Exploring the Effects of Mathematics Laboratory Usage on students' Skills Development: A Case of Selected Public Secondary Schools in Musanze District, Rwanda

Alphonse Ngayubwiko[1]
Hesbon Opiyo Andala[2]

[1]nalphonzow@gmail.com
[2]heandala@gmail.com

[1,2]Mount Kenya University

…….…

ABSTRACT

The aim of this study was to explore how the use of mathematics laboratories affects the development of mathematics skills in learners from selected public secondary schools in Musanze District, Rwanda. Adopting constructivism theory, the study utilized a descriptive research design and a mixed-methods approach to collect both quantitative and qualitative data from surveys, interviews, and classroom observations, respectively. The study randomly sampled 348 learners and 16 mathematics teachers from the targeted population of 2679 participants. In relation to students' standardized test scores and teacher assessments, the analysis examined the frequency of lab use, lab activities, resource quality, and teacher training. Findings from quantitative data revealed positive correlations between lab usage and skill development across all measures. The frequency of lab use and teacher training were particularly strong predictors of improved performance. The results show that how often teachers use the lab (B =.122, p <.001) and their training and support (B =.150, p =.010) have a big effect on their evaluations, which means that these things have a positive effect on evaluations. In contrast, the types of lab activities and the quality of lab resources have no significant impact. These findings suggest that enhancing lab use frequency and providing robust training and support for teachers are crucial for improving teacher assessments. Interview results show that hands-on activities significantly boost critical thinking and the real-world application of mathematical concepts. From classroom observations, the study revealed remarkable discrepancies in student participation and resource availability between day and boarding schools. The findings suggest that the school administration should incorporate lab activities into the curriculum, enhance the frequency of lab use, and facilitate continuous teacher training by providing sufficient resources. Teachers should integrate engaging lab activities to strengthen theoretical concepts and encourage active learning. Students are urged to actively participate in lab sessions and look for help when necessary. These results help us understand how mathematics laboratories can improve learning outcomes in Rwandan secondary schools.

Keywords: Lab Usage, Mathematics, Public Secondary Schools, Skill Development, Standardized Test Score, Teacher Assessment

…….…

I. INTRODUCTION

In developing countries, mathematics education influences individual learners with numeracy skills by strengthening their critical thinking, economic development, and digital literacy (Jayanthi, 2019). Societal points of view significantly shape school mathematics curricula, and varied perspectives on mathematics influence teaching methods and subject development (Umugiraneza et al., 2017). In general, mathematics laboratories have contributed much more to education, with early 20th-century educators like John Dewey advocating for hands-on and experiential learning to help students grasp abstract concepts (Zrudlo, 2024). This method focused on active participation and experimentation in learning mathematics.

The introduction of computers and calculators in the mid-20th century restructured mathematics education, allowing developed countries to integrate technology into mathematics laboratories for navigating complex concepts and real-world applications (Hankeln, 2020). In developed countries, these laboratories now emphasize inquiry-based learning, enhancing critical thinking, creativity, and mathematical reasoning (Abdurrahman et al., 2021). In developing countries, mathematics laboratories emphasize collaborative learning, teacher professional development, and engaging local communities, as mentioned in programs like Mathematicians in the Middle and Mathematics Circles (Bilican & Senler, 2021; Sujeewa et al., 2021). These laboratories also emphasize practical, culturally relevant teaching methods and have integrated technology to fortify learning (Barakabitze et al., 2019).

The execution of substantial educational reforms in Rwanda has happened since the 1994 Tutsi genocide, emphasizing education as a critical tool for national reconstruction with a three-tiered system and a focus on science, technology, and vocational training. Apart from progress, challenges like limited resources and urban-rural disparities persist, pointing out the need for inclusive and high-quality education (Rapoport & Berta, 2019; Jeong, 2020). Mathematics laboratories in Rwanda are limited and underused, leading students to view mathematics as abstract and difficult. Thus, the government of Rwanda's emphasis on STEM education provides opportunities to improve mathematics teaching through active, laboratory-based approaches (Baharin et al., 2018). Inscribing challenges such as inadequate resources, teacher training, and infrastructure can help to consolidate the potential of mathematics laboratories to promote active learning, real-world applications, and professional development for teachers (Nizeyimana et al., 2021; D'Angelo et al., 2022).

Mathematics laboratories in Rwanda present both challenges and opportunities for enhancing mathematics education. In Rwanda, mathematics laboratories face key challenges and opportunities. It faces challenges in terms of limited resources for establishing and maintaining mathematics laboratories. This includes, but is not limited to, a lack of funding, access to appropriate technology, and the availability of manipulatives and materials. Mathematics laboratories involve skilled and trained teachers who can effectively use the resources and techniques available (Nungu et al., 2023). However, a lack of teacher training and professional development opportunities in Rwanda hinders the effective implementation of mathematics laboratories. Additionally, in some regions of Rwanda, there is limited infrastructure and connectivity, which presents challenges in accessing technology-based mathematics laboratories (Scholar, 2021).

Two related issues exist in Musanze District: students struggle to develop their mathematics skills, and insufficient use of mathematics laboratories leads to poor performance in assessments and a lack of confidence in real-life mathematics practices. These intertwined issues negatively affect the students' academic performance and future opportunities. Poor mathematics performance can moderate students' chances of pursuing STEM-related fields, perpetuating socioeconomic disparities (Ohei, 2023). Weak problem-solving and critical thinking skills can hinder future career prospects in a data-driven economy (Ezinwanyi, 2020). Negative attitudes towards mathematics can limit personal growth and societal progress towards innovation and development (Makarova et al., 2019). In this context, this study aims to investigate the effects of mathematics laboratory usage on students' skill development in selected public secondary schools in Musanze District, Rwanda.

1.1 Problem Statement

The education system in Rwanda has prioritized universal access and quality since the 1994 Tutsi genocide, with much emphasis on science and technology education (Ministry of Education, 2023). Despite remarkable advancements, hurdles persist in optimizing mathematics education and equipping students with critical skills, as national and international assessments prove Rwandan students are scoring below regional and global averages (Vuong et al., 2019). The Rwandan Basic Education Board (REB) has implemented a competency-based curriculum and initiatives like "One Laptop per Child" to intensify learning opportunities, but issues such as rote learning, teacher scarcity, and limited training in active learning persist (Fidele et al., 2019). Mathematics labs have the potential to address these difficulties by upgrading active learning and real-world applications, but their utilization in Rwanda is still limited and requires further investment and research to extend their effect (Nsengimana, 2021).

Despite Rwanda's small number of schools equipped with mathematics laboratories, resource constraints and inadequate maintenance continue to plague them (Ukobizaba et al., 2021). Most of the time, teachers lack the knowledge and skills to effectively incorporate laboratory activities into their curriculum, and this ends up with underutilization and misconceptions about the purpose of these laboratories (Sibomana et al., 2021; Bainomugisha et al., 2023).

These issues contribute to students' difficulties in developing mathematics skills, resulting in poor performance, low confidence, and limited opportunities in STEM fields (Ohei, 2023). Furthermore, to the best of the researcher's knowledge, studies on mathematics education did not examine mathematics laboratory usage. Addressing mathematics education challenges in Musanze District secondary schools is crucial for ensuring quality learning experiences and skill acquisition. Hence, this study intends to fill this gap, with particular emphasis on the use of mathematics laboratories. The study evaluates teachers' and students' perspectives and analyzes how lab usage influences students' skills and academic achievements, ultimately enhancing mathematics education in Musanze District.

1.2 Study Objectives

The general objective of this study was to determine the effect of Mathematics laboratory usage on students' Mathematics skills development in public secondary schools in Musanze District, Rwanda. Specifically, the study intends to:

i. Assess the effects of Mathematics laboratory usage components (frequency of lab use, types of lab activities, quality of lab resources and teacher training and support) on student Mathematics test scores in selected secondary schools.
ii. Identify the effect of Mathematics laboratory usage components on teacher assessments in selected secondary schools.

1.3 Research Questions

The study seeks to address the following questions:

i. What are the effects of Mathematics laboratory usage components (frequency of lab use, types of lab activities, quality of lab resources and teacher training and support) on learner Mathematics test scores in selected secondary schools?
ii. Is there any significant effect of Mathematics laboratory usage components on teacher assessments in selected secondary schools?

II. LITERATURE REVIEW

2.1 Theoretical Review

The study was based on constructivism theory. Zaccaro et al. (2015) stated that constructivism, as an educational theory, highlights learners' active role in constructing knowledge through experiences and interactions. In mathematics education, it is suggested that students develop understanding by actively engaging with the material, connecting new information to prior knowledge, and collaboratively constructing meaning through problem-solving and inquiry. According to Voogt et al. (2015), building on existing knowledge and experiences serves as a foundation for new learning. Additionally, connecting mathematical concepts to real-world contexts enhances relevance and promotes deeper understanding (Baker et al., 2023). Morgan (2021) considers that constructivism advances collaborative learning environments where students solve problems together, emphasizing the importance of social interaction and communication in building mathematical knowledge. In addition, Slavin (2018) highlights that this approach focuses on problem-solving as a key component of math education, helping students relate concepts, develop critical thinking, and transfer their knowledge to new situations.

According to Jeong (2020), active learning fosters curiosity, ownership of learning, and a deeper appreciation for mathematics. Students develop critical thinking and analytical skills through hands-on exploration and open-ended tasks. Moreover, Schwarts et al. (2023) confirm that constructivism strongly emphasizes active learning, encouraging students to explore mathematical concepts through hands-on activities and real-world applications. They stated that by actively engaging with the material, students develop a deeper understanding of mathematical principles.

Baker et al. (2023) indicated that experiential learning involves engaging students in activities, projects, and real-world applications to deepen their understanding of mathematical concepts. Learners actively engage with mathematical concepts through exploration, experimentation, and real-world activities. Students also reflect on their experiences, connect them to existing knowledge, and extract key insights and learnings. Learners explore mathematical concepts within authentic contexts, rendering them relevant and meaningful. In addition, Kunwar (2020) showed that learners work together, share ideas, and learn from each other's perspectives, fostering communication and teamwork skills.

Vuong et al. (2019) argue that experiential learning activities nurture communication, collaboration, and adaptability. Slavin (2018) illustrates that students inscribe real-world problems by applying mathematical concepts and working together to discover solutions. In addition, Jeong (2020) highlights the role of interactive simulations and educational games in making mathematics attractive. Moreover, Jones and Tiller (2017) emphasize using concrete objects to help students envision and appreciate abstract concepts.

Jeong (2020) states that this approach helps bridge the gap between abstract mathematical concepts and their practical applications. Kunwar (2020) asserts that taking students on field trips to mathematical exhibits, museums, or inviting guest speakers from various mathematical professions provides firsthand experiences that connect classroom learning to real-world contexts.

In a constructivist mathematics classroom, teachers aid learners who use concrete materials to grasp abstract concepts. Collaborative problem-solving builds resilience, while different resources and technologies design a dynamic and learner-centered environment. This approach highlights active participation, collaboration, and real-world problem-solving, enhancing critical thinking and appreciation for mathematics. Experiential learning further links concepts to real-world applications; it deepens understanding and improves problem-solving skills.

2.2 Empirical Review

Ordinarily, strong mathematics skills are crucial for personal and societal well-being, fostering analytical thinking, problem-solving, and logical reasoning (Filgona & State, 2020). They enhance cognitive growth, support financial literacy, and are essential for high-demand STEM careers, driving innovation and economic competitiveness (U.S. Department of Labor, 2023). Despite their significance, inadequate teaching methods and limited resources continue to pose challenges in mathematics education. However, we can address these issues through active learning, technology integration, and improved teacher training (Akkus, 2016). Developing these skills is vital for informed decision-making, resilience, and contributing meaningfully to society (Kunwar, 2020).

Mathematics laboratories play a paramount role in enhancing learning by providing students with hands-on and experiential activities. These promote and deepen understanding of abstract mathematical concepts. These laboratories facilitate active participation, collaborative learning, and problem-solving, which foster critical thinking and decrease mathematics anxiety (Charles-Ogan & Otikor, 2016; Slavin, 2018). Incorporating technology in these laboratories further reinforces the learning experience, preparing students for data-driven fields and polishing their ability to visualize complex mathematical ideas (Nungu et al., 2023). By catering to various learning styles and making mathematics more relevant through real-world applications, mathematics laboratories create a dynamic and supportive environment that improves students' conceptual understanding and confidence in their mathematical abilities (Baker et al., 2023).

Among the issues impeding quality mathematics education, one can mention limited infrastructure, teacher training, outdated curricula, student participation issues, and inadequate resources (Morgan, 2021). Investment in infrastructure, teacher professional development, and the discrepancy between curricula and national standards are among the other critical factors. Moreover, Kunwar (2020) reports that these challenges include fostering student engagement with real-world applications, improving resource access, and promoting culturally responsive teaching. In the same vein, constructivist and experiential learning theories pinpoint active student engagement and real-world relevance, while cognitive theories impart skill development approaches (Baker et al., 2023; Jean de Dieu et al., 2022). Technology integration, especially through mathematics laboratories, boosts active learning, collaboration, and critical thinking. It necessitates ongoing professional development and equitable access considerations (Jeong, 2020).

Empirical research methodology uses real-world data to generate evidence-based insights (To & Future, 2020). Mathematics laboratories provide hands-on learning to nurture students' understanding of mathematical concepts through practical activities and technology (Tugade et al., 2016). These laboratories support critical thinking, problem-solving, and collaboration skills by allowing students to apply theoretical knowledge to real-world scenarios (Bilican & Senler, 2021). Despite historical and modern issues such as costs and teacher training, well-implemented mathematics labs enable significant increases in student participation and achievement (Bittner et al., 2017; Slavin, 2018). Productive global models, such as those in Singapore and Finland, show the effectiveness of incorporating technology and real-world applications in mathematics education (Leary & Walker, 2018; Kallunki et al., 2023).

As a matter of fact, research predicates that mathematics laboratories hold vast potential to boost mathematics education all over the world, where improving STEM skills is pivotal for development. In Ghana, for instance, the "Mathematics in a Box" program uses mobile laboratories equipped with manipulatives and technology to attend rural schools, ending up with improved problem-solving and critical thinking skills in participating students (Agyei et al., 2018). In South Africa, the Numeracy Lab Project in disadvantaged schools utilizes hands-on activities and technology to consolidate understanding and engagement, leading to increased student motivation and improved achievement in standardized tests (Kuhl, 2021). In Ethiopia, the "Mathematics on the Move" program calls upon teachers to carry out engaging activities using regionally available materials. Moreover, this program positively impacts teachers' confidence and student learning outcomes (Delorme, 2016). Success in these cases depends on context-specific activities, ongoing teacher training, and collaboration with parents and NGOs to ensure sustainability and effectiveness (Barakabitze et al., 2019; Vuong et al., 2019).

III. METHODOLOGY

This research utilized a descriptive research design and a mixed-methods approach to collect both quantitative and qualitative data. It focused on understanding the effect of mathematics laboratory usage on student skill development in Musanze secondary schools. Based on Slovin's formula (2010), as quoted in Lohr (2021), the study used a sample size of 364 respondents, including 348 mathematics students selected randomly from a population of 2663 and 16 mathematics teachers, for a total population of 2679 participants, selected purposefully from the targeted schools. Data collection involved surveys, interviews, and observations to gather comprehensive insights into mathematics education practices and their effects on student learning outcomes. The statistical package for social sciences (SPSS) software was used to handle quantitative data. The analysis of information collected through interviews with mathematics teachers and mathematics classroom observations was carried out using narrative techniques.

IV. FINDINGS & DISCUSSIONS

4.1 Quantitative Data

This section is concerned with data presentation, interpretations and discussions. It includes quantitative data as generated from questionnaire questions from both teachers and students, and qualitative data collected through interview with Mathematics teachers and observation of Mathematics class.

4.2 Response Rate

The table below illustrates the response rate for all participants relative to the total sample size.

Table 1

Responses Rate

Targeted Schools	Students			Mathematics teachers		
	Participants	**Responses**	**%**	**Participants**	**Responses**	**%**
GS Cyabagarura	76	76	100	4	4	100
GS Karwasa	116	116	100	5	5	100
ESSA-Ruhengeri	70	70	100	3	3	100
GSNDA Rwaza	86	86	100	4	4	100
Total	**348**	**348**	**100**	**16**	**16**	**100**

As shown in Table 1, all the respondents actively participated in the information gathering. In other words, the response rate is 100% for both students and Mathematics teachers.

4.3 Respondents Characteristics

The identification of the participants who contributed to this study, demographic information was collected. This included details such as participant category, gender, age range, years of teaching experience and educational background. The accompanying table presents this essential data. About the demographic information of students, the details included gender, age, time spent at the current school, type of program and class enrolled in.

Table 2

Demographic Information of Teachers (N=16)

Descriptive	Label	Frequency	Percentage
Category of Respondents	Regular Teacher	14	87.5
	Part Time Teacher	2	12.5
Gender of Respondents	Male	10	62.5
	Female	6	37.5
Age group of Respondents	18-30 Years	3	18.8
	31-42 Years	7	43.8
	43-55 Years	5	31.3
	56 Years and above	1	6.1
Teaching Experience	0-1 year	2	12.5
	2-5 years	3	18.8
	6-10 years	6	37.5
	11 years and above	5	31.1
Education level	A2	0	0.0
	A1	3	17.8
	A0	13	81.2

Table 2 shows that 87.5% of respondents are regular teachers, while 12.5% are part-timers. Table 2 indicates that 62.5% of respondents are male and 37.5% are female, with fewer female mathematics teachers. The age category reveals that 43.8% of respondents are between 31 and 42 years old, and only 6.1% are 56 years and older, suggesting that most mathematics teachers are younger. Table 2 shows that 37.5% have 6–10 years of teaching experience, 31.1% have over 11 years, and 12.5% have less than one year. Most mathematics teachers (81.8%) hold a bachelor's degree, aligning with Rwanda's education policy requiring secondary school teachers to have completed university studies.

Table 3

Demographic Information of Students (N=348)

Descriptive	Label	Frequency	Percentage
Gender of Respondents	Male	70	20.1
	Female	278	79.9
Age of Respondents	Below 14 Years	24	6.9
	15-18 Years	213	61.2
	19 Years and above	111	31.9
Time spent at this School	Less than or equal one Year	95	27.3
	2-5 Years	249	71.6
	6 Years and above	4	1.1
Type of Program	Day Scholar	192	55.2
	Boarding	156	44.8
Class enrolled in	2nd Year	41	11.8
	3rd Year	45	12.9
	4th Year	84	24.1
	5th Year	154	44.3
	6th Year	24	6.9

Table 3 shows that 20.1% of students were male and 79.9% were female. Most students (61.2%) were aged 15-18, with 6.9% below 14. Regarding their time at the current school, 27.3% had spent 1 year or less, 71.6% had spent 2-5 years, and 1.1% had spent over 6 years. Additionally, 55.2% were day scholars, while 44.8% were boarders. The majority were in Senior Five (44.3%), and the minority were in Senior Six (6.9%).

4.4 Perceptions on Standardized Test Scores

Tables 4 and 5 present findings on the perceptions of students and teachers regarding standardized test scores in the study area.

Table 4

Perceptions of Students on Standardized Test Scores

Statements	Mean	Comments	Std. Dev.	Comments
I achieve high grades because I use the Math lab.	4.3621	Strong	.93040	Heterogeneous
Grades accurately represent the extent of Math skills development.	4.6638	Strong	.70336	Heterogeneous
Engaging in Math lab activities significantly boosts my test scores.	4.8161	Strong	.41662	Homogeneous
Overall Total	**4.614**			

Table 4 reflects strong agreement among students regarding standardized test scores, with an overall mean of 4.614. They strongly agreed that using the mathematics lab contributes to achieving high grades (mean 4.3621), despite diverse opinions (standard deviation 0.93040). Students also agreed that grades accurately reflect mathematics skill development, with a mean of 4.6638 and varied perceptions (standard deviation 0.70336). Moreover, they strongly agreed that engaging in math lab activities significantly boosts test scores (mean 4.8161) with consistent perceptions (standard deviation 0.41662). The results in Table 6 match the findings of Bittner et al. (2017), who investigated the effect of using mathematics labs on student mathematics achievement. Their research revealed a positive correlation between using mathematics labs and student performance on standardized test scores. This implies that students who incorporate mathematics labs into their learning process tend to achieve higher grades. These findings confirmed the statement of Agresti and Franklin (2015), who explained that in statistics and probability theory, standard deviation measures variation or diversity in data, indicating how far values are from the mean. A low standard deviation means that points are close to the mean, while a high standard deviation indicates a wide range of values. A standard deviation of 0 means all values are identical. The (-) symbol represents one standard deviation below the mean, and the (+) symbol represents one standard deviation above the mean.

Table 5
Teachers' Perceptions on Standardized Test Scores

Statements	Mean	Comments	Std. Dev.	Comments
Students' Mathematics performance in terms of grades is high in this school	3.5000	Tend to Strong	.73030	Heterogeneous
When teachers use Math lab resources effectively, it positively impacts students' Math skills development, evident in improved standardized test scores.	4.3750	Strong	.50000	Homogeneous
The Mathematics Lab is essential for enhancing students' performance and grades.	4.5625	Strong	.51235	Heterogeneous
Overall Total	**4.15**			

Teachers generally strongly agreed on the positive impact of mathematics labs on students' performance, with an overall mean of 4.15. They perceived students' mathematics grades to be high (mean of 3.50), but their views varied (standard deviation of 0.73030). They strongly agreed that effective use of mathematics lab resources improves mathematics skills and test scores (mean of 4.3750, standard deviation of 0.50) and that the mathematics lab is essential for enhancing performance and grades (mean of 4.5625, standard deviation of 0.51235). The findings here are consistent with Tugade et al. (2016), who discovered that effective use of mathematics lab resources by teachers leads to high student grades and improved standardized test scores, highlighting the lab's essential role in enhancing students' mathematics performance.

4.5 Perceptions of Respondents on Mathematics Laboratory usage

This section describes how respondents (students and teachers) perceive thorough Mathematics Laboratory usage. The sub-variables of Mathematics laboratory usage are frequency of lab use, types of lab activities, quality of lab resources and teacher training and support.

Table 6
Teachers' Perceptions on Frequency of Lab Use

Statements	Mean	Comments	Std. Dev.	Comments
Using the Mathematics lab more often helps students better understand and master mathematical concepts.	4.6875	Strong	.60208	Heterogeneous
The frequency of lab use in a Mathematics lab has no significant impact on students' overall academic performance in Mathematics	2.0000	Weak	1.15470	Heterogeneous
The Mathematics lab is used for teaching and learning in the subject.	4.5000	Strong	.51640	Heterogeneous
Overall Total	**3.729**			

Table 6 shows that respondents, with an overall mean of 3.729, generally strongly agreed on the frequency of lab use. Teachers frequently use the mathematics lab to enhance students' skills, with a strong mean of 4.6875. They strongly disagreed that lab use frequency has no significant impact on academic performance, as indicated by a low mean of 2.000 and diverse opinions (standard deviation of 1.15470). Teachers consistently agreed that the mathematics lab is essential for teaching and learning, with a strong mean of 4.500 but varied perceptions (standard deviation of 0.51640). The data in this table align with Bittner et al. (2017), who studied employment, training, and job design. Their research suggests that regular practical experience boosts consistent performance and success. Similarly, frequent lab use has a positive effect on mathematical academic performance.

Table 7
Teachers' Perceptions on Types of Lab Activities

Statements	Mean	Comments	Std. Dev.	Comments
Hands-on lab activities in a Mathematics lab positively impact students' understanding and development of mathematical skills	4.6875	Strong	.47871	Homogeneous
Working together on lab activities in a Mathematics lab helps students improve their teamwork and problem-solving skills.	4.7500	Strong	.44721	Homogeneous
Doing real-world application activities in a Mathematics lab helps students link Math concepts to real-life situations and boosts their problem-solving skills.	4.8125	Strong	.40311	Homogeneous
Overall Total	**4.75**			

Table 7 shows that most teachers strongly agree on the benefits of mathematics lab activities, with an overall mean of 4.75. They believe hands-on activities enhance understanding (mean of 4.6875), collaborative activities improve teamwork and problem-solving (mean of 4.7500), and real-world applications help link mathematics concepts to real life (mean of 4.8125). Perceptions were consistent, with low standard deviations (uniform perceptions). The results in this table align with Kuhl (2021), who argued that hands-on activities and technology consolidate understanding and participation, leading to increased student motivation and improved achievement in standardized tests. In addition, the results confirm the findings of Sibomana et al. (2021), who investigated the factors affecting the achievement of twelve-year basic students and discovered a positive correlation between the frequency of mathematics lab use and mathematics activities with improved test scores and teacher assessments.

Table 8

Teachers' Perceptions on Quality of Lab Resources

Statements	Mean	Comments	Std. Dev.	Comments
Students' Mathematics skills development is influenced by the availability of advanced laboratory resources	4.1250	Strong	.80623	Heterogeneous
Technology assists my students in enhancing their skills and performance	4.0000	Strong	.73030	Heterogeneous
The lab resources are enough and work well to improve students' understanding and practice.	3.5000	Tend to Strong	1.26491	Heterogeneous
Overall Total	**3.875**			

The overall mean of 3.875 in Table 8 shows that teachers generally strongly agree with the quality of lab resources. They believe that advanced lab resources significantly enhance students' math skills, with a strong mean of 4.1250. Teachers also agreed that technology improves student performance, with a mean of 4.000, despite varied opinions (standard deviation of 0.73030). Additionally, teachers agreed that lab resources are adequate and effective for improving students' understanding, with a mean of 3.5000, though their perceptions varied widely (standard deviation of 1.26491). Findings are in confirmation with Agyei et al. (2018) who noticed that to use mobile laboratories equipped with manipulatives and technology to serve rural schools, resulting in improved problem-solving and critical thinking skills among participating students.

Table 9

Teachers' Perceptions on Teacher Training and Support

Statements	Mean	Comments	Std. Dev.	Comments
I assist my students in applying practical skills in the Mathematics laboratory.	3.9375	Tend to strong	.85391	Heterogeneous
Teachers who get thorough training and support in using Math lab resources are more likely to use the lab frequently in their classrooms.	4.3750	Strong	.80623	Heterogeneous
Continued training and support for teachers help them feel more confident and skilled in using Math lab resources for teaching.	4.5000	Strong	.89443	Heterogeneous
Overall Total	**4.27**			

Based on the information in the Table 9, the overall mean of 4.27 shows that most instructors strongly agree with the statements about teacher training and support. Teachers agreed that helping students apply practical skills in the Mathematics lab is important, with a mean of 3.9375. They strongly agreed that thorough training and support encourage frequent use of the math lab, as indicated by a mean of 4.3750, despite a diverse range of opinions (standard deviation of 0.80623). Furthermore, teachers strongly agreed that continued training and support boost their confidence and skills in using math lab resources, as shown by a mean of 4.5000 and a standard deviation of 0.89443, reflecting varied perceptions. According to Vuong et al. (2019), success in Mathematics relies on context-specific activities, continuous teacher training, and collaboration with parents and NGOs to ensure sustainability and effectiveness.

Table 10

Perceptions of Students on Frequency of Mathematics Lab use

Statements	Mean	comments	Std. Dev.	Comments
Our teacher provides us with numerous Math lab exercises.	4.4080	Strong	.92056	Heterogeneous
Mathematics classes in the lab are quite hands-on.	4.6437	Strong	.74736	Heterogeneous
We attend Math lab classes every day.	4.5144	Strong	.95267	Heterogeneous
Overall Total	**4.52**			

The overall mean of 4.52 shows that respondents generally strongly agreed with the statements. They agreed that teachers provide numerous Math lab exercises, with a strong mean of 4.4080. Students strongly agreed that hands-on Math lab classes help teachers assess skill development, with a mean of 4.6437 and diverse opinions (standard deviation of 0.74736). They also agreed that they attend Math lab classes daily, with a mean of 4.5144 and varied perceptions (standard deviation of 0.95267). The findings are in confirmation to Sibomana et al. (2021), who investigated the factors affecting the achievement of twelve-year basic students and noticed a positive correlation between the frequency of lab use and Mathematics activities with improved test scores and teacher assessments.

Table 11

Perceptions of Students on Types of Lab activities

Statements	Mean	Comments	Std. Dev.	Comments
Students who view problem-solving activities in the Math lab as effective notice greater development in their Mathematics skills.	4.7960	Strong	.49932	Homogeneous
Engaging in practical exercises allows me to evaluate and enhance my academic progress.	4.8994	Strong	.37762	Homogeneous
Using technology enhances my skills and performance	4.6552	Strong	.67611	Heterogeneous
Overall Total	**4.78**			

Table 11 summarizes students' opinions on types of lab activities. The overall mean of 4.78 indicates strong agreement among respondents. They agreed that problem-solving activities in the Math lab enhance their Mathematics skills, with a strong mean of 4.7960 and consistent opinions (standard deviation of 0.49932). Students strongly agreed that practical exercises help evaluate and improve academic progress, with a mean of 4.8994 and uniform perceptions (standard deviation of 0.37762). They also agreed that technology enhances their skills, with a mean of 4.6552, though opinions varied (standard deviation of 0.67611). The results support D'Angelo et al. (2022), who noticed that frequent lab use and Mathematics activities foster Mathematics academic performance. Additionally, Jeong (2020) asserts that active learning enhances curiosity, ownership of learning and a deeper appreciation for Mathematics, while also developing critical thinking and analytical skills through hands-on exploration and open-ended tasks.

Table 12

Perceptions of Students on Quality of Lab Resources

Statements	Mean	Comments	Std. Dev.	Comments
Students who believe that Math lab resources sufficiently cover the curriculum experience increased development in their Mathematics skills.	4.8818	Strong	2.74870	Heterogeneous
Math lab resources offer clear instructions and explanations to experience higher development in Mathematics skills.	4.7385	Strong	.55583	Heterogeneous
Math lab resources that are current and relevant to learning need notice higher development in Mathematics skills.	4.7781	Strong	2.20346	Heterogeneous
Overall Total	**4.80**			

Table 12 shows that students generally strongly agreed with the quality of lab resources, with an overall mean of 4.80. They agreed that sufficient coverage of the curriculum by Math lab resources enhances their Mathematics skills, with a strong mean of 4.8818. Students also strongly agreed that clear instructions and explanations from Math lab resources aid in skill development, with a mean of 4.7385, despite varying perceptions indicated by heterogeneous standard deviations. The findings align with Jeong (2020), who discovered that active learning enhances curiosity, ownership of learning and a deeper appreciation for Mathematics through hands-on exploration and open-ended tasks. Kunwar (2020) positively braces this by confirming that field trips and guest speakers link classroom learning to real-world contexts. Additionally, Agyei et al. (2018) demonstrate that mobile laboratories with manipulatives and technology fostering problem-solving and critical thinking skills in rural learners.

Table 13

Perceptions of Students on Teacher Training and Support

Statements	Mean	Comments	Std. Dev.	Comments
Well-trained teachers in Math lab usage effectively support students' improvement.	4.8333	Strong	.45657	Homogeneous
Support from teacher in the Math lab helps me enhance my performance.	4.7902	Strong	.46703	Homogeneous
Students receiving sufficient support from their teachers in using the Math lab show higher levels of engagement and motivation in learning Mathematics.	4.7471	Strong	.54150	Heterogeneous
Overall Total	**4.79**			

Table 13 shows that respondents strongly agree on the importance of teacher training and support, with an overall mean of 4.79. They agreed that well-trained teachers in Math lab usage effectively support student improvement (mean of 4.8333) and had consistent perceptions (standard deviation of 0.45657). Students also strongly agreed that teacher support in the Mathematics lab enhances their performance (mean of 4.7902) with uniform perceptions (standard deviation of 0.46703). Additionally, they agreed that sufficient support from teachers boosts engagement and motivation in learning math (mean of 4.7471), though perceptions were more varied (standard deviation of 0.54150). The results are in accordance with Vuong et al. (2019), who showed that success in Mathematics relies on context-specific activities, continuous teacher training, and collaboration with parents and NGOs to ensure sustainability and effectiveness.

4.6 Effect of Mathematics Laboratory Usage Components on Student Mathematics Test Scores

Multiple regression analysis extends beyond simple linear regression by incorporating two or more independent variables to predict the value of a dependent variable. The dependent variable, also known as the outcome or target variable is what we aim to predict. Independent variables, also referred to as predictors, are used to determine the value of the dependent variable. This part shows how the information gathered helped answer research question and reach objective.

Table 14

Model Summary of Standardized Test Scores

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.450[a]	.202	.193	.63189

a. Predictors: (Constant), Frequency of lab use, Types of lab activities, Quality of lab resources, Teacher training and support

The model indicates a moderate positive relationship between predictors (frequency of lab use, types of activities, quality of resources, and teacher training) and the dependent variable (standardized test scores), with a correlation coefficient of 0.450. The coefficient of determination (R Square) suggests that these predictors explain 20.2% of the variability in test scores, adjusting for the number of predictors with an Adjusted R Square of 0.193, indicating precision in predicting the dependent variable. The results are in accordance with Morgan (2021) that demonstrated that among issues impeding Mathematics quality education, one can mention limited infrastructure, teacher training, outdated curricula, student participation issues and inadequate resources. Students test scores are influenced by their activities and the skills of the facilitator.

Table 15

ANOVA of Standardized Test Scores

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.708	5	8.677	21.731	0.000[b]
	Residual	136.956	343	0.399		
	Total	171.664	348			

a. Dependent Variable: Standardized test scores.

b. Predictors: (Constant), Frequency of lab use, Types of lab activities, Quality of lab resources, Teacher training and support.

The regression analysis in Table 15 shows that predictors including lab use frequency, types of activities, resource quality, and teacher training explain significant variability in standardized test scores (F (5, 343) = 21.731, p

< 0.001). The model's total sum of squares is 34.708, with an F-statistic confirming its statistical significance. Despite a residual sum of squares of 136.956, the model effectively predicts test scores in Musanze District's secondary schools, affirming the impact of Mathematics lab usage on student outcomes. The results agreed with Baker et al. (2023) who indicated that Mathematics laboratories produce a dynamic and supportive environment that improves students' conceptual understanding and confidence in their mathematical abilities.

Table 16

Coefficients on Standardized Test Scores

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.777	.485		3.663	.000
	Frequency of lab use	.175	.040	.229	4.324	.000
	Types of lab activities	.230	.042	.299	5.423	.000
	Quality of lab resources	.081	.026	.178	3.137	.002
	Teacher training and support	.397	.070	.306	5.662	.000

a. Dependent Variable: Standardized test scores

Table 16 summarizes a regression analysis predicting standardized test scores using standardized coefficients. The intercept value is 1.777 (SE = 0.485, t = 3.663, p < 0.001), indicating a significant baseline effect. Frequency of lab use (B = 0.175, SE = 0.040, Beta = 0.229, t = 4.324, p < 0.001), types of lab activities (B = 0.230, SE = 0.042, Beta = 0.299, t = 5.423, p < 0.001), quality of lab resources (B = 0.081, SE = 0.026, Beta = 0.178, t = 3.137, p = 0.002), and teacher training and support (B = 0.397, SE = 0.070, Beta = 0.306, t = 5.662, p < 0.001) all significantly enhance test scores.

Teacher training has the strongest impact, followed by types of activities, frequency of use, and quality of resources, suggesting improvements in these areas can positively influence students' standardized test performance. The findings in Table 18 are in confirmation with Slavin (2018) that investigated that improving teacher training and diverse activities significantly enhance students' standardized test performance.

4.7 Effect of Mathematics Laboratory Usage Components on Teacher Assessments

This section demonstrates how the collected data addresses the second research question and fulfills the second objective of the study. Then, the tables below are related to regression analysis and correlation coefficients for consistent interpretation.

Table 17

Model Summary on Teacher assessments

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.358[a]	.128	.116	.53220

Predictors: (Constant), Frequency of lab use, Types of lab activities, Quality of lab resources, Teacher training and support

The table 17 Model Summary Two presents the results of a regression analysis, revealing a moderate positive relationship indicated by the correlation coefficient (R) of 0.358 between the predictors (frequency of lab use, types of lab activities, quality of lab resources, and teacher training and support) and the dependent variable (Teacher assessments). The coefficient of determination (R Square) of 0.128 indicates that approximately 12.8% of the variability in the dependent variable can be explained by these predictors. Adjusting for the number of predictors, the Adjusted R Square is 0.116, suggesting that after accounting for the complexity of the model, about 11.6% of the variability in the dependent variable is explained. The standard error of the estimate, at 0.53220 units, signifies the average deviation of observed values from predicted values. In summary, while the model demonstrates a moderate relationship between the predictors and the dependent variable (Teacher Assessments), they collectively explain approximately 12.8% of its variability. Adjusting for the number of predictors slightly reduces this explanatory power to 11.6%. The precision of predictions made by the model is indicated by the standard error of the estimate. The results agreed with Kallunki et al. (2023) who showed that the frequency of Mathematics lab use, along with the Mathematics activities conducted and the quality of lab resources used, positively influences teacher assessments, which in turn leads to improved standardized test scores.

Table 18

ANOVA on Teacher Assessments

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.224	5	2.845	10.044	.000[b]
	Residual	96.583	343	.283		
	Total	110.807	348			

a. Dependent Variable: Teacher Assessments

b. Predictors: (Constant), Mathematics laboratory usage components

Table 18 highlights that the regression model predicts Teacher Assessments. Mathematics laboratory usage components collectively explain a significant portion of the variability in Teacher Assessments as indicated by the regression sum of squares (14.224) and the significant F-statistic (10.044, $p < 0.001$). This suggests an effective model to explain differences in Teacher Assessments based on the included predictors. Fokianos et al. (2020) provide a comprehensive explanation of regression analysis and ANOVA, the breakdown of sum of squares into regression and residual components. They believe that this can help in understanding the model's explanatory power. In this context, the predictors account for about 12.8% of the variance in Teacher Assessments thus indicating some relevance but leave substantial unexplained variability. The proportion of variance explained (R^2) that can be calculated as the ratio of sum squares regression and sum squares total. This means that approximately 12.8% of the variability in Teacher Assessments is explained by the predictors.

This matches the R^2 value given in the previous regression summary. The lower explained variance (12.8%) suggests that other factors not captured by the current predictors may play a significant role in influencing Teacher Assessments. Then, further research could include additional predictors or interaction effects to enhance the model's explanatory power.

Table 19

Coefficients on Teacher Assessments

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.439	.378		6.450	.000
	Frequency of lab use	.122	.033	.198	3.675	.000
	Types of lab activities	.052	.064	.046	.808	.420
	Quality of lab resources	.017	.010	.083	1.624	.105
	Teacher training and support	.150	.058	.144	2.587	.010

a. Dependent Variable: Teacher Assessments

The regression analysis Table 19 Coefficient Two reveals two significant predictors of teacher assessments of Math lab effectiveness: frequency of lab use ($B = 0.122$, $p < 0.001$, Beta = 0.198) and teacher training and support ($B = 0.150$, $p = 0.010$). Frequency of lab use emerges as the strongest predictor. Types of lab activities ($p = 0.420$) and quality of lab resources ($p = 0.105$) do not show statistically significant impacts. The model's constant is 2.439 ($p < 0.001$). While the effects are modest, these findings suggest that increasing lab use frequency and enhancing teacher training could most effectively improve teacher perceptions of Mathematics lab effectiveness, providing valuable insights for optimizing Mathematics laboratory implementation. According to Kuhl (2021), hands-on activities and technology to consolidate understanding and participation, direct to increased student motivation and improved achievement in standardized tests.

Table 20

Correlation analysis of the Relationship between Mathematics Laboratory Usage and Development of Students' Mathematics Skills (N=348 students)

Descriptive		Standardized test scores	Teacher assessments
Frequency of lab use	Pearson Correlation	.316	.318
	Sig. (2-tailed)	.000	.000
Types of lab activities	Pearson Correlation	.193	.234
	Sig. (2-tailed)	.000	.000
Quality of lab resources	Pearson Correlation	.289	.298
	Sig. (2-tailed)	.000	.000
Teacher training and support	Pearson Correlation	.394	.338
	Sig. (2-tailed)	.000	.000

N=348

Table 20 reveals the Pearson correlation coefficients between standardized test scores and four predictors: frequency of lab use, types of lab activities, quality of lab resources, and teacher training and support. All correlations are statistically significant at the $p < 0.01$ level. The strongest positive correlation is between teacher training and support (0.394) and standardized test scores, followed by frequency of lab use (0.316), quality of lab resources (0.289), and types of lab activities (0.193). This suggests that improvements in these areas are positively associated with higher standardized test scores. The findings are in accordance with Delorme (2016) who said that frequency of lab use, types of lab activities, quality of lab resources and teacher training and support all influence standardized test scores and teacher assessments.

Table 21

Correlation analysis of the Relationship between Mathematics Laboratory Usage and Development of Students' Mathematics Skills (N=16 Teachers)

Descriptive		Standardized test scores	Teacher assessments
Frequency of lab use	Pearson Correlation	.378	.378
	Sig. (2-tailed)	.149	.149
Types of lab activities	Pearson Correlation	.364	.218
	Sig. (2-tailed)	.166	.417
Quality of lab resources	Pearson Correlation	-.051	.154
	Sig. (2-tailed)	.850	.568
Teacher training and support	Pearson Correlation	.585	-.061
	Sig. (2-tailed)	.017	.824

N=16

The table 21 indicates the Pearson correlation coefficients between standardized test scores and four predictors: frequency of lab use, types of lab activities, quality of lab resources, and teacher training and support, based on a sample of 16. The correlation between teacher training and support and standardized test scores is significant at the 0.05 level (0.585, $p = 0.017$), indicating a strong positive relationship. The correlations for frequency of lab use (0.378) and types of lab activities (0.364) are positive but not statistically significant. The quality of lab resources shows a very weak negative correlation (-0.051) that is not statistically significant. Overall, teacher training and support has the most substantial and statistically significant positive impact on standardized test scores in this sample. This is supported by Bilican and Senler (2021) who indicated that laboratories support critical thinking, problem-solving and collaboration skills by allowing students to apply theoretical knowledge to real-world scenarios.

4.8 Presentation of Qualitative Results

This section discusses the information collected from interview with teachers and data collected from the classroom observation. The observed classrooms involved Mathematics subjects to get first-hand information of what goes on during learning.

4.8.1 Information Collected from Interview

This section presents information gathered from interviews with four teachers of Mathematics teachers: three males with Bachelor's degrees and one female with a Diploma. Two of the teachers have over five years of teaching experience, while the other two have less than five years. The interview focused on three questions about laboratory activities' contributions to students' Mathematics skills, their enhancement of mathematical abilities, and their role in the overall learning process. Additionally, the interview explored the role of standardized test scores, teacher assessments, and self-reported measures in evaluating students' Mathematics performance.

For the first question, respondents' views on how laboratory activities contribute to students' Mathematics skills development, respondents highlighted "Exercises, home works, quizzes, group works or projects are specific activities that have a more significant impact on students learning outcomes in Mathematics". Further, they revealed that "Understanding and memorization without providing efforts and level of success are consolidated by Mathematics laboratory activities". One of the respondents stressed "Critical thinking, problem solving, experiments, demonstrations (remembering), preciseness and connecting to real life problems are built on use of Mathematics Lab materials". Another highlighted that "through calculation and manipulation of Mathematics lab tools, using ICT tools (Apps) contribute to the development of Mathematics skills."

The second question is concerned with how different types of laboratory activities contribute to the enhancement of students' mathematical abilities; and the role these activities play in the overall Mathematics learning process. Participants focused on collaboration and active learning and practicals as they say, "Collaboration and discussions contribute to the enhancement of Mathematics abilities by influencing each other", and "Active learning contributes a lot to the development of Mathematics skills by evoking their effort". "Practice makes better than memorization. To mean that Mathematics activities foster the development of Mathematics abilities" "Mathematical lessons boost or foster students' abilities and help them to like Mathematics".

When asked on the role of the standardized test scores when they are evaluating students' Mathematics performance, teachers said that the "Level of understanding, confidence, grading, promoting areas to improve and hardworking are all influenced by these measures." They further revealed that "to know where is the problem for improvement, to facilitate students for betterment, come from these measures." One of the respondents stressed that "Scrutinizing students' abilities, valuing what they are studying, improving strategies and methods, self-evaluation, grading and career guiding facilitated these measures." while another posits that "Understanding and level of knowledge and skills about Mathematics, influence to like Mathematics, adaptability of each student in using Math lab materials, all help students to be familiar with Mathematics tools."

All in all, interviews with the four teachers from different schools highlighted the significance of various laboratory activities in developing students' Mathematics skills. Teachers emphasized that exercises, group work, and IT tools foster critical thinking, problem-solving, and real-life application of mathematical concepts, with collaboration and active learning proving more effective than memorization. Standardized test scores, teacher assessments, and self-reported measures play crucial roles in evaluating students' performance, identifying areas for improvement, boosting confidence, and guiding career paths. Therefore, diverse hands-on activities and comprehensive evaluation methods in Mathematics education are found important. Conclusively, Mathematics lab use significantly contributes to students' development of Mathematics skills.

4.8.2 Information Collected Through Class Observation

Observations of S5MCE (day scholars) and S5PCM (boarding school) Mathematics classes insinuate significant differences in student participation and resource availability. Students of S5PCM displayed higher motivation, active participation and better problem-solving skills, supported by ample resources such as calculators, ICT gadgets and exercise materials. In contrast, S5MCE students were less engaged and had limited access to essential learning tools. This disparity underscores the importance of well-equipped laboratories and supportive environments in improving learners' motivation, participation and mathematical proficiency. This highlights the need for equitable resource accessibility and effective teaching methods in all school settings.

Table 6 and Table 7 indicate strong student and teacher agreements on the positive impact of Mathematics labs, emphasizing improved grades and test scores despite some varying opinions. Students rated the overall impact highly, with an average mean score of 4.614 and standard deviation of 93.04%. Teachers also support the benefits of Mathematics labs for enhancing student performance, with an average mean score of 4.15 and standard deviation of 73.030%.

Model Summary data shows a moderate positive relationship between predictors (frequency of lab use, types of lab activities, quality of lab resources, and teacher training) and standardized test scores, with a correlation coefficient of 0.450. The coefficient of determination (R Square) is 0.202, indicating that 20.2% of the variability in test scores is explained by these predictors. Overall, enhancing these factors, particularly teacher training, types of activities, frequency of use, and quality of resources, can significantly improve students' performance on standardized tests.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

The research was conducted in GS Cyabagarura, GS Karwasa, ESSA-Ruhengeri, and GSNDA Rwaza, focusing on the impact of mathematics laboratory usage on students' mathematics skills. Findings highlighted that all factors of lab usage (frequency, types of activities, quality of resources, and teacher training and support) positively affect the development of students' mathematics skills in the selected public schools in Musanze District.

The analysis confirms that both students and teachers recognize the significant positive impact of mathematics laboratory usage on student performance, particularly in terms of achieving higher grades and improving test scores. There is a moderately positive relationship between math lab usage components and standardized test scores, with a correlation coefficient of 0.450, indicating that increased frequency of lab use, types of activities, quality of resources, and teacher training positively influence test scores. These predictors account for 20.2% of the variability in test scores, with teacher training having the most substantial effect. Enhancing these factors can therefore significantly boost students' performance on standardized tests.

The evaluation of mathematics labs revealed that both students and teachers strongly agree on their effectiveness, with students rating the labs highly (mean of 4.64) for contributing to continuous grade improvement and skill development, and teachers similarly endorsing their impact (mean of 4.416). The regression analysis revealed a moderately positive relationship (R = 0.358) between mathematics lab usage components and teacher assessments, with these factors explaining about 12.8% of the assessment variability. From both student and teacher perspectives, these findings highlight the perceived value of math labs in enhancing students' academic performance and skill acquisition.

5.2 Recommendations

While it was found that using mathematics laboratories enhances students' mathematics skills and positively impacts their standardized test scores, certain improvements are still necessary to enhance the use of mathematics laboratories and subsequently improve the development of students' mathematics skills in public secondary schools in Musanze District, Rwanda. Schools should schedule regular and frequent lab sessions as part of the curriculum, and teachers should be encouraged to incorporate these activities into their weekly lesson plans. Hands-on and interactive activities and technology tools should be incorporated into lessons to create dynamic and engaging learning experiences. Schools should also avail themselves of enough quality resources to meet current educational standards. There is a need for continuous professional development for teachers on strategies to integrate lab activities into everyday teaching.

Teachers are recommended to integrate mathematics lab activities into their lessons and ensure they reinforce the theoretical concepts taught in class. Moreover, they should encourage active learning and provide support to learners through experiments and group work to foster teamwork and peer learning during lab sessions. Students are recommended to actively engage in sessions, utilize resources, collaborate with peers, and participate in discussions.

Parents and other stakeholders should play a practical role in their children's education by providing them with mathematics lab materials. Notwithstanding the results of this study, future studies are encouraged to explore factors influencing mathematics test scores in secondary schools, which account for 79.8% of variability. Upcoming studies should also delve into integrating advanced technology in math labs to enhance student engagement and performance. The long-term effects of mathematics lab usage on student outcomes and career paths can be examined too.

REFERENCES

Abdurrahman, M. S., Halim, A. A., & Sharifah, O. (2021). Improving polytechnic students' high-order-thinking-skills through inquiry-based learning in *Mathematics* classroom. *International Journal of Educational Research and Evaluation, 10*(3), 976–983. https://doi.org/10.11591/ijere.v10i3.21771

Agresti, A., & Franklin, C. (2015). *Statistics: The art and science of learning from data*. Pearson.

Agyei, D., Adu, S., Yeboah, E., & Tachie-Donkor, G. (2018). Establishing the Knowledge of Health Information among Adolescent Postpartum Mothers in Rural Communities in the Denkyembour District, Ghana. *Advances in Research, 14*(1), 1–8. https://doi.org/10.9734/air/2018/39939

Akkus, M. (2016). The common core state standards for *Mathematics*. *International Journal of Research in Education and Science, 2*(1), 49–54. https://doi.org/10.21890/ijres.61754

Baharin, N., Kamarudin, N., Abdul, U. K., & Manaf, A. (2018). Integrating STEM Education Approach in Enhancing Higher Order Thinking Skills Integrating STEM Education Approach in Enhancing Higher Order Thinking Skills. *International Journal of Academic Research in Business and Social Sciences, 8*(7), 810–821. https://doi.org/10.6007/IJARBSS/v8-i7/4421

Bainomugisha, E., Bradshaw, K., Ujakpa, M. M., Nakatumba-nabende, J., Nderu, L., Mduma, N., Kihoza, P., & Irungu, A. (2023). *Computer Science Education in Selected Countries from Sub-Saharan Africa*, *1*(1), 23.

Baker, C., Hjalmarson, M., & Fennell, F. (2023). Advancing Research about *Mathematics* Specialists and *Mathematics* Teacher Leaders. *Investigations in Mathematics Learning, 15*(1), 1–10. https://doi.org/10.1080/19477503.2022.2154061

Barakabitze, A. A., Lazaro, A. W., Ainea, N., Mkwizu, M. H., Maziku, H., Matofali, A. X., Iddi, A., & Sanga, C. (2019). Transforming African Education Systems in *Science, Technology, Engineering, and Mathematics (STEM)* Using ICTs: Challenges and Opportunities. *Education Research International, 2019*(6), 1-29.

Bilican, K., & Senler, B. (2021). Fostering *Teacher Educators' Professional Development* through Collaborative Action. *International Journal of Pedagogy and Curriculum, 17*(2), 0–2. https://doi.org/10.29329/ijpe.2020.332.28

Bittner, S., Schietinger, M., Schroth, J., & Weinkopf, C. (2017). *Call centres in Germany: Employment, training and job design. Re-Organising Service Work: Call Centres in Germany and Britain*. Aldershot: Ashgate, 63–85.

Charles-Ogan, G. I., & Otikor, M. S. (2016). *Practical Utility of Mathematics Concepts among Senior Secondary*

School Students in Rivers State. *European Journal of Mathematics and Computer Science, 3*(1), 15–22.

D'Angelo, S., Marcus, R., & Ngabonzima, E. (2022). Teaching and learning for life skills development: Insights from *Rwanda's 12+ programme for adolescent girls*: Special Issue *Youth & Adolescent Skills Development: Preparing young people for diverse global challenges*. *Development Policy Review, 40*(S2), 1–18. https://doi.org/10.1111/dpr.12622

Delorme, S. (2016). *Technology in the elementary mathematics classroom: Supporting students learning and engagement in mathematics in today's elementary classrooms through the use of iPads* (Master's Research Paper, Ontario Institute for Studies in Education of the University of Toronto).

Ezinwanyi, U. (2020). Comparative Effects of *Mathematics Laboratory Resources* on Interest and Achievement of Students in *Mathematics*. *Ihendinihu, 23*(2), 15–19.

Fidele, U., Kizito, N., Angel, M., & Jean, U. (2019). Insights of teachers and students on *Mathematics* teaching and learning in selected Rwandan secondary schools. *African Journal of Educational Studies in Mathematics and Sciences, 15*(2), 93–106. https://doi.org/10.4314/ajesms.v15i2.8

Filgona, J., & State, A. (2020). *Teachers' Pedagogical Content Knowledge and Students' Academic Achievement*: A Theoretical Overview. *Journal of Global Research in Education and Social Science, 14*(2), 14-44.

Hankeln, C. (2020). *Mathematical modeling in Germany and France*: A comparison of students' modeling processes. *Educational Studies in Mathematics, 103*, 209–229.

Jayanthi, R. (2019). *Mathematics* in society development - A Study. *Iconic Research and Engineering Journals, 3*(3), 59–64.

Jean De Dieu, H., Theogene, H., Philothere, N., & Ke, Z. (2022). *Quality Education in Rwanda*: A Critical Analysis of Quality Indicators. *Journal of Humanities and Social Science (IOSR-JHSS), 27*(2), 52–70. https://doi.org/10.9790/0837-2702065270

Jeong, E. (2020). *Education reform for the future*: A case study of Korea. *International Journal of Education and Development Using Information and Communication Technology (IJEDICT), 16*(3), 66–81.

Jones, J. P., & Tiller, M. (2017). *Using Concrete Manipulatives in Mathematical Instruction*. *Dimensions of Early Childhood, 45*(1), 18–23.

Kallunki, J., Kauko, J., & Pizmony-levy, O. (2023). *Finland's Famous Education System*. In *Finland's Famous Education System*. Springer Nature Singapore. https://doi.org/10.1007/978-981-19-8241-5

Kuhl, K. (2021). Intersections of class and gender in learners' conceptualisations of sexuality education at a private, all-girls school. *South African Journal of Education, 41*(December), 1–10. https://doi.org/10.15700/saje.v41ns2a2016

Kunwar, R. (2020). *Mathematics Laboratory in School Level Education in Nepal*: An Overview. *International Journal of Science and Research (IJSR), 9*(9), 327-334. https://doi.org/10.21275/SR20904111237

Leary, H., & Walker, A. (2018). *Meta-analysis and meta-synthesis methodologies*: Rigorously piecing together research. *TechTrends, 62*(5), 525–534.

Lohr, S. L. (2021). *Sampling: Design and analysis*. Chapman and Hall/CRC.

Makarova, E. A., Makarova, E. L., & Korsakova, T. V. (2019). The Role of Globalization and Integration in Interdisciplinary Research, Culture and Education Development, *8*(1), 111–127. https://doi.org/10.7596/taksad.v8i1.1957

Ministry of Education. (2023). *Education sector strategic plan 2018/19 to 2023/24*. Republic of Rwanda Ministry of Education.

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

Nizeyimana, G., Nzabalirwa, W., Mukingambeho, D., & Nkiliye, I. (2021). Hindrances to Quality of Basic Education in Rwanda. *Rwandan Journal of Education, 5*(1), 53–67.

Nsengimana, V. (2021). Implementation of Competence-based Curriculum in Rwanda: Opportunities and Challenges. *Rwandan Journal of Education, 5*(1), 129–136.

Nungu, L., Mukama, E., & Nsabayezu, E. (2023). Factors influencing student achievement in *mathematics and science education*: A case study. *Education and Information Technologies, 28*(9), 10865–10884. https://doi.org/10.1007/s10639-023-11607-w

Ohei, K. (2023). Research in Business & Social Science Incorporating new technologies into teaching in South Africa, *12*(6), 286–295.

Rapoport, R., & Berta, K. (2019). Methodology report: American fears survey. *Chapman University*. https://www.chapman.edu/wilkinson/research-centers/babbie-center/_files/full-survey-methodology-2019.pdf

Scholar, A. (2021). *Mathematics Education in Sub-Saharan Africa: Status, Challenges and Opportunities*. *International Journal of Educational Research and Evaluation, 23*(8), 203–218.

Schwarts, G., Elbaum-Cohen, A., Pöhler, B., Prediger, S., Arcavi, A., & Karsenty, R. (2023). *The servants of two discourses*: How novice facilitators draw on their mathematics teaching experience. *Educational Studies in Mathematics, 112*(2), 247–266. https://doi.org/10.1007/s10649-022-10182-0

Sibomana, A., Nicol, C. B., Nzabalirwa, W., Nsanganwimana, F., Karegeya, C., & Sentongo, J. (2021). Factors affecting the achievement of twelve-year basic students in *mathematics and science* in Rwanda. *International Journal of Learning, Teaching and Educational Research, 20*(7), 61–84. https://doi.org/10.26803/IJLTER.20.7.4

Slavin, R. E. (2018). *Educational Psychology: Theory and practice*. Pearson.

Sujeewa, A., Polgampala, V., Shen, H., & Huang, F. (2021). STEM Teacher Education and Professional Development and Training: Challenges and Trends. *American Journal of Applied Psychology*, 6(5), 93-97. https://doi.org/10.11648/j.ajap.20170605.12

Tugade, M. M., Devlin, H. C., & Fredrickson, B. L. (2016). *Positive emotions*. In S. J. Lopez & C. R. Snyder (Eds.), *The Oxford Handbook of Positive Psychology* (2nd ed., pp. 18–32). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199396511.013.1

U.S. Department of Labor. (2023). *The Employment Situation - November 2023*. www.bls.gov/cps

Ukobizaba, F., Nizeyimana, G., & Mukuka, A. (2021). Assessment Strategies for Enhancing Students' *Mathematical Problem-solving Skills*: A Review of Literature, *17*(3), 2–10.

Umugiraneza, O., Bansilal, S., & North, D. (2017). Exploring teachers' practices in teaching *Mathematics and statistics* in KwaZulu-Natal schools. *South African Journal of Education, 37*(2), 1–13. https://doi.org/10.15700/saje.v37n2a1306

Voogt, J., Laferrière, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science, 43*(3), 259–282. https://doi.org/10.1007/s11251-014-9340-7

Vuong, Q.-H., Vinh, L. A., & Trung, T. (Eds.). (2019). *Academic contributions to the UNESCO 2019 forum on education for sustainable development and global citizenship*. Sustainability. Retrieved from https://www.mdpi.com/journal/sustainability/special_issues/UNESCO_2019

Zaccaro, S. J., Connelly, S., Repchick, K. M., Daza, A. I., Young, M. C., Kilcullen, R. N., Gilrane, V. L., Robbins, J. M., & Bartholomew, L. N. (2015). The influence of higher order cognitive capacities on leader organizational continuance and retention: The mediating role of developmental experiences. *Leadership Quarterly, 26*(3), 342–358. https://doi.org/10.1016/j.leaqua.2015.03.007

Zrudlo, I. (2024). Philosophical Inquiry in Education: Was Dewey (Too) Modern? *The Modern Faces of Dewey, 28*(3), 222–236.