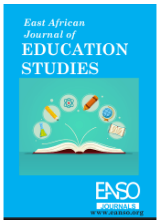

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Original Article

Science Laboratory Availability and Functionality in Secondary Schools of Mbarara City, Uganda: A Qualitative Investigation

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ABSTRACT

The science laboratory is crucial for teaching general science and natural science subjects. It provides a space to apply theoretical knowledge and promotes engaging and visual learning. Students can express their creativity, ignite their enthusiasm for scientific inquiry, and develop their critical problem-solving abilities through hands-on experiences. This paper is part of the doctoral thesis, which aims to assess the state of science laboratories in secondary schools in Mbarara City, Uganda. The research was conducted in 36 secondary schools, which include both Government and Private schools in Mbarara City, from January 2025 to April 2025, to investigate and identify the issues in the science laboratories of schools. The study used a qualitative approach, and data was gathered based on the type of school, encompassing both government and private institutions, through interviews with 30 headteachers and non-participant observations of the laboratories of all selected 36 schools. The findings indicated that school laboratories mainly serve general purposes, with a notably inadequate system of specialized labs for each science discipline, particularly in private schools, due to limited funding and resources. 82.75% of the total sampled schools have inadequate resources. Regarding laboratory tools, chemicals, and specimens, government schools are generally better equipped than their private counterparts. Apart from the inadequate resources, other issues like teachers' unavailability, scarcity of books, and many other issues also arose, directly or indirectly hampering the science laboratory's availability and functionality. The study will shed light on the need for timely monitoring of different aspects of science laboratory teaching at schools. Each school was observed only once, restricting the range of teaching-learning activities and observer effect can influence conclusions based on observation and data analysis.

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INTRODUCTION

Advancements in education are widely regarded as essential for expediting a nation's development (Onanuga & Saka, 2015). By investing in educational progress, countries can promote growth and enhance overall well-being. The laboratory serves as a platform where learners are provided the opportunity to engage with subjects, beliefs, ideas, statements, and various forms of experimental tests. With the expectation of daily science instruction, all secondary-level students should have multiple opportunities each week to explore scientific laboratories. In executing practical work, particular emphasis should be placed on its foundational purpose: specifically, the rationale for students' engagement in practical activities and the potential benefits they may gain from the scientific learning experience, rather than concentrating solely on the actions undertaken during the process (Isozaki, 2017). The laboratory has been recognized as the cornerstone of a robust scientific program, enabling school students to partake in experiences aligned with the objectives of scientific literacy.

Where will future scientists come from if we do not inspire our students through experiences of practical science, enabling them to see how accepted scientific theories and the body of knowledge were discovered, running experiments to produce data to support theory, and allowing them to develop skills to carry out original research themselves?

The science laboratory has transformed into a diverse learning space vital for enhancing scientific education in the modern educational landscape. Issues faced during experiments are frequently cited as reasons for insufficient commitment and an inability to understand experiments' essential role in comprehending scientific concepts (Kumari, 2024). Integrating practical lessons with theory lessons is mainly influenced by laboratory conditions, equipment, chemicals, lighting, waste disposal, etc.

LITERATURE REVIEW

Considerable efforts have been made in pointing the scientific evolution in the direction of teaching and learning science (De-silva et al., 2018, as cited in Rukundo & Bashaija, 2022). Science education in Africa promises to foster innovative breakthroughs and cultivate a new wave of scientists and innovators. However, its advancement on the continent faces significant obstacles (Margaret, 2021). This paper by Margaret aims to explore the challenges in science education and demonstrate how they inhibit African nations from excelling in sustainable development. The essential reliance on textbooks in science instruction imparts knowledge but fails to enhance practical skills (Parliament, 2021, as cited in Maate, 2023).

Science education influences Uganda's future by equipping students with essential critical thinking, problem-solving skills, and scientific knowledge (Uganda Professional Science Teachers' Union

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(UPSTU), 2023). According to Kiconco and Karyarugokwo (2022), Uganda stands out among African nations by prioritizing a science-driven paradigm to promote growth and development. However, merely enhancing science teachers' salaries may not suffice to improve science performance; instead, it is crucial to consider additional factors. Scientific learning, instruction, and education cannot be effectively achieved without adequately equipped facilities that include well-established laboratories (Shahzadi et al., 2023, as cited in Kumari, 2024). In Uganda, the prevailing policy stipulates that all secondary educational institutions must present sciences as a mandatory subject at the ordinary level (Eitu, 2015).

According to the findings from NDP III, considerable progress has been made in establishing various facets that can enhance Science, Technology, and Innovation (STI), including institutions, curriculum frameworks, and infrastructure. Nevertheless, the rate at which innovations are transformed into actionable outputs that significantly influence economic development remains insufficient. The National Development Plan acknowledges the prevailing shortcomings in the education sector, such as low efficiency and inconsistent quality at the secondary level. Analysis in planning activities and supporting a hands-on, mind-on approach to teaching is essential (Needham, 2014). However, an extensive study is needed to minimize the gap in science teaching. Various factors, particularly the lack of financial resources, impact the quality of education (Muhangi, 2019). Key challenges for optimal laboratory conditions include insufficient resources, inadequate teacher training, time limitations, and weak technological infrastructure (Kit et al., 2023). The quality of science education is influenced by factors such as Inadequate Resources, Teacher Shortages and Training, Limited Infrastructure, Gender Disparity, Curriculum, and Pedagogical Approaches (UPSTU, 2023). This situation highlights the critical need for science education and the promising opportunities it can offer.

One anticipated learning outcome of the lower secondary curriculum is to value the physical, biological, and technological disciplines while making informed decisions concerning sustainable development and its implications for individuals and the environment (NCDC, 2019). The objectives of the secondary curriculum also emphasize the necessity of equipping individuals with fundamental scientific, technological, technical, agricultural, and commercial skills essential for self-employment (NCDC, 2025).

Despite several studies regarding school infrastructure, water quality, and various educational or health factors, there is a notable scarcity of research that zeroes in specifically on the availability and functionality of science laboratories in schools located within Mbarara City. Most existing literature found during the course of the study tends to address broader issues rather than providing specific insights into the conditions of science labs in this region.

The study aimed to investigate the state of science laboratories at secondary schools in Mbarara City, Uganda. It was supplemented with a thematic analysis of the observation checklist and interviews of respondents used for data collection.

Research Questions

In order to understand the availability and functionality of laboratories at secondary schools in Mbarara City, this study was primarily guided by the following research question:

• What is the condition of science laboratories at schools in terms of facilities, resource availability, funding, and the training of teachers on-site?

Responses to this question reflect the actual circumstances of science laboratory education at secondary schools in Mbarara City, Uganda. Furthermore, the components of the question were developed into themes within the methodologies, which facilitated a detailed investigation of the study subject.

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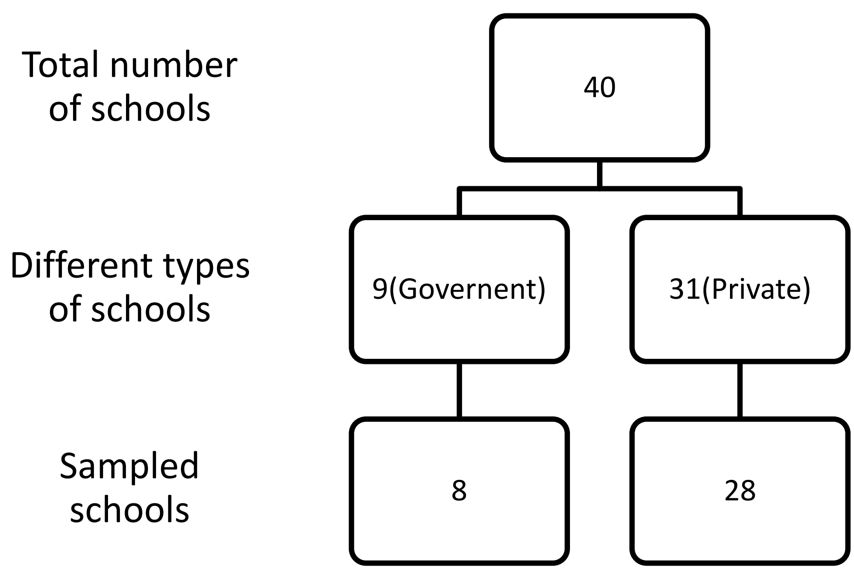
METHODOLOGY

This study employs a qualitative research approach to explore the availability and functionality of science laboratories in secondary schools in Mbarara City, Uganda. The research design aligns with a qualitative case study approach for several reasons. First, it focuses on a specific setting: secondary schools in Mbarara City, exploring science laboratory education. Case studies provide deep insights into phenomena within real-world contexts. Second, the study relies on in-depth interviews and non-participant observations rather than numerical data, fitting qualitative research methodologies. Lastly, it is descriptive and exploratory, aiming to understand challenges, perspectives, and conditions instead of testing hypotheses with statistical analysis.

Data Collection

The study sample was based on stratified random sampling. In total, 36 schools were taken from the 40 schools (at the time of data collection and as per records from the SESEMAT office and Education office records) for the study. Among them, 8 were government and 28 were private schools. Further schools covered are from both the north and south divisions of Mbarara City. The study was conducted from January 2025 to April 2025. Prior permissions were obtained from the DEO and interviewees, who were the head teachers of the schools. In-depth interviews and non-participant observations were the data collection strategies. All interviewees consented to participate in the discussion of the subject. The interview participants were head teachers of selected schools. Out of 36 head teachers, 30 were interviewed, achieving data saturation, the point at which no new conceptual insights are generated from subsequent interviews. This method ensured the data collected was both comprehensive and deeply contextualized, which was essential for answering the research question. They were interviewed to gain insights into their views about science laboratory education and the challenges they face in integrating it into teaching. Science laboratories of all the selected secondary schools were observed to delve deeper into the conditions of the science laboratory. The key areas, like safety and lab management, time management, and physical environment and resources, were used for preparing an observation checklist to assess laboratory availability and functionality at schools. These criteria used for the observation of the laboratory provided a holistic and constructive view of the science laboratory.

Figure 1: Sampling of Schools



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Data Analysis

Thematic analysis is a qualitative method that involves identifying and interpreting inherent themes. Themes can be identified by examining the keywords provided by participants (Naeem, et al., 2023). As cited in Nowell (2017), Braun and Clarke (2006), along with King (2004), posited that thematic analysis serves as a practical methodology for exploring the perspectives of various research participants, thereby illuminating both similarities and differences while generating unforeseen insights. Additionally, thematic analysis proves beneficial in summarizing the salient features of extensive data sets, compelling the researcher to adopt a meticulously structured approach to data management, which in turn aids in producing a clear and organized final report.

Responses to the interviews were collected in both written and recorded formats. The raw data obtained from the recorded interviews were initially transcribed. Subsequently, the transcripts underwent a coding process utilizing open and axial coding methods. During the open coding phase, the data were categorized and conceptualized, while the axial coding phase sought to identify the underlying logic among the various data categories (Huang Z, Ouyang, Huang X, Yang, & Lin, 2021). The transcripts were compared with the written notes to ensure accuracy and consistency. This process involved thorough reading and rereading to gain familiarity with the data.

Table 1: Themes Generated from Interviews

Codes from Interviews	Themes
Not Adequate	Inadequate Resources
Missing A Bit	
Inadequate Resources	
Lack of Materials	
Facilities Lacking	
Expensive Chemicals	
Not Easily Accessible Chemicals and Resources	
Need More	
Requires Lots of Apparatus	
Inadequate Space	
Inadequate Teachers Training	Teachers Unavailability and Lack of Teachers Training
Lack of Preparation	
Improper Teacher -Student Ratio	
Lack of Teachers	
Old Prepared	
Still Not Mastered	
More Motivation of Teachers	
Challenge of Adapting New Curriculum	
Teachers Struggling with New Curriculum	
Lack of Books	Scarcity of New Curriculum Books, Vast Syllabus, Tiresome, And Time Consuming,
Uneven Distribution of Books	
Inadequate Books	
Less Time	
Time-Consuming	
Tiresome	
Less Interest from Students	Students' Negative Attitude in Labs
Behaviour of Students in Labs	
Some Students Need Spoon Feeding	

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Subsequently, categories aligned with the corresponding research questions were established, explicitly focusing on teacher-related, book- and syllabus-related, chemical- and equipment-related, and time-related aspects of school laboratories. A comprehensive treatise was developed, highlighting identified themes and sub-themes. Furthermore, patterns and relationships among the interviews and the observation checklist were discerned, culminating in the final synthesis of ideas.

RESULTS

Using thematic content analysis, themes related to teachers, space, chemicals, and equipment arose. As reflected in the compelling quotes, some subthemes were identified during the analysis. These were the high operational costs of laboratories, teacher competence, instructional materials, school infrastructure, and students' interest.

Table 2 summarizes the schools with separate laboratories for different science courses. After the data collection, it became apparent that most schools had only one room for experimentation. However, most government schools are maintained somehow, and around 87.5% of government schools have separate laboratories for different science subjects. Private schools are not at par with this condition, with only 7.1% having separate labs, and the rest are still struggling.

Table 3 shows various indicators essential for the functionality of science laboratory systems in schools. The present study indicated that most schools face the challenge of inadequate resources. 82.75 % of interview respondents agreed that their science laboratory facilities face challenges with insufficient resources, which is more prevalent with the increasing enrollment of students at schools. Teachers' training is also inadequate. Around 41.37% of respondents indicated that teachers still face problems integrating new curricula. They are still not prepared for the new hands-on system.

Observations of school laboratories showed that more than 50% of schools have a maintenance problem, and around 69.44% of schools do not have safety measures inside the lab. A good number of schools, around 33.33 %, do not have lab technicians, and around 38.88% of schools do not have a fixed time for practical lessons. Those that have fixed timetables are mostly for upper-secondary classes.

Table 2: Availability of Separate Laboratories for Different Science Courses

Type of school	Total Number of schools in the study	Schools having separate laboratories for different science courses	
		Yes (%)	No (%)
Government	8	7 (87.5)	1 (12.5)
Private	28	2 (7.1)	26 (92.9)

Figure 2: Availability of Separate Science Laboratories for Different Courses.

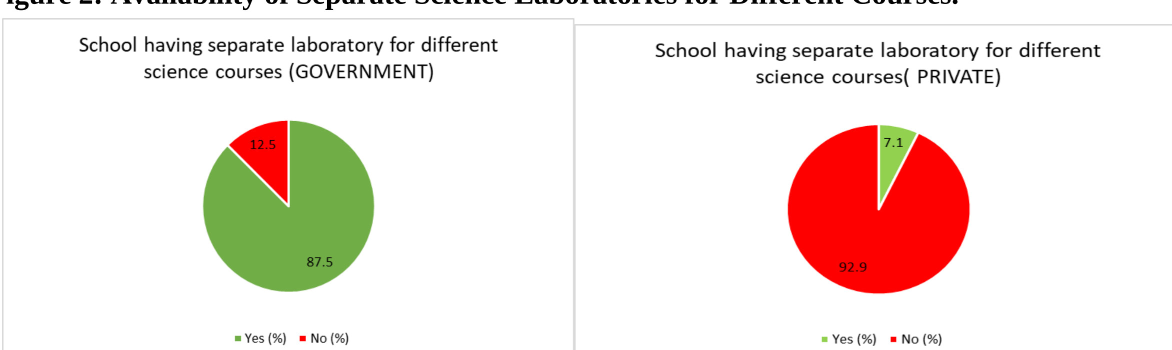

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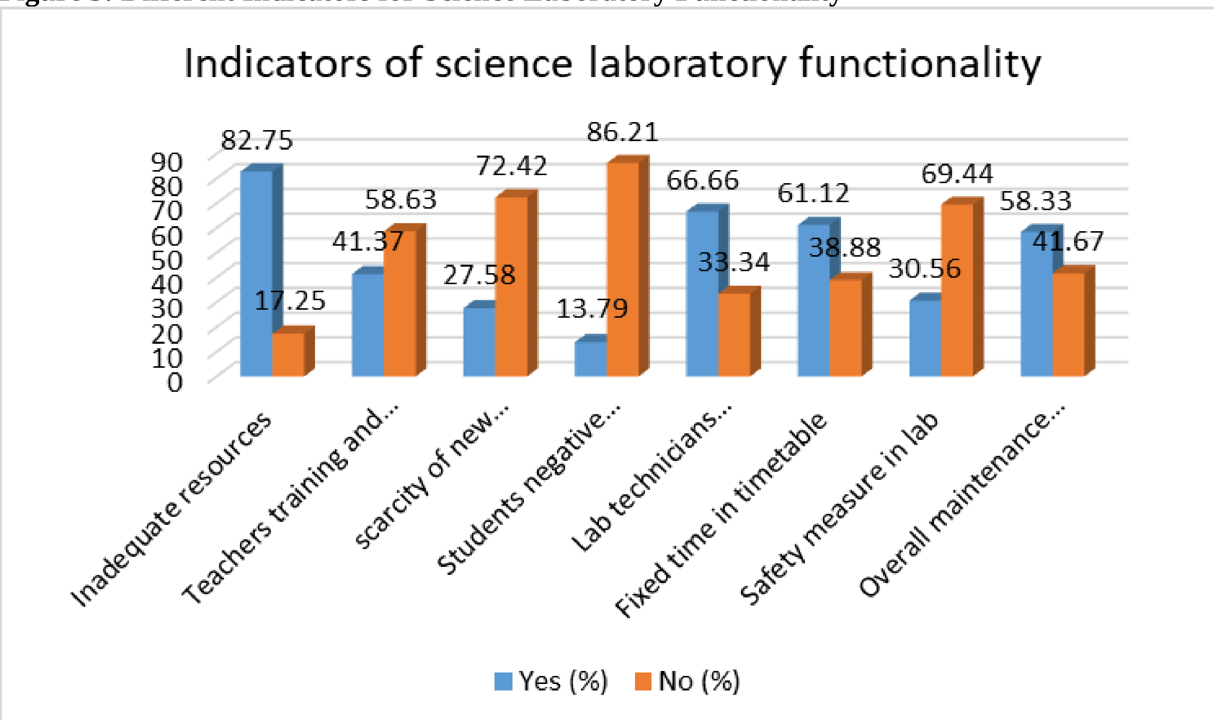
Table 3: Indicators of Science Laboratory Functionality

Data collection tools	Indicators	Yes (%)	No (%)
Interview	Inadequate resources	82.75	17.25
	Teachers training and availability	41.37	58.63
	scarcity of new curriculum books, vast syllabus, tiresome and time-consuming,	27.58	72.42
	Students' negative attitude in labs	13.79	86.21
Non-participant Observations	Lab technician's availability	66.66	33.34
	Fixed time in the timetable	61.12	38.88
	Safety measures in the lab	30.56	69.44
	Overall maintenance problem in the lab.	58.33	41.67

Figure 3: Different Indicators for Science Laboratory Functionality



As data captured from interviews, some of the quotations that reflect major issues are as follows:

Inadequate Resources

> ***Respondent HT1:*** *We have basic but not adequate compared to the number of students. We take them in shifts for practical lessons to accommodate them.*

> ***Respondent HT2:*** *It is an average laboratory. It needs more help getting equipment. Space will not be an issue if help is given in terms of facilities. The school can work on infrastructure if it has enough laboratory resources.*

Teachers' training and availability

> ***Respondent HT1:*** *Adequate teacher training on integrating practicals in lessons is needed. There is a missing link. Students are okay with the practical, but they panic at the time of assessment. Earlier, we used to start practicals at later stages, but now, after this new curriculum, we have to start at an early stage. Now, most teachers have an idea of picking up*

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practical skills at later stages as an independent part instead of integrating.

Respondent HT4: *Since the numbers are too much, the teacher-student ratio is affected. We have to appoint private teachers because what the government is giving is not enough. Integrating labs in teaching is okay, and boys are coping with it.*

Respondent HT8: *Little bit challenging to integrate, teachers are not trained as per the new curriculum.*

Scarcity of Books and a Vast Syllabus

Respondent HT10: *Integrating science laboratories into teaching is challenging for private institutions. Textbooks are distributed unevenly. Sometimes, it is not even distributed.*

Respondent HT11: *Integrating is good given that enrollment is big, only one lab and time is not enough to integrate science practicals with teaching properly.*

Respondent HT21: *Of course, it is supportive and relevant. The challenge is that we lack new books. The new curriculum needs materials, and we lack those.*

DISCUSSION OF FINDINGS

This study assesses the status of science laboratories at secondary schools in Mbarara City, Uganda. Data was collected through interviews and observation checklists.

According to the Uganda National Examinations Board (UNEB) (2017), evidence continues to indicate a predominance of theoretical instruction in the sciences despite substantial initiatives undertaken by the Ministry of Education and Sports to enhance schools' access to laboratory materials and equipment. The study's major findings are summarised in Table 4 below.

Table 4: Key Findings from the Study.

Method	Major Findings	Linked Academic Issues
Observation schedule	• The quality of the equipment/chemicals for each demonstration room or skills lab is in demand and needs improvement. • There is a lack of regular practical classes. • The observation regarding the laboratory stakeholders, like lab technicians' availability, also demands improvement. • Safety measures in laboratories are also not proper. • Most schools have maintenance problems in science labs, including handling and storing chemicals.	• Labs are not meeting the demands required to be maintained in schools. • Improper management of labs at the school level hinders the proper functionality of labs. • Most of the time, practical lessons are converted into theory lessons due to inadequate facilities, such as working space for students, equipment, and safety issues.
Interview	• Necessary chemicals/equipment in labs are on the lower side. Around 82.75% of schools have inadequate resources. • Teachers' availability and teachers' training still need improvement. Around 41.37% of interviews mentioned the issue. • Other issues affecting science laboratory education at schools are scarcity of books, vast theories to teach, and students' negative attitudes towards science subjects.	• The science lab's capacity to provide instruction is affected by the shortage of equipment, Chemical. • Little opportunity to work in labs and even less of several performing practicals individually. • There is still a lack of skills in arranging practicals for students.

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This study on the condition of science laboratories in secondary schools in Mbarara City, Uganda, employed a qualitative approach and argues that, despite a national policy mandating science education, there is a significant disconnect between policy and practice. The core problem identified was the widespread inadequacy of science laboratories in terms of equipment, safety, management, and opportunities for practical work. This deficiency fundamentally undermines the goals of science education, converting hands-on learning into theoretical instruction and failing to equip students with essential practical skills for sustainable development.

The research effectively situated the study within the larger discourse on science education as a driver for innovation and development in Africa. It acknowledges the continent's ambitions but immediately pivots to the "significant obstacles" (Margaret, 2021). It highlights Uganda's specific policy landscape, which makes the findings more poignant. Key policies include Science as a compulsory subject at the ordinary secondary level (Eitu, 2015), creating a high demand for quality instruction. National Development Plan (NDP III) that acknowledges the importance of Science, Technology, and Innovation (STI) but also recognizes existing "shortcomings in the education sector" and Curriculum Goals

The findings, clearly presented in Table 4, paint a comprehensive picture that can be grouped into several themes:

Inadequate Physical Resources: This is the most dominant theme. Findings show a severe lack of quality and quantity of equipment and chemicals. The statistic that 82.75% of selected 36 schools have inadequate resources is a powerful indictment of the current state.

Failure of Practical Instruction: A direct consequence of resource scarcity is that practical learning is compromised. "Lack of regular practical classes" and the conversion of "practical lessons into theory lessons" showed that the very essence of science education is being lost. Students have "little opportunity to work in labs," especially individually.

Human Resource and Management Deficiencies: The problem isn't just a lack of "staff." The results pointed to a lack of trained personnel, including lab technicians and properly trained teachers. Improper management hinders the functionality of the few resources that were available.

Safety and Maintenance Concerns: The results highlighted that safety measures are "not proper" and that schools struggle with the maintenance and storage of chemicals. This not only affects the quality of education but also poses a direct risk to students and staff.

Negative Student Attitudes: An important secondary finding was the students' negative attitudes towards science subjects. This is likely a consequence of the unengaging, theory-heavy teaching style that results from poor lab facilities.

CONCLUSION AND RECOMMENDATION

This study effectively demonstrated that the Ugandan government's vision for a science-led future is being critically undermined at the foundational level of secondary education. The lack of functional, safe, and well-managed science laboratories in Mbarara City creates a learning environment where practical skills development and curriculum goals are unmet, and students may become disengaged from science.

Centuries of exclusively deductive methodologies have not yielded the same practical benefits as a few decades of experimental work. This observation underscores the importance of science laboratories in science education, suggesting that schools lacking laboratory facilities for conducting practical experiments in biology, chemistry, and physics may produce graduates deficient in the practical knowledge necessary to succeed in the senior school

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certificate examination. Several prominent factors contributing to the increasing disinterest in science education are identified as follows:

- Inadequate equipment
- Insufficiently trained and qualified teachers
- High teacher turnover resulting from the stresses of the current educational environment
- Budgets that are insufficient compared to the needs
- Poor Student-teacher ratio
- Unscheduled time for practicals
- Poor safety measures in the laboratory
- Lack of maintenance
- Unavailability of books as per the curriculum

Considering that science education is a continuum, examining its development and implications at the school level is imperative. Science is taught at the lower secondary level as an integrated whole rather than a compartmentalized discipline. Discipline-oriented teaching and learning begin at the S5 and S6 standards, corresponding to 18- to 20-year-olds. Furthermore, school facilities have been identified as a significant factor influencing the quality of education. The findings of this study showed that laboratory facilities are highly inadequate and far below expectations, and in most schools, science experiments are not being conducted. This study also revealed that there is no timely monitoring of science practical activities and conditions of science laboratories, which also influences their functionality over the years.

The paper serves as a powerful call to action, highlighting that investment in science education must go beyond policy and teacher salaries to include the essential infrastructure that makes true scientific inquiry possible. As recommendations after the study, it is essential to monitor school laboratories in a timely manner. There is also a need for more extensive pre-service and in-service teacher training, strategic funding, and proper implementation of policies after evaluation.

Implications for Further Research

The results obtained from the study only reflect subjective perceptions. The study was conducted only in Mbarara, but it can also be carried out in other districts. To delve deeper into understanding, extensive studies with empirical methods can be done.

Delimitation of the Study.

The study has highlighted significant inadequacies, which are discussed. However, this dissertation has limitations.

- The schools were sampled using stratified random sampling in Mbarara city. Therefore, the findings cannot be generalized to the whole district or block.
- All schools included in the sample are observed only once, which limits the variety of teaching-learning activities and observations.
- During the whole data collection, the observer effect may be significant. How observers predict from observation and how data is analyzed play significant roles in concluding.

Conflict of Interest and Acknowledgement.

There are no conflicts of interest to declare. This paper is part of the Doctoral thesis, and the author, Preeti Kumari, PhD scholar, coined the study and designed the tool under the supervision and Guidance of Dr Sudi Balimuttajjo and Dr Irene Aheisibwe.

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