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Science Laboratory Education and Students' Perceived Behavior Towards Science Education: A Review

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Abstract: *Science, as defined by The Oxford Advanced Learner Dictionary (2006), is knowledge about the structure and behavior of the natural world based on facts that can be proven through experimentation. Science laboratory teaching heavily influences the effective teaching and learning of science as it is a place for conducting experiments and the birthplace of a comprehensive and practical understanding of science. With its emphasis on hands-on experiences, laboratory learning is crucial in preparing students for future scientific endeavors. Consistent practice leads to proficiency in what the learner has been taught during classroom instruction. The saying 'practice makes perfect' (Hager, 1974, as cited in Pareek, 2019) also holds true in science education. This review paper aimed to illuminate the transformative role of science laboratory education in shaping students' attitudes toward science subjects and motivation to make a career in science and technology. A Constructivist approach to learning guided this review. Science education significantly benefits from the use of science laboratories, as supported by Dewey's learning by doing, Kolb's experiential learning theory, and Kuhn's paradigm shift theory. According to the instructional theory of learning interaction, the science laboratory directly impacts students' attitudes and motivation, leading to better academic performance. The literature was thoroughly researched and critically analyzed in the area of interest in the review. The literature sources mainly focus on the last ten years (2013-2023), with some current additions to the present knowledge economy. As recommendations after the literature search, on one side where teacher competency is essential, there is an urgent need to address resource mobilization issues at schools, targeting the problems of budget, space, etc., to make space for innovation.*

Keywords: *Science education, Science laboratory, Attitude, Motivation, Scientific temperament, Hands-on learning*

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1. Introduction

Quality education is the fourth of the 17 SDGs (United Nations Department of Economic and Social Affairs). Although it focuses more on enhancing basic literacy skills, it also sheds light on the quality of education. Education can be a goal for any country and a catalyst for achieving SDGs. Building scientific temperament and thinking out of the box is essential in the era of innovations. The goals of science education have undergone a significant transformation over the past century from 'ways we do science' education to 'what it means to do science' education (Odden et al., 2021). When research strands of psychology, neuroscience, and computational learning theory are simultaneously assessed, it indicates that curiosity and learning are firmly connected, and it affects learning (Oudeyer, 2016).

According to Kilag et al. (2023), developing a deeper understanding of scientific concepts, fostering collaboration and teamwork skills, and promoting the practical application of knowledge are potential benefits

and the essence of utilizing a science laboratory. Science teaching and practical work are inseparable elements in science education. Science learning, teaching, and education are not possible without dedicated facilities comprising well-established laboratories (Shahzadi et al., 2023). Studying and using labs and science materials is essential for growth in daily life and a crucial step towards progress and success (Musah & Umar, 2017, as cited in Kumi-Manu, 2024). The importance of science laboratories in promoting collaboration and teamwork skills cannot be overlooked in the context of science education. These skills play a vital role in the learning process and contribute significantly to students' overall understanding. Additionally, the effectiveness of teaching and learning facilities greatly influences students' levels of comprehension.

According to the HLS-EU consortium (2012), as cited by Matte (2023), science combinations at the school level allow students to freely join science professions like engineering, aeronautics, and many more. In a comprehensive study conducted by Finne et al. (2022), the effect of hands-on laboratory activities compared to purely theoretical classes was thoroughly examined. The findings indicate that engaging in laboratory experiences and cultivating strong relationships with educators within the lab environment play a significant role in enhancing students' educational journeys. Such interactions foster meaningful dialogue and constructive feedback, which are essential for deepening comprehension.

The objectives of laboratory activities are to encourage accurate observation and description, to make scientific phenomena more natural, to enhance the understanding of scientific ideas, to arouse and maintain interest (particularly in younger pupils), and to promote a scientific method of thought (Hofstein, 2017). There is a demand for quality science education at the individual and the more comprehensive socio-economic and political level, anticipating the continual events shaping the world. The need to comprehend and apply scientific principles in life has placed a greater demand on studying science (Anwer et al., 2012, as cited in Kabunga, 2016). Science lessons are distinguished by their dynamic focus on hands-on activities and experimentation, which makes learning engaging and fosters a deeper understanding of scientific concepts (Ismael, 2018).

This review paper aims to provide an in-depth exploration of the multifaceted significance of science laboratory education. It will discuss how effective laboratory experiences contribute to high-quality science education by enhancing student engagement, promoting critical thinking, and developing practical skills essential for scientific inquiry and discovery. These practical skills, gained through science laboratory education, reassure us of the effectiveness of this approach in preparing students for future scientific endeavors.

1.1 Research Questions

This article reviewed and analyzed information from studies performed over the last decades to answer the following questions.

(1) What characterizes laboratory work in secondary school science teaching to develop students' interest in learning science?

(2) What characterizes laboratory work in secondary school science teaching to motivate students to choose science as a career?

2. Literature Review

Teaching in the laboratory is related to using the five sense organs. The VARK (Visual, Auditory, Reading/Writing, Kinesthetic) model, emphasizing laboratory use at secondary schools, is essential (Sreenidhi and Helena, as cited in Matte, 2023). This includes their attitude and motivation in choosing science as a career. Linn (1997), as cited in Kamba (2019), emphasizes that the extensive use of laboratories in science education serves several constructive purposes. Laboratories provide students with hands-on experiences that make abstract and complex scientific concepts more accessible and understandable. They also promote the development of problem-solving and analytical skills by encouraging exploration of the scientific process. Additionally, these environments help cultivate practical skills and specialized talents among students while engaging in activities in the lab, which inspires motivation and fosters a positive attitude toward scientific inquiry. This comprehensive approach enhances learning and nurtures a lifelong appreciation for science.

2.1 Science laboratory work and attitude towards science

According to the Cambridge Dictionary, attitude is a feeling or opinion about something or someone or a way of behaving caused by those feelings and opinions. Students' attitudes play a pivotal role in science education as well. The process-oriented guided inquiry learning method, which involves students working in small groups using specially designed materials, has proven highly effective.

Finne et al. (2022) also mentioned in their study that the students generally feel missing out on something when they are not in the laboratory and doing the experiments themselves. It is a fact that whenever there is an unconducive teaching-learning environment, the students will not achieve the objectives of any learning process at

the end of the lesson. The discomfort of continuously sitting at desks in class is enough to distract and discourage students' interest in the whole day's work, leading to low interest in science subjects. They will have a low level of understanding because interest also plays a vital role in facilitating learning. Therefore, the knowledge delivered to the students would not be fully understood.

Laboratory instruction is meant to assist students in identifying their learning abilities and developing everyday scientific problem-solving and critical-thinking skills (Yildirim, 2016). Laboratory learning is one method that provides students with data and guiding questions from the instructor to help them form valid conclusions, essentially following the scientific method. It is a powerful tool for improving students' attitudes and performance in science (Okam, 2016). Okam (2016) wrote it in the context of chemistry teaching, but it can also be employed in overall laboratory teaching.

According to Crawford (2014), as cited in Gericke (2022), science practices describe a broader but articulated understanding of doing science compared to inquiry. The idea involves students going beyond experiencing inquiry by interpreting and evaluating data as evidence to developing arguments, explanations, and models. The concept of science as a problematic stream significantly contributes to their perceptions of the science laboratory environment, fostering their science learning self-efficacy (Lee et al., 2020). Student attitudes should be central to educators because affective dispositions are potent predictors of student performance (Kabunga et al., 2016).

The study by Namayanja et al. (2022) concluded that improving students' attitudes and perceptions of science is paramount. This emphasis, advocacy for practical teaching, and timely syllabus completion will improve students' perception and performance in the sciences and enhance their understanding of STEM subjects, underscoring the crucial role of educators and policymakers in shaping students' attitudes toward science.

Nicol et al. (2022) conducted a systematic review to explore students' views, opinions, and perspectives on laboratory learning and the potential implications for current science laboratory practices and science education research. When reflecting on science laboratory topics, students showed a strong interest in demonstrating sufficient knowledge of the aims and purposes of laboratory learning, its effectiveness or impact, challenges, anxieties, and preferences in laboratory learning activities.

According to Omiko (2015), in science education, it is believed that the laboratory can potentially merge theory and practice for students. These goals include grasping scientific concepts, fostering interest and motivation, developing practical skills, and enhancing problem-solving abilities. Imagining experiments only, especially in chemistry and physics, hinders their learning. Actual demonstrations of experiments will nurture students' minds and motor skills (Arnejo et al., 2021).

In terms of the purpose of laboratory learning, Harman et al., 2016 discussed that, in students' opinion, it includes permanent learning and the application of learned concepts. Aykutlu et al., 2019 mentioned that in the view of students, the purpose of the science laboratory is learning for curiosity, learning by direction, and learning by labor. In the study by George-Williams et al. (2018) cited by Nicol et al. (2022), students stated that laboratory teaching aims to impart knowledge of scientific ways of reasoning and the appropriate use of scientific language.

2.2 Science laboratory work and motivation for choosing science as a career

The use of laboratories by the students plays an important role, i.e., in building up interest in science in the students and coping with the fear of science as a career. Learning becomes intrinsically motivational and may lead to increased cognitive and psychomotor gains when students hold the correct opinions about laboratory activities. Research by Meyers, 2021 supported the importance of motivation in student learning. According to (Vedder-Weiss and Fortus, 2011, as cited in Meyers, 2021), students lose motivation as they advance in their academic careers, which affects their learning of the subject. It was observed in Meyer's 2021 study that many of the students were engaged and enthusiastic about the activity.

Scientific facilities play a crucial role in supporting the development of acquisition and retention skills and cultivating positive student attitudes and behavior. High-quality science education in schools develops scientific literacy and is expected to predispose students to study science at the University level (Zengele & Alemayehu, 2016). The study, which was conducted in Ethiopia, indicated a considerable gap between actual and ideal situations. Foundation for future scientists, doctors, engineers, teachers, etc., is laid in schools. Producing the required workforce for the country's development, especially in science, heavily depends on how we teach it in secondary schools. At this stage, students will develop their interest in science and pursue it as a career later in life (Kelkey, 2023).

The amount of practical work increases the quality of science subjects, students' views of science, and achievement. In 2016, Lin-Siegler and colleagues conducted a study on motivation, emphasizing a varied

group of students, and found that the prevalent belief among the students was that they could not pursue careers in science because of their abilities. Undoubtedly, motivation to learn science has been a perplexing topic of interest for educational researchers.

As the adverse effect of not having a functional lab at school, students have confusion, loss of interest, and poor concentration in science subjects, which demotivate them to choose careers in science-related areas (Arnejo et al., 2021). The study in the Philippines showed that students acknowledge using functional labs at schools. The paper recommended that schools have functional labs to support students' learning and motivation in science education.

3. Methodology

The review aimed to provide a comprehensive and in-depth examination, encompassing exploratory, explanatory, and descriptive analyses of how science laboratory education influences students' attitudes, behaviors, and overall engagement with science education. The review scope emerged from the identified need for laboratory science education to improve science education quality and promote youth engagement toward science-oriented careers. The review article involved an extensive search and analysis of a wide range of literature sources within the field of interest to elucidate the critical role of science laboratories in science education.

The sources included various online and offline materials such as articles, books, and papers. This approach enabled a thorough exploration of the research questions, effectively enhancing our ability to generalize, contextualize, and analyze the results with credibility. Combining different studies with different methodologies will provide a multidimensional picture of how science laboratory education influences students' attitudes and motivation toward science education.

3.1 Literature search and selection criteria

The focus of the search was broad. The literature was mainly searched via Google Scholar, Research Gate, Academia, and Taylor and Francis. The literature search consists of critical terms like science laboratory education, student attitude, student motivation, Active learning, learning by doing, laboratory at schools, practical activity, scientific temperament, and Secondary school teaching. In the initial phase of the literature search, a comprehensive review was conducted to identify the various factors that influence the quality of education, focusing on the critical role of science education.

This analysis aimed to explore how laboratory instruction enhances the overall quality of science education, thereby determining its effectiveness in fostering a deeper understanding and appreciation of scientific concepts among students. This review searched for almost 45 pieces of literature, and after going through them, around 28 were included in this review article. The literature, which was within the considerable year range and related to its implications on students' attitudes and motivation, was reviewed.

Table 1. Exclusion and Inclusion

Aspects	Included	Excluded
Learning stage	Secondary level of education	Primary education and Higher education institutions
Activity	Science Laboratory Education	Classroom teaching
Studies reviewed	Studies published 2013-23, Peer-reviewed publications, Thesis,	Older than 2013,
Context of studies reviewed	Studies conducted in any country Studies supporting laboratory learning benefits.	
Measurable Outcomes in the studies	Findings Relating student's Attitude and Motivation toward science education	Cross-cutting issues, performance, institutional barriers

4. Results and Discussion

4.1 Results

Most of the literature searched gave an empirical understanding of the transformative roles of science laboratory education in quality science education. The review strengthened the view that the importance of science laboratory teaching is underscored by its influence on students' perceptions, including attitude and motivation, which also leads to students' performance in science subjects. Science lessons stand out from other subjects because they prioritize hands-on activities and experimentation. This approach makes learning more engaging and enhances students' understanding and appreciation of scientific concepts, providing them with valuable skills for the future.

4.1.1 Laboratory work in secondary school science teaching to develop students' interest in learning

A comprehensive review of the existing literature indicates that when students engage in science experiments in a laboratory setting, their grasp of scientific facts and concepts improves significantly. This practical, hands-on experience enhances their understanding and promotes a more positive attitude toward science. Additionally, the role of teachers is crucial, as both formal instruction and informal support, such as direct interactions, conversation, and close supervision in the laboratory, greatly influence students' levels of interest and enthusiasm for science. These experiences foster a deeper connection to the subject, encouraging students to explore and learn more actively.

4.1.2 Laboratory work in secondary school science teaching to motivate students to choose science as a career

Secondary schools play a crucial role in shaping the educational trajectory of students, providing the essential foundation for higher education institutions like universities. Students are introduced to various subjects, including the sciences, during this formative stage. If they do not receive adequate motivation and support in these areas, they may develop a negative perception of science subjects. This reluctance can significantly impact their future aspirations, making them less likely to consider pursuing careers in science, technology, engineering, and mathematics (STEM) fields. Fostering a positive attitude towards science education in secondary schools is vital for encouraging students to explore and engage with these disciplines, ultimately helping to cultivate the next generation of science professionals.

4.2 Discussion

The central finding from the present literature review showed enough empirical evidence that science laboratory education is an indispensable part of science education. Kamba's research (2019) highlights an important area for improvement in science education. It emphasizes that while theoretical knowledge is essential, incorporating practical experiences is crucial for students to comprehend scientific concepts fully. Moreover, the study points to the significant role of well-equipped laboratories in fostering interest in science subjects such as physics, chemistry, and biology. Ismael’s study (2018) highlights the importance of creating an environment that fosters student engagement and learning by incorporating hands-on experiences. Equipping this environment with the necessary tools and resources can enhance students' understanding of scientific concepts. This proactive approach encourages exploration and discovery and promotes active participation, ultimately enriching the learning experience.

The implications of science laboratory education regarding the pedagogical and epistemological aspects of the teaching-learning process can be explained. However, both pedagogical and epistemological aspects are interrelated. For pedagogical purposes, only theoretical classes lead to a loss of close and informal contact between the teacher and students, as teachers are less available to give face-to-face feedback to all students. However, when students are in the laboratory working with instruments and chemicals to generate data, there is more scope for discussion of findings, which helps the students get concepts more clearly. When epistemological instances are considered, students' understanding and comprehension of the results will be more enhanced than in all theory classes. In the laboratory, students learn to translate their findings into texts and results, which engage their minds to relate any phenomenon, experiment, and the data they will achieve. Combining laboratory education's pedagogical and epistemological importance will not only increase science knowledge but also nurture a long-term appreciation for science.

Investing in laboratory facilities and experiential learning programs can potentially enrich the educational experience substantially. These initiatives can inspire students to explore scientific disciplines more deeply and foster a lasting passion for the sciences. By addressing existing gaps in resources and opportunities, we can cultivate a more engaging and effective learning environment that not only encourages student success but also promotes a thriving interest in scientific inquiry.

5. Conclusion and Recommendations

5.1 Conclusion

The science laboratory has evolved into a multifaceted learning environment crucial in advancing scientific education in today's educational landscape. Extensive research literature provides compelling empirical evidence of the significant contribution of science laboratories in achieving academic goals in science. The demand for 21st-century skills has increased, emphasizing the need to cultivate a scientific mindset among students and highlighting the importance of their engagement in science laboratories.

It is often observed that challenges encountered during experiments are used as a justification for a lack of dedication and a failure to grasp the fundamental role experiments play in learning scientific concepts. Unfortunately, even reputable schools sometimes prioritize laboratory work superficially, overlooking its pivotal role in shaping students' understanding of science. On the contrary, positive experiences in well-equipped laboratories have been found to cultivate a better attitude towards science subjects and boost students' motivation to learn and perform. Acknowledging teachers and management's crucial role in facilitating this learning process is imperative. However, socioeconomic background and gender may influence students' attitudes and motivation toward science education.

5.2 Recommendations

In today's era of science and innovation, simply acquiring information is not enough; practical problem-solving skills are essential. However, several challenges need to be addressed to maintain appropriate science laboratories. Issues such as budget constraints, limited space, insufficient resources, and the need for teacher training and development can significantly influence the effectiveness of science education.

Therefore, a student-centered pedagogical approach is recommended, with support from external factors such as teachers and school management. Adequate support from the school administration is crucial to maintaining laboratory resources' high usability and functionality. This support will ensure the proper maintenance and availability of the resources. Competent teachers who have a positive attitude towards laboratory learning can effectively utilize laboratory resources, which in turn can enhance students' motivation and lead to improved performance.

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