices such phones and laptops or flash drives so there was no way we could have videos."* **ST-59**

Contextual and practice impediments

This category refers to the issues which act as barriers and act as challenges to the possibility of using digital supplementary resources for practical work. In addition to lack of pre-requisite infrastructure like electricity as well as digital resources to supplement physical practical work, schools are also negatively affected by some of their own practices such as a 'no cell phone policy' and priorities.

> *"No, phones were not allowed at school. Students were forbidden from bringing phones to school. The computer lab at that time had no internet connection. The only connected office was that of the principal."* **ST-97**
>
> *"There were no digital devices, well until 2021 and I was already in Form E, there was no electricity."* **ST-54**

It is a reality that schools operate with no or with very limited technology resources. Furthermore, some other issues need to be urgently revisited, for example, practices such as a 'no cell phone policy', was mentioned by several students. These schools need to regulate access and the use of cell phones for academic purposes especially during this era of the fourth industrial revolution. The issue of internet connectivity being the principal's privilege had been noted in a previous study.[8]

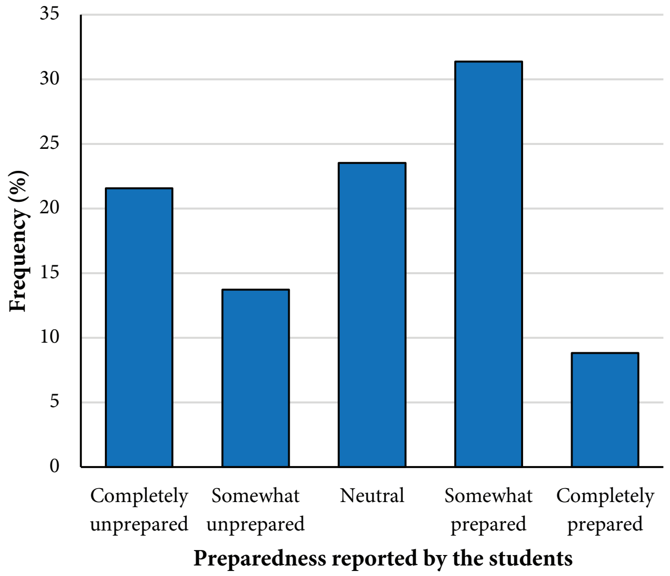

Figure 6: Students' reported level of preparedness for practical work activities

Students' university experience and reflections on their preparedness at high school

Students were asked to share their experiences of first year university practical work with respect to their preparedness from their pre-university training.

It should be noted that the first-year students, on average, did ten 3-hour general chemistry practical work sessions, an average of 30 hours of practical work. This intensive and extensive engagement in practical sessions was a new experience for many students who had never engaged in any practical work or those who were engaged for a very limited time during their pre-university education. A Likert scale question was used to assess the respondents perceived preparedness they received from their pre-university education (see Figure 6).

Figure 6 shows that only 9% respondents stated that they were completely prepared for the University practical work while 31% indicated that they were somewhat prepared. Of concern is the 36% students (students who were completely unprepared or who were somewhat unprepared) felt that they were not ready to engage in university practical work in chemistry. The remaining 24% respondents remained neutral on the issue. The interesting question is whether the respondents who reported having done an estimate of 5 or fewer experiments in their pre-university education, would report that they were adequately prepared for the experimental work at university level? This issue requires its own interrogation to assess what preparedness implied, and the role of instructors in preparing the students for the practical work. Students who had attended the same school, chose relatively similar ratings of preparedness, perhaps due to similar experiences they had in their high school. Further analysis of qualitative responses of students who were unprepared, neutral and prepared gave rise to important issues regarding their experiences with practical work during high school as described by the categories in following sections.

Experience in a laboratory environment

This category includes students' experience in relation to handling laboratory apparatus, instruments and equipment as well as how to work in a science laboratory environment. The respondents who felt unprepared and somewhat unprepared (36%) mentioned some critical issues related to contexts of schools and how arrangements for practicals (where done occasionally) and which significantly affected their preparedness for tertiary practical work. The extract below highlights some of the issues students raised.

> *"Completely unprepared because using some of the apparatus was a struggle because I only knew them from the pictures and I somehow failed to relax in a lab, instead I had this fear of doing anything wrong just because I am not familiar with it."* **ST-81**

The lack of resources in schools deprives students of opportunities to learn the skill to handle instruments and improve self-efficacy in carrying out practical work. Similar sentiments were reported by those who felt that they were somewhat unprepared. One extract below shows provides insights:

> *"Somewhat unprepared because yes we dealt with chemicals but with no proper attire (e.g. lab coats were not worn). We were taught about precautions, but most were not practiced as the attire that girls wore revealed more of their skin (girls wore skirts only). Most students would go to the lab without knowing what they are actually going to do in the lab as teacher did nothing compulsory to see to it that at least students have an idea about what they are to do in the lab (e.g. pre lab questions and a necessity or requirement to write a summary and objective of the experiments). Further students would not submit anything related to the experiments they conducted (e.g. lab report with observations or any results obtained, discussion and conclusion regarding the objectives). Again, going to the lab was only for grade 11 students still they did not have effective lab sessions as they happened once in a while."* **ST-31**

The extract above illustrates several points about the necessity of ensuring first-hand experience of practical work for students to be better equipped with skills and knowledge requisite for university and other fields. University practical work involves activities such as setting up apparatus in some cases, recording observations, data analysis and interpretation of results, and report writing. It seems, however, that some students are not well exposed to such essential practices during their high school education. Many students (77%) highlighted that teacher demonstrations were dominant in their high school chemistry practical work sessions. An excerpt from one student illustrates this:

> *"Experiments were performed by teachers due to shortage of some of the materials in the lab. Learners would watch as the Experiment is being performed and take notes and discuss the results."* **ST-84**

The shortage of material further forced teachers to work with large groups during practical work sessions. In some cases, group sizes reached as many as ten students. One student highlighted:

> *"The lack of apparatus and equipment in general example when experimenting there would be about 8-10 in just one group."* **ST-89**

The issues raised by students who selected the neutral option as shown in Fig 6, overlapped with those raised by students who were somewhat prepared and those who were somewhat unprepared. However, their responses demonstrated some effects of challenges encountered during practical work as described below.

Positive influence of some exposure to practical work activities

This category refers to the ways in which some exposure to practical work manifests in students' feelings of preparedness to engage in practical work activities. For instance, one student said:

> *"Neutral I'd say. This is because though we had limited resources, we knew how to behave in the lab and what to expect. For example, if lab coats and gloves were randomly given to use we would know why we must put them on not just for the sake of being fancy. Also, upon my arrival as a year 1 in the lab, I already knew not to taste anything in the lab and how to use laboratory apparatus including the fume chamber. However, it became a challenge to use some of the apparatus as back in high school, the teacher would simply illustrate how to use the apparatus in a class of 50 students whereas here, each and every student gets to use the apparatus."* **ST-77**

A smaller number of students (9%) indicated that they were prepared during their high school education to engage in chemistry practical work. The topics they raised to support their feeling of preparedness highlighted the importance of prior experiences. For instance, one student pointed out that some of the experiments they did in high school were similar to the ones they did during their first year in university.

> *"Completely prepared, because I know how to navigate or use the apparatus and some of the experiments done, I had already done in high school."* **ST-16**

While not all schools prepare students to make sense of practical work activities, some students mentioned that they were assessed on practical activities, which somehow prepared them to develop analytical skills.

> *"I was somewhat prepared. Teachers would ask questions regarding the experiments we performed in tests and quizzes, which forced us to analyse everything critically."* **ST-41**

In addition to analytical skills, some schools made efforts to familiarise students with laboratory apparatus and how to use them. As a results students acknowledge being equipped with necessary skills to handle apparatus.

> *"Somewhat prepared. I had basic knowledge of names of apparatus and how to properly handle them as well as how to work with certain chemicals during experiments, e.g. using fume cupboard when experimenting on chemicals that produce harmful gases. I had no idea on things like lab reports and proper analysis on results obtained."* **ST-61**

Students' preparedness appears to emphasize different areas: some felt more confident in analytical skills, others in handling apparatus, while laboratory reports writing seems to receive comparatively less attention. Those who felt unprepared also made reference to not having to submit laboratory reports. One student mentioned that,

> "*… Further students would not submit anything related to the experiments they conducted (e.g. lab report with observations or any results obtained, discussion and conclusion regarding the objectives)*". **ST-31**

Basically, the findings show students' varying experiences which provide some evidence that, there are some gaps between high school and first year university chemistry practical work. Moreover, the amount of practical work done does not seem to adequately prepare students to engage in first-year university practical work. As noted in this study some students who reported to have done twenty and more practicals in high school, mentioned that they were unprepared due to high prevalence of teacher-led activities. Interestingly, those who reported to have done between 6 and 10 practical work activities indicated that they were prepared. This varying experiences of students on the number of practical work sessions could be attributed to importance of balancing between quality and the number of practical work sessions.

Suggestions from students on how high school practical work experiences can be improved

The responses of students to the issue of improving high school practical work activities gave rise to three categories. The categories provide some insights in relation to number of practical work activities, availability and state of resources as well as writing of laboratory reports.

More practical work activities

Many students (67%) suggested that more practical work activities need to be made available for students and students need to be provided with opportunities to carry out the tasks. One student stated:

> *"I would advise the chemistry teachers do more experiments and let students do experiments themselves as to practice them."* **ST-23**

Availability and improvement of resources

This category refers to students' suggestions (74%) regarding availability of physical infrastructure, material, instruments, apparatus, chemicals and reagents. It also includes improvement of existing infrastructure. **ST- 54** mentioned that:

> *"I would not really advice the teachers since it's not their fault that the school did not have the equipment, teacher did their job very well in explaining everything even though there were no experiments. I would advise the ministry of education to take a look at the rural school and improve there. Moreover, ministry of education should help in providing those equipments."* **ST-54**

Introduction to scientific reports

A few respondents raised the issue of laboratory report writing (7%) and made suggestions related to report writing in chemistry as part of practical work. An extract from **ST-75** illustrates this:

> *"Teach students an introduction of experimental work, this will include writing a lab report and skills needed in order to do a laboratory work."* **ST-75**

Overall, students' suggestions further reflect their responses on limited exposure to practical work due to several constraints. While many students point to issues of resources and number of practical work activities, an important issue about laboratory reports is raised by a few (7%). Writing reports is crucial as part of practical work as it can serve as a form of assessment and preparation on further engagement in scientific report writing. Students have provided insights that the experiences of high school students regarding practical work in chemistry might be improved if the issues they raised above are addressed.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Discussion

This study explored the experiences of first-year university students in Lesotho with practical work in chemistry, focusing on their pre-university (high school), university-level experiences and their preparedness for university level practical work. The findings highlight significant challenges in the implementation of practical work at the high school level, which have profound implications for students' preparedness for university-level chemistry education. Practical work is a cornerstone of science education, aimed at fostering conceptual understanding, developing scientific skills, and promoting scientific literacy.[1,2] However, the study reveals that many students in Lesotho enter university with limited or no hands-on experience in practical work, largely due to resource constraints, poorly structured activities, and an overreliance on teacher demonstrations.[7,8]

There is a striking disparity in students' exposure to practical work during high school with 16% of respondents reporting no practical work experience and 52% having conducted fewer than five experiments over the entire high school education. This lack of engagement with practical activities undermines the development of essential practical skills and building of confidence which are crucial for success in university-level science programs.[13,17] Furthermore, there is limited use of digital tools that could supplement practical work due to some restrictive school policies (e.g., 'no cell phone' rules), some teachers still hold the belief that science should be taught through physical methods rather than using digital tools.[38]

At the university level, students encounter a more rigorous and autonomous approach to practical work that requires skills in experimental work, data analysis, and scientific reporting.[30,31] While some students felt adequately prepared, possibly due to prior exposure to similar experiments and apparatus, many reported feeling unprepared, citing limited hands-on experience, lack of familiarity with laboratory protocols, insufficient training in critical thinking and overdominance of teachers' demonstration as primary teaching approach.[26,27] These findings align with prior research highlighting similar challenges in the transition from high school to university-level science education, particularly in contexts where practical work is either undermined, constrained by contextual factors, or poorly implemented at the high school level.[22,29]

In light of the findings, this study therefore underscores the importance of aligning high school and university curricula to ensure a seamless transition for students. While the LGCSE curriculum emphasizes essential practical skills, the implementation of practical work is still hindered by systemic challenges that include inadequate infrastructure, limited resources, time management, and insufficient teacher training.[7,10,11] Addressing these challenges requires a concerted effort from all stakeholders such as the Ministry of Education, teachers, researchers and institutions of higher learning in order to improve the quality of science education in Lesotho. This is especially so, given that Lesotho is about to introduce a qualification higher than the LGCSE. It is critical that practical work is given equal consideration if not more than the theoretical aspects as the expectation would be that the students would not have the same entry point into the university as those with the LGCSE qualification.

Conclusion

The findings of this study show that not much has been done to improve students' engagement in practical work since George and Kolobe's[8] study reported over a decade ago. The practical work constraints in Lesotho high schools and the gaps in the implementation of practical work, have far-reaching implications for students' preparedness for university-level science programs. Many students begin university with limited or no hands-on experience in practical work, which hinders their capacity to engage meaningfully with university-level practical work. Resource constraints, such as the lack of functional laboratories, adequate apparatus, and consumables in high schools, severely limit the quality and quantity of practical work that students can engage in. The prevalence of teacher demonstrations in high schools restricts students' opportunities to develop essential scientific skills, autonomy, and confidence in handling laboratory apparatus. As a result, this approach instills fear and anxiety in many students. Consequently, students face significant challenges in adapting to the more rigorous and autonomous nature of university-level practical work, which beyond hands-on activities, also demands experimental design, data analysis, and scientific reporting. There is also a critical need to align high school and university curricula to ensure that students are adequately prepared for the demands of university-level science education.

Recommendations

As much as this study focused on chemistry as a subject, the following recommendations are proposed for the improvement of the quality of practical work in science education in general to enhance students' preparedness for university-level science programs. The government and relevant stakeholders should prioritize investment in the construction and maintenance of functional laboratories in high schools, ensuring that students have access to the necessary facilities and resources for practical work.[41] Teachers should receive ongoing professional development and support to effectively implement practical work in their classrooms, including training on how to design and conduct practical activities that promote critical thinking and scientific inquiry. This could be done through collaborations between universities and high schools to provide guidance and support for the implementation of practical work, which could include workshops, mentorship programs, and resource-sharing initiatives. Where there are inadequacies in the facilities, digital tools such as Artificial Intelligence powered tools, videos and simulations are recommended to support practical work. This calls for the provision of access to electricity and information and communication technology (ICT) tools to schools and review of some of those somewhat outdated 'no cell phone in schools' policies.

The LGCSE curriculum needs to be implemented to provide more opportunities for practical work. This would help to ensure a seamless transition for students into university-level science programs. Emphasis should be placed on developing essential hands-on skills and basic scientific processes. This foundation will allow university training to focus on higher-level competencies such as experimental design, data analysis, and scientific reporting, rather than addressing students' anxieties. Schools should also try to adopt flexible timetables to allocate sufficient time for practical work so that it does not feel like a burden to conduct practical sessions by the science teachers.

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AUTHOR CONTRIBUTIONS

Mosotho J. George: Conceptualization, methodology, investigation, formal analysis, writing original draft, writing; reviewing & editing.
Lereko G. Mohafa: Conceptualization, methodology, investigation, formal analysis, writing original draft, writing; reviewing & editing.

DECLARATION OF COMPETING OR FINANCIAL INTERESTS

There is no competing or financial interest in this study.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

No generative AI and AI-assisted technologies were used in this study.

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