



SCIENCE LABORATORY OPERATIONALIZATION AND STUDENTS' ATTITUDE TOWARDS SCIENCE: A STUDY IN SECONDARY SCHOOLS OF MBARARA CITY, UGANDA

(Research article)

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Received: 25.10.2025

Revised version received: 20.01.2026

Accepted: 02.02.2026

Abstract

Science laboratory work is widely promoted as a driver of learners' engagement and positive attitudes toward science, yet evidence on how laboratory operationalization relates to students' attitudes in Ugandan urban secondary schools remains limited. This study aimed to examine the relation between Science Laboratory Operationalization and Academic attitude towards science subjects among secondary school students in Mbarara City, Uganda. A convergent parallel mixed-methods design was used for the study, covering 36 secondary schools (both private and government). Quantitative data were collected from 373 students selected through stratified proportional random sampling using a structured questionnaire, while qualitative data were obtained through semi-structured key informant interviews with 30 headteachers purposively selected for their leadership roles and experience. Quantitative data were analyzed in SPSS (v26) using descriptive statistics, Pearson correlation, and simple linear regression. Qualitative interviews were analyzed thematically, and findings were integrated through triangulation. Results indicated a weak but statistically significant positive correlation ($r = 0.195$, $p < 0.001$) between lab experience and science attitudes. Regression indicated that lab quality significantly predicts students' attitude, but explains only 3.8% of the variance ($R^2 = 0.038$). Qualitative findings complemented the quantitative results by highlighting enhanced engagement and skill development during practical work alongside constraints related to time, space, resources, and teacher competencies. The study concludes that key factors influencing science choice included aspirations, capacity, background, school issues, and policies. Further, the study concludes that strengthening the operationalization of the science laboratory impacts students' attitudes towards science and recommends investment in maintenance, training, and lab use. In the area of Future research, it should be explored in other districts, including case studies and longitudinal studies.

Keywords: Hands-on activity, secondary school students, engagement, laboratory operationalization, practical skills

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DOI: <https://doi.org/10.5281/zenodo.18631531>

1. Introduction

Constructivist Learning Theory (Piaget, 1970; Vygotsky, 1978) asserts that science laboratories are stimulating environments conducive to active learning, enabling students to develop their understanding through practical activities. When engaging in practical work, focus on its objectives: understanding why students undertake practical activities and the benefits they gain from science learning, rather than just the actions (Isozaki, 2017). Science is a key driver of Africa's post-independence modernization. However, the research-innovation gap needs careful management, with policies and budgets shifting focus to innovation (Kahn, 2022). Over the past century, science education has evolved globally, influencing methods, understanding, and its core purpose (Odden et al., 2021). This shift emphasizes adapting to societal and scientific changes, with laboratories symbolizing the importance of technology, machinery, and infrastructure that aid the writing process and lab record development. Science aims to understand the physical world through observation and experimentation, revealing universal truths and laws (Britannica, 2025). Lab activities aim to promote precise observation, deepen understanding, foster scientific thinking, and encourage a scientific mindset (Abrahams, 2005, as cited in Hofstein, 2017).

Uganda's NCDC curriculum highlights hands-on methods, especially in Physics and Biology, which foster critical thinking, problem-solving, creativity, communication, cooperation, and self-directed learning. Positive attitudes toward science boost motivation; students who enjoy science and believe in their abilities are more motivated. Uganda's efforts to improve science education quality require assessment to recognize achievements and identify areas for improvement. The 2024 S4 exams, with a new curriculum emphasizing critical thinking and analysis over memorization, reflect a positive trend in the Ugandan education system if educators adopt modern teaching and evaluation practices. The revised curriculum from NCDC prioritizes competencies such as critical thinking, communication, and problem-solving over rote memorization.

A significant observation in the paper by Kumari et al. (2025) indicated that students held negative perceptions of science subjects, which may stem from an unengaging, theory-focused teaching approach caused by inadequate lab facilities. Under the context of Mbarara city, which is a young, fast-growing district of Uganda, the study that relates science laboratory operationalization with secondary school students' attitude towards science subjects seems limited. This creates a gap and underscores the importance of this study, which aims to examine the relationship between the operationalization of science laboratories and academic attitudes towards science subjects among secondary school students in Mbarara City, Uganda.

1.1 Literature Review

1.1.1 Theoretical Review

A review of two main theories underpins understanding research. The study draws on Dewey's "Learning by Doing," emphasizing experiential learning where students actively

explore concepts through hands-on experimentation in science labs, engaging directly with materials, observing phenomena, and reflecting afterward. The Theory of Planned Behavior (Ajzen, 1991) explains how lab experiences influence students' attitudes and motivation by shaping beliefs about outcomes, norms, and control. Such activities make learning more interactive, reinforce positive norms, and boost motivation.

1.1.2 Science laboratory operationalization and students' attitude

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 (Syahyuri et al., 2018). Attitudes toward science typically encompass an interest in science, a genuine enjoyment of science education, the perceived relevance of science, and one's self-concept or self-efficacy in science (Osborne et al., 2003). Students' attitudes are not just a part of science education. They are its very essence, its heartbeat. A Nigerian study on the effectiveness of laboratory facilities in enhancing student learning outcomes by Agbola et al. (2017) provides strong evidence that scientific facilities help promote more excellent acquisition and higher retention skills and increase student attitudes and behavior development. The process-oriented guided inquiry learning method, which involves students working in small groups using specially designed materials, has proven highly effective.

Okam (2016) discussed the concept of laboratory learning within chemistry instruction; its applicability extends to laboratory teaching in general. Laboratory learning, recognized as a transformative pedagogical method, equips students with relevant data and guiding questions that facilitate the formulation of valid conclusions. This approach serves as a beacon of hope in the realm of science education. It stands as a robust tool for enhancing students' attitudes and performance in the sciences (Okam, 2016). Science practices articulate a more comprehensive understanding of the scientific process than inquiry-based approaches (Crawford, 2014, cited in Gericke, 2022). The idea involves students going beyond experiencing inquiry by interpreting and evaluating data as evidence to developing arguments, explanations, and models (Ssempala, 2017).

According to a study by Lee et al. (2020), cited in Kumari et al. (2024), science, being a challenging field, greatly influences students' views of their science laboratory environment, enhancing their self-efficacy in science learning. By prioritizing practical teaching and timely syllabus completion, we can positively influence students' perceptions and performance in science while deepening their understanding of STEM. This emphasizes the vital and empowering roles of educators and policymakers in shaping students' attitudes towards science, ultimately affecting their potential impact in science education (Namayanja et al., 2022)

Science, often perceived as the most challenging stream compared to others (Black et al., 2007), is greatly influenced by students' conceptions of science laboratory learning. Student attitudes should be central to educators because affective dispositions are potent predictors of student performance (Kabunga et al., 2016). The paper discussed the relationship between learner attitude and performance in a science subject at A-level schools in Mbarara District.

Kabunga's study also related cross-cutting issues like age and gender. Akugizibwe et al.'s (2022) case study of the school in the Kigezi region concluded that improving students' attitudes and perceptions of science is paramount. In terms of laboratory learning, laboratory instruction is meant to assist students in identifying their learning abilities and developing everyday scientific problem-solving and critical-thinking skills (Yildirim, 2016).

Given the researcher's context and reach, specific details regarding the operationalization of science laboratories in schools in Mbarara city, Uganda, are provided. There seems to be a lack of extensive studies examining the operationalization of science laboratories in secondary schools within Mbarara City, Uganda. This presents an opportunity for a broader investigation that explores the complete context of the issue. The previous literature generally relates attitude in science subjects to students' performance in science subjects. The present study also examined the science laboratory operationalizations on their attitude toward science subjects, leading to better performance in science.

1.2 Objective of the study

To examine the relation between science laboratory operationalization and Academic attitude towards science subjects among secondary school students in Mbarara City, Uganda.

1.3 Research Hypothesis

The following null hypothesis, corresponding to the specific objective, guided the study.

H₀. There is no significant relationship between Science Laboratory operationalization and students' academic attitude towards science subjects among secondary school students of Mbarara City, Uganda.

2. Method

2.1 Research Design

This study's research design was a mixed-methods design and used a convergent-parallel design. Mixed methods research design involved collecting both qualitative and quantitative data to draw insights from the combined data (Creswell & Creswell, 2023). In a convergent mixed-methods design, data were collected simultaneously from different groups of participants using various data collection tools.

2.2 Description of the study site

This study was conducted in secondary schools within Mbarara City's boundaries, established in 2020, comprising 6 administrative divisions Kamukuzi, Kakoba, Nyamitanga, Biharwe, Kakika, and Nyakayojo in the North and South Mbarara City (Mbabazi & Atukunda, 2020). The schools from all six divisions were selected to capture the city's educational and socio-economic

diversity, which offered a comprehensive and contextually grounded basis for understanding the dynamics of science education in the city.

2.3 Population of the study

This is a part of a major study, and for this part, respondents involved are students and headteachers from secondary schools for information on science laboratory operationalization in Mbarara City, Uganda. Students, though not directly responsible, were considered main beneficiaries reflecting the quality of the lab through their learning experiences, group work, active learning, and skills development. Headteachers, as leaders supporting lab-based teaching, were included. The population covered a diverse range of government and private secondary schools.

2.3.1 Sampling Techniques

In the first stage of sampling by using the Krejcie and Morgan sampling technique, 36 schools were taken as the representative sample from 40 secondary schools. In the first stage, a stratified random sampling technique was utilized to select a representative sample of 36 secondary schools. The stratification criteria included school type (public vs. private) and, potentially, location (North vs. South) to ensure that the selected schools from the comprehensive list of all registered secondary schools, which was obtained from the Mbarara City Education Office as well as from the SESEMAT office, reflect the diverse educational landscape of Mbarara City. In the second stage, participants from the selected schools were chosen. For students, stratified proportional random sampling was applied to sample O- and A-level students, and this sampling method used the number of registered students in the Mbarara City Education Office list to ensure every student in the target classes had an equal chance of selection. For head teachers, a purposive sampling technique was employed to ensure a representation in terms of subjects taught, years of experience, due to their unique leadership roles and insights. The sample size for this study was determined based on the requirements of a convergent parallel mixed methods design, which involves parallel collection of quantitative and qualitative data to enable robust triangulation and integration of findings (Creswell & Plano Clark, 2018).

Table 1: Sample size estimation

No.	Category of respondents	Approximate population size	Sample size taken	Sampling techniques
1	Students	19519	377	Stratified Random Sampling
2	Head teachers	40	30	Purposive sampling

Explicit inclusion criteria for participants were being a full-time enrolled student in the specified classes and in-service head teachers of secondary schools in Mbarara City, Uganda. Exclusion criteria involved students with prolonged absences, absent staff, etc.

2.4 Data Collection

2.4.1 Data Collection Methods

In a mixed methods convergent parallel design, data collection involves the concurrent and independent gathering of both quantitative and qualitative data (Creswell & Plano Clark, 2018). For the present research, various data collection methods, including surveys and semi-structured interviews, were administered concurrently to collect data.

2.4.2 Data Collection Instruments

2.4.2.1 Questionnaires

The questionnaire is one of the standard devices for collecting information, and it is a form or instrument that includes a set of questions and secure answers that respondents fill out to give the researcher information needed for the study (Pandey & Pandey, 2015). For the present study, data from students were collected through questionnaires. The students' questionnaire consisted of all closed-ended questions to collect information about students' attitudes and science laboratory operationalization from their perspectives.

2.4.2.2 Semi-structured Interview

Simultaneously, qualitative data were collected through interviews with a purposively selected sub-sample of 30 Head teachers who participated in the study. It was designed to explore their lived experiences and perceptions regarding the operationalization of science laboratories in schools. It gave an administrative angle to findings related to science laboratory operationalizations, along with administrative perception about science laboratory operationalization and its effect on students' attitudes.

2.4.3 Quality Assurance of Tools

The importance of rigorous quality assurance in data collection tool design, including pre-testing and standardization, is a well-established principle in research methodology (Babbie, 2020).

2.4.3.1 Questionnaires

A well-validated questionnaire, a cornerstone of sound measurement, strengthens the trustworthiness of the collected data, ensuring that research conclusions are based on meaningful and accurate assessments of the intended phenomena (DeVellis, 2016). The draft instrument was reviewed by a panel of experts. Each item was evaluated for relevance, clarity, and representativeness, and a Content Validity Index (CVI) was calculated. The overall CVI for the questionnaire was 0.81, exceeding the commonly accepted threshold of 0.70, indicating that the

instrument was content valid (Hassan, 2024). Items rated below 0.70 were fine-tuned or removed from the final version.

Reliability: Test-retest for stability, internal consistency (e.g., Cronbach's alpha) for scales. As per the ideal criteria, if a questionnaire has a Cronbach's alpha of 0.7 or equal to 0.7, the tool is acceptable to be used in a study. For the students' questionnaire, it was 0.725.

2.4.3.2 Interview Guides.

Validating an interview protocol is crucial for ensuring that the data collected is trustworthy and relevant to the research questions. For the present study, Expert review and pilot testing were used for quality assurance of the interview

2.4.4 Data Collection Procedure

Data collection was conducted in line with the study's convergent parallel mixed methods design. For the quantitative strand, questionnaires were distributed in person to students, teachers, and lab technicians during scheduled sessions with clear instructions on how to complete them. They filled out the forms independently and in real time to clarify any ambiguities in the data. Completed questionnaires were collected immediately to ensure high response rates and completeness. Each respondent's questionnaire was coded to maintain the anonymity of the collected data.

In the qualitative component, the researcher personally conducted semi-structured interviews with purposively selected head teachers who served as key informants. Interviews were scheduled in advance and held within the schools, and lasted approximately 30-45 minutes. An interview guide was used to ensure thematic consistency while still allowing flexibility to explore emerging issues. Some of the interviews were audio-recorded with consent and supplemented by brief field notes, while some were just recorded in the form of written notes. Data collection strands were completed within the allocated timeframe.

2.5 Data Management and Analysis

Quantitative data were first reviewed for completeness, accuracy, and consistency before being entered into SPSS version 26. The data were cleaned, coded, and then analyzed. Descriptive statistics, such as frequencies, percentages, means, and standard deviations, were used to summarize the information gathered from the respondents. Correlational analysis and regression analysis were done to understand the relation, whether it is a significant or a non-significant relationship.

To complement the quantitative data, qualitative data were also collected for the second and third objectives, which were analyzed using thematic analysis. The integration of numerical findings with narrative insights enabled a richer and more comprehensive understanding of

science laboratory operationalization conditions at schools and their relation with students’ attitude and motivation in Mbarara City, Uganda.

3. Results

3.1 Quantitative

The study, along with descriptive statistics, uses correlation and regression analyses to explore the relationships between students' practical laboratory experience, which is science laboratory operationalization (oper_lab), and their beliefs about science and the importance of preparation for lab work, which is students’ attitude (std_att1).

3.1.1 Descriptives

Table 2: Descriptive statistics for operationalization and attitude

N	std_att1	ope_lab
Valid	373	373
Mean	2.60	2.12
Median	2.75	2.00
Mode	3	2
Std. Deviation	.272	.298

3.1.2 Correlations

A Pearson correlation analysis was conducted to examine the relationships between science laboratory operationalization (oper_lab) and students’ attitude (std_att1). Students’ attitude is a combination of their belief that it is essential to know the names of lab equipment before lab work, science is composed of both facts and theories, and the science subject is easy/average or difficult, which may represent their overall attitude towards or interest in science.

Table 3: Correlation between operationalization and attitude

		std_att1
ope_lab	Pearson Correlation	0.195**
	Sig. (2-tailed)	<0.001
	N	373

Table 3 provides a quantitative summary of the correlation. The correlation coefficient is 0.195. This value indicates two things about the relationship. The sign is positive, which means the variables move in the same direction. An increase in ope_lab is associated with an increase in std_att1. The value of 0.195 is close to 0, which suggests a weak linear relationship. The p-value is <0.001. A p-value this low (typically less than 0.05 or 0.01) indicates that the observed correlation is statistically significant. This means there is a very low probability (less than 1%) that the relationship observed in the sample data occurred by chance. There is a statistically significant but weak positive correlation between ope_lab and std_att1.

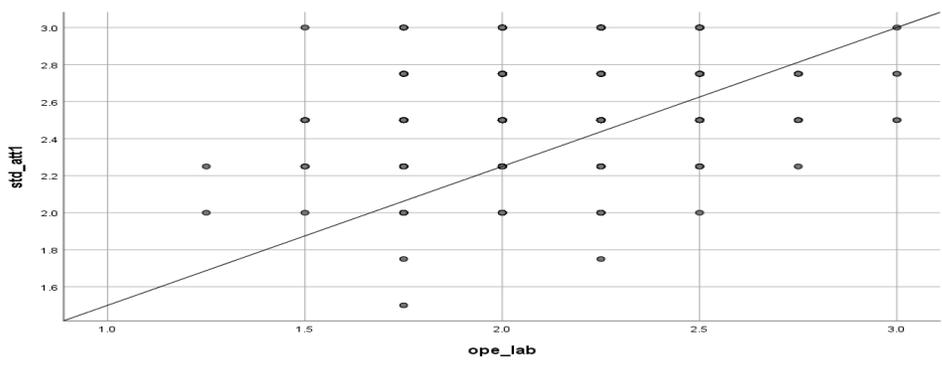


Figure 1: A scatter plot between ope_lab and std_att1

The scatter plot in Figure 1 confirms the positive correlation identified in the table. The data points are widely scattered around the line of best fit, which indicates that while there is a general positive trend, the relationship between the two variables is weak, which is consistent with the small coefficient ($r = 0.195$). While the significance level confirms that this relationship is unlikely due to random chance, the low correlation coefficient indicates that the association is not very strong. Therefore, knowing the value of one variable provides only a limited ability to predict the value of the other.

3.1.3 Regression analysis

Table 4: Regression analysis operationalization vs attitude

Model Summary						
Model	R	R ²	Adjusted R ²	Std. Error of the Estimate		
1	.195 ^a	.038	.035	.267		

ANOVA ^a						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1.048	1	1.048	14.680	.000 ^b
	Residual	26.491	371	.071		
	Total	27.540	372			

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	95.0% Confidence Interval for B	
		B	Std. Error	Beta	T	Sig.
1	Constant	2.219	.100		22.258	.000
	ope_lab	.178	.047	.195	3.831	.000

The Model Summary table 4 indicates that the model accounts for a small portion of the variance in the dependent variable. The R-squared value is 0.038, indicating that approximately 3.8% of the variability in *std_att1* is explained by *ope_lab*. The adjusted R-squared, which accounts for the number of predictors, is slightly lower at .035. The ANOVA table shows that the regression model is statistically significant, with an F-statistic of 14.680 and a significance value (p-value) of .000. This indicates that the independent variable *ope_lab* is a significant predictor of *std_att1*. The Coefficients table provides details about the relationship between the independent and dependent variables. The unstandardized coefficient for the constant is 2.219. This is the predicted value of *std_att1* when *ope_lab* is zero. The unstandardized coefficient for *ope_lab* is 0.178. This suggests that for each one-unit increase in *ope_lab*, *std_att1* is predicted to increase by 0.178 units. This relationship is statistically significant with a t-statistic of 3.831 and a significance value of .000. The 95% confidence interval for the unstandardized coefficient of *ope_lab* ranges from .087 to .270. Since this interval does not contain zero, it further confirms the statistical significance of "*ope_lab*" as a predictor.

Table 5: Residual Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2.44	2.75	2.60	.053	373
Residual	-1.031	.514	.000	.267	373
Std. Predicted Value	-2.926	2.955	.000	1.000	373
Std. Residual	-3.859	1.922	.000	.999	373

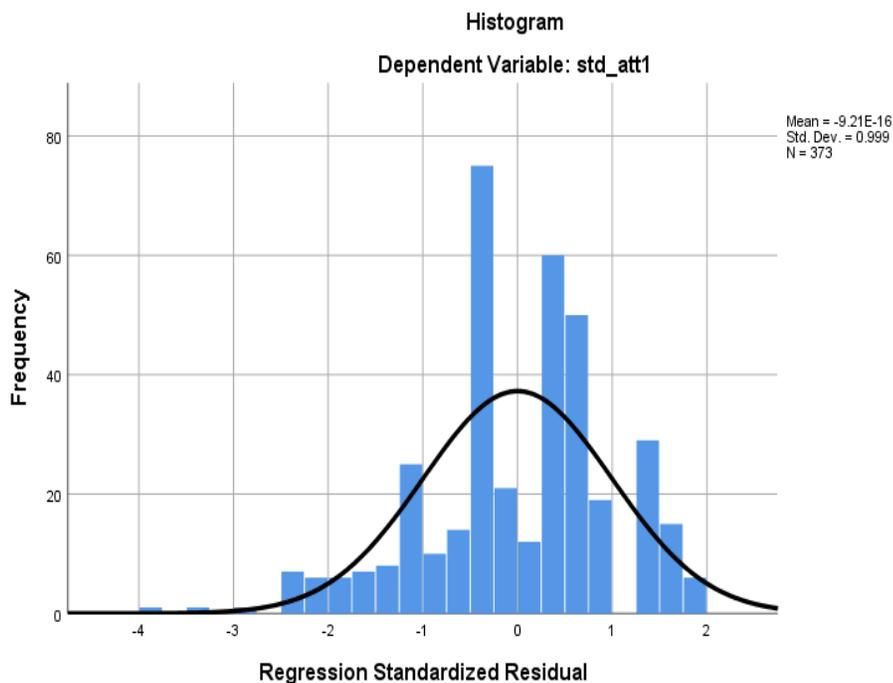


Figure 2: Histogram for regression standardized residual

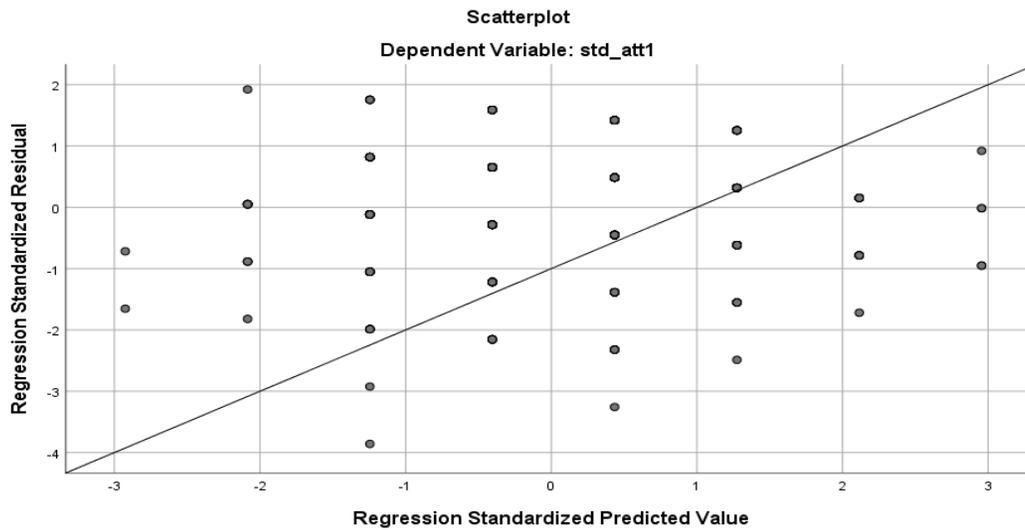


Figure 3: Scatterplot for standardized residual

Figures 2 and 3, showing a histogram, scatterplot, and Table 5, standardized residual, provide insight into the assumptions of the linear regression model. Table 4 shows that the mean of the residuals is zero, which is an expected outcome in regression analysis. The histogram of the regression standardized residuals displays a distribution that is approximately bell-shaped, suggesting that the residuals are normally distributed.

The results indicate that the regression model is statistically significant ($F(1, 371) = 14.680, p < .001$), which shows that *ope_lab* is a valid predictor of *std_att1*. However, the model explains only a small portion of the variance in the dependent variable, with an R-squared value of .038. The analysis of the coefficients shows that *ope_lab* has a statistically significant positive effect on *std_att1* ($B = .178, p < .001$). For each one-unit increase in *ope_lab*, the *std_att1* is predicted to increase by .178 units. The residuals appear to be normally distributed, and their variance is consistent across the range of predicted values.

Based on the above analyses, there is a clear and statistically significant link between a student's lab experience and their overall attitude towards science subjects. The more they engage in practical lab work, the more positive their perception of science appears to be.

3.2 Qualitative thematic analysis

For this study, the head teachers were asked questions about the skills students develop during lab activity, about the differences in students' engagement during practical and theory lessons, and whether the students' behaviors in the laboratory hinder science teaching.

3.2.1. Skills developed during lab work

Table 1 in Appendix I shows the results of the question from the interview with the head teacher about skills developed during lab work. The results revealed that the benefits of lab work extend far beyond technical proficiency. Breakdown of each skill category and how the specific observations support it are described in the following section.

Self-Confidence: *Hands-on training, shyness and fear get off, brainstorming, don't forget, Observation.* The lab fosters confidence by providing practical, hands-on experience, which is a powerful way to build competence. This practical engagement helps individuals overcome personal inhibitions like shyness and fear. Participating in collaborative activities like brainstorming and successfully observing and retaining procedures (don't forget) further reinforces their belief in their own abilities.

Team Working: *Social-psychosocial skills, communication, sharing, cooperation, coordination.* This was a very strong and clear theme generated from the results. Lab work is inherently collaborative. To succeed, participants must engage in effective communication, share knowledge and resources, cooperate on tasks, and coordinate their efforts. These actions collectively build essential social-psychosocial skills, which are fundamental to effective teamwork.

Documentation: *Manipulation, interpretation, record keeping, organization skills, presentation, translation.* This goes beyond simple note-taking. It encompasses the scientific process: performing experiments (manipulation), making sense of the results (interpretation), maintaining accurate logs (record-keeping), and structuring the findings (organizational skills). Finally, the ability to communicate these findings through a presentation or by translating complex data into understandable conclusions is a key outcome.

Adaptability: *Application, find ease, and appraise new knowledge.* Labs are dynamic environments where things don't always go as planned. Participants learn to be flexible by applying theoretical concepts to practical problems. Over time, they find ease and become more comfortable with new techniques and unexpected challenges. A key skill developed is the ability to appraise new knowledge and incorporate it into their work critically.

Problem Solving: *Discover new ideas of innovation, investigation, and creativity.* This theme positions the lab as a center for inquiry, not just procedural repetition. The process encourages active investigation and the thrill of discovery. It pushes participants to think outside the box, fostering creativity and the generation of new ideas and innovations to solve complex problems. This provides powerful evidence that lab-based learning is a multifaceted educational tool.

Supporting Quote:

Respondent HT4: They can appraise the knowledge and application of knowledge done by students very well.

Respondent HT 8: How to research, problem solving, team working, socio-psychosocial relations get improved, communication.

Respondent HT 13: They understand better when they do experiments then relate with real life situation.

3.2.2 Difference in students' engagement

The result in Table 2 of Appendix I is for responses to a question asking about the characteristics of a practical, hands-on teaching method. The central idea showed that practical classes are significantly more engaging for students than the implied alternative (presumably traditional, theory-based classes). The breakdown of the subthemes that reveal the nature of engagement in practical classes is discussed as follows.

Increased Participation and Activity: More engaged in practicals, more hands-on, so there is a difference; everybody is participating, Active, and more involved. Several subthemes point directly to a more active, hands-on experience where students are not passive listeners. This is the most direct statement of comparison that explicitly links the hands-on nature of practicals to a perceived difference in the learning experience. This suggests universal involvement, unlike a theory class, where some students may not participate, but also reinforces the idea of physical and mental participation.

Enhanced Cognitive Engagement: Student-centered, ask questions, explore, and are more attentive. The results indicate that students are more mentally stimulated and curious during practicals. The focus shifts from the teacher to the learner, empowering students, which is a sign of curiosity and critical thinking. Students are actively trying to understand concepts rather than just memorizing them. Practical work encourages discovery-based learning where students are paying closer attention, likely because the subject matter is more stimulating and requires their focus.

Positive Emotional and Attitudinal Response: Eager, develop a positive attitude, more excited, and enjoy. The emotional experience in practical classes is overwhelmingly positive, which is a key component of engagement. Students show a willingness and keenness to learn. The experience fosters a better disposition towards the subject. There is a heightened sense of positive anticipation and energy. Learning is perceived as a pleasurable activity.

Supporting Quote:

Respondent HT7: Yes. Most case in theory are less engaged as compared to practicals.

Respondent HT34: Yes, mostly in lab they are more active.

Respondent HT29: When they are in practicals almost all students want to engage.

Based on the data, the difference in engagement between practical and theoretical classes can be summarized as follows: practical classes are perceived as more Participatory, More Student-Centered, More Stimulating, and More Enjoyable.

3.2.3 Whether practical activity hinders science teaching

Based on the head teachers' interviews in Table 3 of Appendix I, the answer to whether practical activity hinders science teaching is nuanced. It suggests that practical activities themselves are highly beneficial, but they can indeed hinder science teaching when faced with specific constraints and challenges. Practical activities are an inherently valuable and motivating tool for science teaching. However, their potential can be severely hindered or even negated by external factors such as insufficient time, a lack of resources, and challenges in teacher and classroom management. The results clearly identify several categories of problems that can turn a practical activity from a learning opportunity into a hindrance.

Time Constraints: The Lab takes longer, leaving less time to explore, resulting in students wasting time. This indicates that practical lessons are time-consuming to set up, conduct, and clean up. This can eat into valuable curriculum time, leading to a feeling that there is *less time to explore* the concepts deeply. The time spent on logistics and managing students ("settling students wastes time) can outweigh the instructional time.

Resource Inadequacies: inadequate resources, do not take them to the lab due to limited space, equipment, carry apparatus in class, and only a few can work at a time. Lack of proper equipment, materials, or even a suitable lab space is a significant barrier. It can prevent the activity from happening at all or force compromises that reduce effectiveness. When only a few students can participate, it hinders learning for the rest of the class.

Teacher Competencies: a teacher lacking what is required, the way of handling, and Balance. The success of a practical activity is heavily dependent on the teacher. If a teacher lacks the skills to manage the lesson, handle the equipment, or guide the students effectively, the activity can become chaotic and unproductive. The need for balance suggests that managing student excitement while ensuring learning objectives are met is a key skill, and a lack thereof can be a hindrance.

Student Attitude: too much interest, some try to temper. This suggest that even a positive factor like student enthusiasm can become a hindrance. *Too much interest* can lead to a lack of focus, students rushing ahead, or off-task behavior that needs to be *tempered*. This creates a classroom management challenge that can detract from the learning goals.

Supporting Quotes:

Respondent HT10: It depends on teachers' competencies. That disturbance is essential.

Respondent HT17: It takes time to settle in practical. So it hinders sometimes so it may need co-teachers who can students to settle when they are teaching.

Conversely, the result also provided strong evidence that practical activities are fundamentally beneficial and are seen as a positive force in science education. Student Attitude

is influenced as lab work stimulates learning, full of discoveries, tries to explore, like practical lessons, and they want to know. The results show the immense power of practical work. It stimulates curiosity, makes learning exciting, and fulfills students' intrinsic desire to explore and know. This positive attitude is a powerful facilitator of learning, not a hindrance.

Based on the gathered data, both quantitative and qualitative results reflect and complement each other, relating science laboratory operationalization to attitude. Science laboratory work has a profoundly positive impact on students' attitudes towards learning. Their curiosity is piqued, which is a key driver for deeper engagement. The activities promote a wide range of skills. These include personal skills like self-confidence, interpersonal skills through teamwork, and cognitive skills related to problem-solving. It also develops procedural skills in documentation. The analysis highlights significant barriers to effective lab work, such as Teacher Competencies, Time Constraints, and Resource Inadequacies.

4. Discussion

Objective was a comprehensive analysis of the relationship between science laboratory operationalization and students' attitudes towards science. Theory of Planned Behavior (TPB) delineates the essential psychological needs of individuals, namely autonomy, competence, and relatedness. Therefore, effective laboratory operationalization must go beyond simply dictating rules; it necessitates fostering positive attitudes towards safe and efficient practices among all personnel, recognizing that these deeply held beliefs ultimately translate into actionable behaviors that uphold the integrity and safety of the scientific endeavor.

The results of the study reveal a statistically significant, albeit weak, positive correlation. The quantitative portion of the study analyzed two key variables: "std_att1" (students' beliefs about science and the importance of lab preparation) and "ope_lab" (students' practical laboratory experience). Descriptive statistics indicated mean scores of 2.60 for "std_att1" and 2.12 for "ope_lab". A Pearson correlation analysis established a positive but weak linear relationship with a correlation coefficient of 0.195. Despite its weakness, this correlation was statistically significant ($p < 0.001$), suggesting that as practical lab experience increases, students' positive attitudes toward science also tend to increase. Regression analysis further supported this, with "ope_lab" identified as a significant predictor of "std_att1". However, the R-squared value of 0.038 indicates that lab experience explains only a small portion, 3.8%, of the variability in students' attitudes.

The qualitative analysis, derived from interviews with head teachers, complemented the quantitative results with themes that emerged, like Holistic Skill Development, Increased students' engagement, highlighting the multifaceted impact of laboratory activities. Lab work was found to cultivate a wide range of crucial skills beyond technical proficiency. These include heightened self-confidence, improved teamwork and communication, and enhanced cognitive abilities such as documentation, adaptability, and problem-solving. The study strongly indicates that practical classes are significantly more engaging for students than traditional, theory-based lessons. This is characterized by increased participation, a more student-centered learning

environment, enhanced cognitive stimulation, and a more positive emotional and attitudinal response.

Despite the clear benefits, the effective implementation of practical activities faces several significant barriers. These include time constraints, inadequate resources and lab space, and a lack of necessary teacher competencies for managing lab sessions effectively. Interestingly, even high student enthusiasm was identified as a potential "paradoxical hindrance" if not properly managed.

In conclusion, the results underscore the value of hands-on laboratory experience in fostering a positive attitude towards science and developing a broad range of essential skills. While the statistical relationship is modest, the qualitative findings provide powerful evidence of the profound impact of practical work on student engagement and development. However, the study also highlights the critical need to address the logistical and pedagogical challenges that can hinder the effectiveness of science teaching in a laboratory setting.

5. Conclusions and Recommendations

5.1 Conclusion

Based on Dewey's Learning by Doing, which established the foundational rationale for the study, TPB offers essential insights into the factors that underpin student engagement and perseverance in laboratory activities. An effective science laboratory experience is likely to integrate principles from all these theories: presenting engaging, hands-on tasks (Dewey), cultivating students' beliefs in their capabilities and the value of the tasks, and satisfying their needs for autonomy, competence, and relatedness.

The study found a statistically significant, though weak, positive correlation between hands-on lab work and students' positive attitudes towards science. The hands-on nature of lab work fosters a more positive perception of science among students. Qualitative data supported the fact that when students use the lab and do practicals, they not only learn the subject but also important life skills, which influence their attitude towards the particular subject. Results support the rejection of the Null hypothesis and indicate that practical classes are significantly more engaging for students, leading to cognitive stimulation and a more positive attitudinal response.

5.2 Recommendations and Areas of Further Research

5.2.1 Recommendations

Some recommendations that can be made on the basis of the results from the study are

1. Enhance Teacher Training and Welfare: Continuous professional development opportunities can enhance the effectiveness.
2. Promote Innovative Teaching Methods: Encourage the use of laboratories, peer teaching, and technology integration to enhance student engagement and learning outcomes.

3. Address Social Issues: Integrating the daily life experience and connecting lab work with community issues into the curriculum will help connect the learners more and develop a positive attitude in students towards science subjects.

5.2.2 Areas of Further Research

1. The methodology used here covers the broad area of science laboratory operationalization. Future studies can use a case study for more detailed, concise results. Also, Longitudinal studies can be done to see the extent to which the science laboratory operationalization impacts the outcome of science teaching.

2. The study is done specifically in secondary schools, and the same studies can be done at the primary level as needed assessment for the science laboratories at primary schools, and also at the tertiary level of education

3. A comparative analysis can be done between the districts to see any disparity and to resonate with the reasons for the good outcomes in some of the parts.

5.3 Limitations of the study

1. Sample size was prepared as per the city offices' list and SESEMAT office list of enrolled schools by 2024, which may not have covered schools that opened after or were not yet enrolled.

2. The study was carried out in secondary schools of Mbarara City, Uganda, and this limited the generalization of the findings to other districts of the Country.

3. The study was only focused on secondary schools of Mbarara City, Uganda, and cannot be generalized to primary or tertiary level institutions.

4. The respondents were only secondary school students and in-service school head teachers. Other stakeholders at different levels may hold different views.

Acknowledgements

We acknowledge the invaluable administrative assistance of the District Education Officer of Mbarara City and all secondary school head teachers in Mbarara City, whose cooperation enabled access to schools and respondents. A sincere thanks to all the respondents who took part in this study for sharing insights that provided the essential empirical foundation for this research work. Also, we acknowledge the use of Grammarly in checking the language and grammar while writing this paper.

Declaration of Conflicting Interests and Ethics

The authors declare that this paper, titled Science laboratory operationalization and students' attitude towards science: A study in secondary schools of Mbarara City, Uganda, " is my original work and has never been submitted to any other institution for any award. There are no conflicts of interest to declare. The author, Preeti Kumari, PhD scholar, designed, conducted the study, and reviewed the resources used for this article under the Guidance of Dr Sudi Balimuttajjo and Dr Irene Aheisibwe.

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Appendix I: Tables of themes from the Interview

Table 1: Skills developed in labs

Open Codes	Axial Code(Sub themes)	Themes
Observation		
Hands-on training		
Shyness and fear get off	Self confidence	
Brain storming		Personal Skills
Don't forget		
Application		
Find ease	Adaptability	
Appraise new knowledge		
Social-psychosocial skills		
Communication		
Share	Team working	Interpersonal Skills
Cooperation		
Coordination		
Manipulation		
Interpretation		
Record keeping		
Organisation skills	Documentation	
Presentation		
Translation		Cognitive skills
Discover		
New idea of innovation	Problem solving	
Investigation		
Creativity		

Table 2: *Difference in student engagement between theory and practical classes*

Open codes	Axial codes (Sub themes)	Themes
More handson		
More engaged in practicals		
Everybody participating	Increased participation and activity	
Active		
More involved		
Student centred		More Engaging
Ask questions	Enhanced cognitive engagement	
Explore		
More attentive		
Eager		
Develop a positive attitude	Positive emotional and attitudinal response	
More excited		
Enjoying		

Table 3: *Whether practical activity hinders science teaching*

open codes	axial codes (Sub themes)	Themes
It may hinder out of too much interest		
some try to temper	Students attitude	
Balance		
teacher lacking what is required		
the way of handling	Teacher competencies	
The way they are taken in		Hinderance in teaching
Lab take more time		
less time to explore	Time constraints	
settling students waste time		
Don't take them to the lab due to limited space, equipments		
carry apparatus in class	Resource inadequacies	

inadequate resources

only few can work at a time

try to explore

like practical lessons

Stimulate learning

Support learning

Support teaching and learning

full of discoveries

they want to know
