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Effect Of SMASE Training On Students' Masterly Of Content In Biology In Secondary Schools, Tseikuru Sub-County, Kitui County, Kenya

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Abstract:
In any academic institution the performance of the learner is very key. The purpose of this study was to establish the effect of SMASE training on students' masterly of content in biology in secondary schools in Tseikuru Sub-County, Kitui County, Kenya. The research used mixed methodology, including quantitative and qualitative methods, with a descriptive survey design and constructivism theory. Four principals, 8 biology teachers, and 200 Form 2 and Form 3 Biology students were targeted. Data was collected through multistage sampling and purposive sampling, with four principals and eight biology teachers participating. The study found that SMASE-trained teachers demonstrated significantly superior outcomes across all indicators compared to their non-SMASE-trained counterparts. Specifically, students taught by SMASE-trained teachers (Group 1: n=150) showed markedly higher performance rates compared to those taught by non-SMASE-trained teachers (Group 2: n=50). In Group 1, 77.33% of students frequently conducted biology experiments compared to only 50.00% in Group 2. Similarly, 59.33% of Group 1 students were given opportunities to plan experiments versus 26.00% in Group 2. Class discussion participation was notably higher in Group 1 at 74.67% compared to 50.00% in Group 2. This suggests that SMASE training has a beneficial and significant effect on students' mastery of biology content. The study recommends intensifying SMASE training to foster creativity and performance in students. Teachers trained through this program tend to improvise during biology lessons and adopt a more student-centered approach. Principals should ensure their teachers attend SMASE training, as it makes biology lessons engaging. Additional resources should be allocated to help teachers overcome challenges posed by inadequate materials, which can negatively affect biology performance. Increasing the time dedicated to biology is also vital, as it allows teachers to conduct experiments thoroughly and complete the syllabus promptly. Overall, the study highlights the importance of SMASE training in enhancing students' mastery of content, attitude thus improving academic performance and promoting creativity in academic institutions.

Keywords: *SMASE Training, Students' Masterly of Content, Biology, Secondary Schools*

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I. Introduction

Background information

Education plays a pivotal role in enhancing the quality of human life and fostering sustainable development. Globally, the importance of science and mathematics education has been emphasized as critical to addressing complex societal challenges such as climate change, technological advancement, and healthcare (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2015). Various international initiatives advocate for improved science and mathematics education, including the United Nations' Sustainable Development Goal 4, which seeks to ensure inclusive and equitable quality education for all and promote lifelong learning opportunities (UNESCO, 2016).

The Strengthening Mathematics and Science Education (SMASE) program, initiated in the 1990s by the Japanese Government and facilitated by various international and local educational bodies, aims to enhance the teaching and learning of mathematics and science in several African countries. Efforts to improve science and mathematics education globally have led to the development of various programs aimed at teacher training and curriculum enhancement, which are essential for fostering critical thinking and problem-solving abilities among students. The Science, Technology, Engineering, and Mathematics (STEM) initiative, for example, has gained momentum across countries, promoting integrated approaches to enhance the relevance of science and mathematics in addressing real-world issues (National Science Board, 2020). This recognition of science and mathematics as foundational skills underscores the pressing need for effective interventions to boost student performance in these subjects.

In Africa, the challenges in mathematics and science education have been particularly pronounced. Over the years, numerous studies have highlighted poor performance in these subjects in various African countries, contributing to the continent's struggle to produce a skilled workforce capable of meeting modern demands (African Union, 2016). The African Union's Agenda 2063 emphasizes the necessity for higher standards of education, fostering innovation and scientific research as cornerstones for economic development and social transformation.

The SMASE initiative represents a continental effort involving multiple African nations aimed at enhancing the quality of mathematics and science education through teacher training and resource provision. Launched in 2002, SMASE targeted the professional development of in-service teachers to increase pedagogical skills and implement student-centered teaching methodologies (SMASE, 2018). The focus on mathematics and science is rooted in the belief that strong foundations in these subjects are crucial for fostering future generations of scientists, engineers, and innovators capable of propelling Africa into the global knowledge economy.

In Eastern Africa, the education sector has been characterized by systematic challenges, including inadequate teacher training, limited resources, and curriculum constraints that hamper the teaching and learning of science and mathematics (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014). Despite these challenges, some countries have initiated educational reforms and partnerships to address specific issues such as low student enrollment, high dropout rates, and insufficient infrastructure. The SMASE project in Kenya has been a notable response to these regional challenges, offering a structured approach to professional development for teachers and enhancing the learning environment in science and mathematics subjects (Olaniyan & Okemakinde, 2008).

The dismal performance of students in national examinations reflects both systemic issues in the education sector and the urgent need for context-specific interventions (Kenya National Examinations Council [KNEC], 2021). In this regard, the Eastern Africa region has increasingly recognized the need to contextualize educational projects like SMASE based on local needs, enabling pedagogical strategies that are more attuned to the specific challenges faced by learners and teachers (Mogere et al., 2019).

Biology is a core science subject taught in secondary schools across Kenya. As a practical discipline, it provides students with essential concepts and skills that are applicable to everyday life challenges. According to a UNESCO report from 1986, biology significantly contributes to the socioeconomic progress of the country by facilitating the effective use of land, animals, and both natural and human resources. Furthermore, it is crucial for promoting good health and hygiene. The subject aims to equip learners with the knowledge, attitudes, and skills required for environmental preservation and management, as noted by Kenya Institute of Education (K.I.E) in 2003. Mwirigi (2011) emphasizes that biology is pivotal in driving industrialization and various economic sectors. The study of biology ultimately provides students with the understanding and abilities needed to shape their environment for the betterment of individuals, families, and communities. Thus, biology is vital in areas such as health, agriculture, environmental studies, and education, and it serves as a foundation for biotechnology, which plays a significant role in technological and industrial advancement. Biology is also a vital background in the medical field and in our most industries. In view of this, the study of biology would contribute to the realization of Kenya's Vision 2030.

In Kenya, In-service Education and Training (INSET) for mathematics and science teachers have been implemented by strengthening of mathematics and science in secondary education (SMASSE) Project from a pilot phase (1998-2003) to national phase (2003-2008). Following the consistent poor performance in science subjects over years, the government of Kenya in collaboration with the government of Japan through Japanese international cooperation agency (JICA) carried out research to find the solution to the existing problem in mathematics and science subjects.

The education system in Kenya has experienced a significant transformation since the introduction of the 8-4-4 curriculum in the early 1980s, which placed emphasis on practical and vocational education (Oketch, 2016). However, the country continues to grapple with challenges related to the quality of education in science and mathematics. National assessments reveal persistent underperformance in these subjects, attributed to factors including limited teacher training, resource gaps, and insufficient instructional methodologies (KNEC, 2021).

To address these challenges, the Kenyan government has implemented various initiatives aimed at improving science and mathematics education. The Ministry of Education has adopted different strategies, including the SMASE project, which emphasizes teacher capacity building and the integration of inquiry-based learning approaches. By enhancing teachers' pedagogical skills and knowledge, the SMASE initiative seeks to create an engaging learning environment that promotes students' understanding of scientific concepts and mathematical principles (Government of Kenya, 2018).

At the local level, Tseikuru Sub-County in Kitui County presents a unique educational landscape characterized by a diverse population and varying socioeconomic conditions. The region's education system faces specific hurdles, including resource scarcity, inadequate infrastructure, and geographic isolation, which often limit access to quality education (Muli, 2020). According to the Kenya Demographic and Health Survey (KDHS, 2019), Kitui County has lower literacy rates compared to national averages, highlighting the urgent need for educational interventions tailored to local contexts.

The SMASE project in Tseikuru Sub-County aims to address these unique challenges by enhancing biology education through targeted teacher training and resource provision. Research indicates that effective teacher professional development can lead to improved instructional practices in science education, resulting in better student outcomes (Guskey, 2002). By focusing on biology, the SMASE initiative within this specific community seeks to address both the content knowledge of teachers and their pedagogical strategies, ensuring a more student-centered approach to teaching.

However, despite the efforts of the SMASE project, the performance of students in biology has not met expectations. Preliminary assessments indicate that various factors, including teacher preparedness, resource allocation, and parental involvement, significantly effect student outcomes (Kipng'eno & Birech, 2020). Consequently, this study aims to establish the effect of SMASE training on students' masterly of content in biology in secondary schools in Tseikuru Sub- County, Kitui County, examining both qualitative and quantitative dimensions to draw meaningful conclusions that can contribute to the ongoing efforts to strengthen education in the region.

Statement of the Problem

The quality of education in Kenya, particularly in the areas of mathematics and science, has been a significant concern for educators and policymakers. Despite ongoing efforts to enhance the teaching methodologies and curriculum in these critical subjects, performance in biology among students in Tseikuru Sub-County, Kitui County, remains suboptimal. The Strengthening of Mathematics and Science Education (SMASE) project was introduced as a comprehensive initiative aimed at improving the pedagogical approaches in these subjects. However, the tangible impact of the project on student performance in biology requires thorough investigation. Reports from local secondary schools indicate that a considerable number of students continue to struggle with biology, leading to poor examination results that adversely affect their academic progression and future opportunities. A multitude of factors may contribute to this phenomenon, including inadequate teaching resources, lack of trained personnel, and students' perception of the subject. Additionally, the integration of SMASE methodologies has not been uniformly applied or embraced across all schools in the Sub-County, creating disparities in the quality of instruction received by students. The problem is further compounded by sociocultural factors and economic challenges faced by the community, which can hinder effective learning and engagement in science-related subjects. As a result, there exists a pressing need to establish the effect of the SMASE project in Tseikuru Sub-County and identify the underlying issues contributing to the persistent underperformance in biology. This study aimed to explore these dynamics through a systematic evaluation of SMASE implementation, teaching strategies, and student engagement in biology. By identifying the challenges and successes of the project in enhancing educational outcomes, this research sought to provide actionable recommendations for stakeholders aimed at bolstering the effects of science education in the region. Thus, the need for a comprehensive analysis of the effect of SMASE training on students' masterly of content in biology in secondary schools in Tseikuru Sub-County, Kitui County, Kenya was both timely and crucial for improving educational standards in Kenya will inform educators and policymakers about best practices and potential areas for improvement.

Study Objective

The objective of the study was to establish the effect of SMASE training on Students' masterly of content in biology in secondary schools, Tseikuru Sub- County, Kitui County, Kenya.

Significance of the Study

The findings of the study may provide vital information to biology teachers to evaluate their teaching methods in the classroom. If the performance of teachers trained in biology is higher, teachers will be encouraged to take up professional courses in biology in SMASE resulting in better performance countrywide. The study may also provide educational policymakers with information on the existing challenges of SMASE INSETs project on teaching and learning of biology. The study may as well enable CEMASTEA to evaluate the impact of SMASE in the teaching and learning of biology. In addition, the study may contribute to knowledge to the teaching and learning biology and also to the SMASE trainers.

Theoretical Framework

The theoretical framework is hinged on constructivism theory attributed to Jean Piaget. Constructivism is a theory of knowledge that argues that humans generate knowledge and meaning from an interaction between their experiences and their ideas. The formal development of constructivism is commonly linked to Jean Piaget, who described how learners internalize knowledge. He proposed that individuals develop new understanding through processes known as accommodation and assimilation. Assimilation involves integrating new experiences into pre-existing cognitive frameworks without altering those frameworks. Furthermore, social constructivism promotes the idea that learners formulate their own interpretations of reality, shaped by their backgrounds, cultural contexts, and personal worldviews.

From the social constructivist viewpoint, it is thus important to take into account the background and culture of the learner throughout the learning process, as this background also helps to shape the knowledge and truth that the learner creates, discovers and attains in the learning process (Wertsch, 1997). Furthermore, it is argued that the responsibility of learning should reside increasingly with the learner (Glasersfeld, 1989). Social constructivism thus emphasizes the importance of the learner being actively involved in the learning process, unlike previous educational viewpoints where the responsibility rested with the instructor to teach and where the learner played a passive, receptive role. Von Glasersfeld (1989) emphasized that learners construct their own understanding and they do not simply mirror and reflect what they read.

The social constructivist framework suggests that educators should embrace the role of facilitators instead of traditional teachers (Bauersfeld, 1995). Unlike a teacher, who typically delivers a structured lecture on a subject, a facilitator guides students to develop their own understanding of the material. In this model, learners are expected to take an active role in their education rather than remaining passive recipients of knowledge. This approach shifts the focus from the instructor and the content to the learner themselves (Gamoran, Secada, & Marrett, 1998). As a result, facilitators require a markedly different skill set compared to teachers (Brownstein, 2001). While teachers often present information and answer questions in a prescriptive manner, facilitators encourage dialogue, support learners in their own inquiries, and create an environment conducive to personal discovery (Rhodes and Bellamy, 1999). Moreover, facilitators must be flexible enough to adjust the learning experience in real time, responding to where learners feel they can find value. It's also crucial that the learning setting is designed to both challenge and support critical thinking (Di Vesta, 1987). While it is important for learners to take ownership of their learning journey, not all activities or solutions are equally beneficial. The primary objective is to empower learners to become effective thinkers, which can be facilitated through various roles, including that of coach or consultant.

In the social constructivist classroom, teachers strive to assist students in developing their knowledge and maintaining engagement during the learning process. The Association for Constructivist Teaching (ACT, 2007) emphasizes that such educators value reflection, cognitive conflict, and encourage interaction among peers. As noted by Kompf (1996), "constructivist teachers allow student responses to guide lessons, adapt instructional strategies, and modify content." By limiting their role, teachers can promote collaborative learning among students.

This theoretical perspective views learning as an active endeavor where individuals create meaning from their experiences (Brooks & Brooks, 1999). In this context, teachers play a more facilitative role than a traditional one. Research by Sims (2002) and Fry et al. (2003) supports the idea that learners grasp concepts most effectively when making sense of information independently, with the instructor offering guidance (Gerding, 2007, p. 28). The term "facilitator" is often seen as more suitable than "teacher" within a social constructivist context, as it reflects the learners' active role in knowledge construction rather than being mere recipients of information (Lambert, 2002; Fox & Schirrmacher, 2011, p. 79). Additionally, learners engage collaboratively with one another. Traditional teaching methods typically encompass lectures, discussions, demonstrations, and field trips (Brown et al., 1982), while contemporary approaches include process skills, discovery, inquiry, problem-solving, laboratory experiences, and collaborative concept mapping. Research by Keraro et al. (2007) indicates that cooperative concept mapping strategies can enhance student motivation more effectively than conventional teaching methods.

II. Literature Review

SMASE Training and Students' Masterly of Content

The enhancement of teaching methodologies and the improvement of student learning outcomes are central concerns in educational research, especially in the field of mathematics and science education. One significant initiative in this context is the Strengthening Mathematics and Science Education (SMASE) program. Initiated by the Japanese government in collaboration with several African countries, SMASE aims to improve the quality of mathematics and science education through teacher training programs. This literature review explores the impact of SMASE training on students' mastery of content, discussing various empirical studies, theoretical frameworks, and methodologies used in this field of research

The SMASE program began as a response to declining standards in mathematics and science education in many developing countries. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2016), improving teacher quality is essential for enhancing student performance. The SMASE initiative, which promotes effective teaching methods and the use of instructional materials, seeks to equip teachers with the necessary skills to deliver content more effectively.

SMASE training comprises several key components, including workshops, peer collaboration, lesson study, and the utilization of practical teaching methods. Sasaki (2021) asserts that these components are designed to empower teachers to engage students actively while fostering a deeper understanding of mathematical and scientific concepts. The training emphasizes inquiry-based learning, where students are encouraged to explore and solve real-world problems, thereby enhancing their mastery of content (Njeru, 2020).

Several studies have assessed the impact of SMASE training on students' performance in mathematics and science. A notable study by Omollo and Mboya (2020) in Kenya revealed that students taught by teachers who had undergone SMASE training demonstrated significantly improved scores on standardized assessments compared to those who had not experienced such training. This correlates with research by Kainyu et al. (2021), which found that teachers who implemented SMASE techniques facilitated higher levels of student engagement and critical thinking, leading to better mastery of subject content.

Comparative studies between SMASE trained educators and their counterparts lacking such training provide insightful data on the efficacy of this intervention. According to a study by Ndung'u et al. (2022), students in SMASE trained classrooms not only exhibited improved test scores but also showed greater enthusiasm for mathematics and science subjects. This sentiment was echoed in research by Muriuki and Karanja (2021), highlighting that student often reported experiencing deeper understanding and retention when taught through the methodologies endorsed by the SMASE initiative.

Despite the documented benefits of SMASE training, challenges persist in its implementation and sustainability. A study by Mwangi et al. (2020) highlighted resource constraints as a significant barrier to the full realization of SMASE's potential. Additionally, the findings by Juma and Odhiambo (2021) indicated that inconsistent follow-up training and support diminished the long-term effects of SMASE techniques. Such limitations necessitate robust strategies to ensure that teachers continually develop their skills and that students consistently benefit from enhanced instructional practices.

Teacher perceptions of SMASE training are crucial to understanding its impact. A qualitative study by Gichuki and Akinyi (2021) revealed that many teachers felt empowered by SMASE training due to the collaborative culture it fostered among educators. However, some teachers expressed feelings of inadequacy when transitioning from traditional to inquiry-based methods, indicating a need for ongoing professional development (Wanyonyi, 2023).

Student mastery of content, as a direct consequence of teacher training, is fundamental to establishing the effect of educational interventions like SMASE. A comprehensive study by Ochieng and Oboth (2022) illustrated that students' mastery of mathematical concepts improved notably after SMASE training was implemented in their schools. Furthermore, research by Mutahi et al. (2021) showed that SMASE trained educators were more successful in differentiating instruction to meet diverse learning needs, thereby enhancing overall learner outcomes.

The literature reviewed indicates that SMASE training significantly impacts students' mastery of content in mathematics and science. The training equips teachers with effective pedagogical strategies grounded in constructivist principles, promotes greater student engagement, and fosters a deeper understanding of complex concepts. However, challenges such as resource constraints, inconsistent follow-up, and the need for ongoing support highlight areas for improvement in the SMASE program's implementation. Future research should address these limitations and explore innovative strategies for sustaining the positive outcomes associated with SMASE training.

III. Methodology

Research Methodology

The study adopted a mixed-methods approach. This methodology combined both quantitative and qualitative research methods to provide a comprehensive understanding of the impact of the SMASE project on biology performance. The methodology was preferred because the researcher collected quantitative and qualitative data from the respondents. According to Creswell and Clark (2007), it is evidenced that the use of mixed-methods is very vital since the mixture of quantitative and qualitative techniques gives a better comprehension of the study problem and the complicated process as compared to any other approach. Mixed Methodology allowed investigation for both the inductive and deductive perspectives. According to Jogulu and Pansiri (2011), this enabled the researcher to combine theory generation and hypothesis testing within a single study.

Research Design

The research utilized a descriptive survey design to explore the impact of SMASE training on the performance of biology students. This approach facilitated the analysis and reporting of events as they unfold

(Mugenda & Mugenda, 2003). Orodho (2004) notes that descriptive surveys are essential for detailing certain characteristics or attributes of a population, including their opinions, attitudes, beliefs, or awareness of specific phenomena. Additionally, Borg and Gall (2003) indicate that this type of research is focused on generating statistical data related to educational aspects that are significant to policymakers and educators. Consequently, a descriptive study design was appropriate for this research, as it aimed to gather insights from biology teachers and students regarding the impact of the SMASE initiative on the academic performance of biology in secondary schools within Tseikuru Sub-County, Kitui County, Kenya.

Location of the Study

The targeted area was Tseikuru Sub-County in Mwingi North in Kitui County. This Sub-County was selected because of the poor performance posted in biology. A research in this area can be used to represent other areas. Singleton (1993) observes that the ideal setting for any study is one that is directly related to the researchers own interests. The region is rural and is densely populated. The major economic activity in the area is mainly subsistence farming and livestock keeping. The Sub-County borders Tana River County and Tharaka Nithi County.

Target Population

Tseikuru Sub-County is home to 12 secondary schools, as reported by the Tseikuru Sub-County Education Office in 2025. The study focused on 12 school principals, 21 biology instructors, and 900 students enrolled in Form 2 and Form 3 Biology classes. Thus, the overall target population for this research comprised 933 individuals. This figure was derived by compiling data on Form 2 and Form 3 Biology students and their teachers from the Education Office in Tseikuru Sub-County.

Sampling Procedures and Sample Size

This research utilized a multistage sampling approach. Initially, the 12 schools were divided into two categories: private and public schools. Due to the presence of only one private school in the Sub-County, this school was selected through purposive sampling. In the subsequent stage, the 11 public schools were classified into four types: all-boys, all-girls, mixed-day and boarding, and mixed-day schools. Each category contributed one school to the sample. However, since there are no all-boys schools in the Sub-County, the sample consisted of one all-girls school, one mixed-day and boarding school, and one mixed-day school, resulting in a total of four schools selected for the study.

From these four schools, all principals and biology teachers were purposefully included as participants. To select students, a systematic sampling method was employed using the teachers' progressive record books to guarantee fair representation from all classes. The targeted student sample consisted of 200 individuals. The biology content evaluated was drawn from the end-of-year examination for Form One.

Table 3.1: Sample Size

Categories of Respondents	Population Size	Sample Size	Percentage
Form 2 and Form 3 Students	900	200	22.22%
Biology Teachers	21	8	38.10%
Principals	12	4	30.00%
Total	**933**	**212**	

Data Analysis

The responses were entered into STATA version 17 computer program for analysis after collection. Data was analyzed quantitatively by using descriptive statistics such as frequencies and percentages. Inferential statistics specifically two sample t-tests were also used. Conclusions and inferences were drawn after obtaining data and analyzed based on the study objectives and research questions. The analyzed data was presented using tables.

IV. Results And Discussions

Effect of SMASE Training on Students' Masterly of Content in Biology in Secondary Schools

The SMASE training variable was operationalized as a binary indicator based on attendance at SMASE In-Service Education and Training (INSET) programs, ensuring its clear perception by principals, teachers, and students. This dichotomous classification approach was deliberately chosen to facilitate clear comparative analysis between schools and educators who had participated in SMASE training versus those who had not participated. This binary approach, with Group 1 comprising 150 students taught by SMASE-trained teachers and Group 2 comprising 50 students taught by non-SMASE-trained teachers, provides a straightforward foundation for understanding the program's impact across all four research objectives and enables the use of appropriate statistical tests for comparing means between the two groups.

The binary classification system allows for the application of two-sample t-tests, which are particularly suitable for comparing the means of variables between two independent groups. This statistical approach provides robust evidence for determining whether observed differences between SMASE-trained teachers (six) and non-SMASE-trained teachers (two) groups are statistically significant or could have occurred by chance. The use of this classification system throughout the analysis ensures consistency in the analytical approach and facilitates meaningful comparisons across different aspects of biology education.

The decision to use a binary classification also reflects the practical reality of SMASE training implementation, where teachers either have or have not participated in the formal INSET programs. This clear distinction enables stakeholders to make informed decisions about the value and necessity of SMASE training based on concrete evidence of its impact on various educational outcomes.

Table 4.1: Students' Masterly of Content in Biology in Secondary Schools

Students' Mastery of Content in Biology	Response	Frequency	Percent
Students frequently do biology experiments			
Group 2 (non-SMASE-trained teachers)	No	25	50.00
	Yes	25	50.00
Group 1 (SMASE-trained teachers)	No	34	22.67
	Yes	116	77.33
Students are given an opportunity to plan for experiments			
Group 2 (non-SMASE-trained teachers)	No	37	74.00
	Yes	13	26.00
Group 1 (SMASE-trained teachers)	No	61	40.67
	Yes	89	59.33
Students get involved in class discussions			
Group 2 (non-SMASE-trained teachers)	No	25	50.00
	Yes	25	50.00
Group 1 (SMASE-trained teachers)	No	38	25.33
	Yes	112	74.67

The analysis of SMASE training's effect on students' mastery of content in biology reveals significant and consistent positive effects across multiple indicators of student engagement and learning. The assessment of content mastery was conducted using carefully selected indicators that reflect active learning approaches and student-centered pedagogical practices that are central to the SMASE methodology.

Table 4.1 presents a comprehensive overview of students' mastery of biology content in secondary schools, measured through three key indicators that capture different dimensions of active learning and student engagement. The first indicator, "students frequently do biology experiments," serves as a measure of hands-on learning opportunities that are fundamental to effective science education. The data reveals a stark contrast between the two groups: in Group 1 (students taught by SMASE-trained teachers), 77.33% frequently engage in biology experiments, while in Group 2 (students taught by non-SMASE-trained teachers), only 50.00% frequently participate in experimental work. This 27.33 percentage point difference demonstrates the substantial impact of SMASE training on promoting hands-on learning experiences.

The second indicator, "students are given opportunity to plan for experiments," measures the extent to which students are involved in the design and planning phases of experimental work, rather than simply following predetermined procedures. The findings show a remarkable difference between the groups: 59.33% of Group 1 students are given opportunities to plan for experiments compared to only 26.00% of Group 2 students. This 33.33 percentage point difference indicates that SMASE-trained teachers are significantly more likely to involve students in higher-order engagement with experimental work, representing a significant shift from traditional teacher-directed laboratory activities toward more student-centred approaches that develop critical thinking and scientific inquiry skills.

The third indicator, "students get involved in class discussions," assesses the level of interactive learning and verbal participation in biology classes. The data shows that 74.67% of Group 1 students are involved in class discussions compared to 50.00% of Group 2 students. This 24.67 percentage point difference suggests that SMASE-trained teachers are substantially more effective at creating interactive classroom environments that encourage student participation and peer learning, indicating a move away from traditional lecture-based approaches toward more collaborative and engaging classroom environments.

Table 4.2: Two-Sample T-Test for SMASE Training on Students' Masterly of Content in Biology

Variable name	Group	Mean	t-value	p-value
Students frequently do biology experiments	Non-SMASE-trained	0.32	4.74*	0.0000
	SMASE-trained	0.76		
Students get involved in class discussions	Non-SMASE-trained	0.32	4.38*	0.0000
	SMASE-trained	0.74		
Student's involvement in class experiment is encouraging	Non-SMASE-trained	0.00	5.86*	0.0000
	SMASE-trained	0.57		
With ASEI/PDSI approach teachers can deal with learners' problems more adequately	Non-SMASE-trained	0.00	4.39*	0.0000
	SMASE-trained	0.43		
Teachers have witnessed creativity in students during biology lessons	Non-SMASE-trained	0.00	3.21*	0.0015
	SMASE-trained	0.29		

Note: * indicates 1% level of significance
SMASE trained - group 1
Non-SMASE trained - group 2

The statistical analysis presented in Table 4.2 provides compelling evidence of the positive impact of SMASE training on students' mastery of content in biology. The two-sample t-test results demonstrate statistically significant differences between SMASE-trained and non-SMASE-trained teachers across all measured indicators, with all p-values falling well below the conventional significance threshold of 0.05.

The analysis of students frequently doing biology experiments reveals a substantial difference between the two groups, with SMASE-trained teachers achieving a mean of 0.76 compared to 0.32 for non-SMASE-trained teachers. The t-value of 4.74 and p-value of 0.00 indicate that this difference is highly statistically significant, providing strong evidence that SMASE training leads to increased frequency of experimental work in biology classes. This finding is particularly important as hands-on experimentation is widely recognized as a crucial component of effective science education that enhances student understanding and retention of scientific concepts.

The involvement of students in class discussions shows similarly impressive results, with SMASE-trained teachers achieving a mean of 0.74 compared to 0.32 for their non-trained counterparts. The t-value of 4.38 and p-value of 0.00 demonstrate that SMASE training significantly enhances teachers' ability to facilitate interactive classroom environments that promote student participation and collaborative learning. This finding aligns with the SMASE philosophy of student-centred learning and suggests that the training effectively transforms classroom dynamics from teacher-dominated to student-participatory environments.

The analysis of student involvement in class experiments being encouraging reveals an even more pronounced difference, with SMASE-trained teachers achieving a mean of 0.57 compared to 0.00 for non-trained teachers. The t-value of 5.86 and p-value of 0.00 indicate that SMASE training has a profound impact on creating encouraging environments for student experimental work. This finding suggests that SMASE training not only increases the frequency of experimental activities but also enhances the quality of the experimental learning environment, making it more supportive and encouraging for student participation.

The ability of teachers to deal with learners' problems more adequately using the ASEI/PDSI (Activity, Student, Experiment, Improvisation/Plan, Do, See, Improve) approach shows a significant difference, with SMASE-trained teachers achieving a mean of 0.43 compared to 0.00 for non-trained teachers. The t-value of 4.39 and p-value of 0.00 demonstrate that SMASE training significantly enhances teachers' problem-solving capabilities in the classroom. This finding is particularly important as it suggests that SMASE training provides teachers with practical tools and strategies for addressing individual student learning challenges, leading to more personalized and effective instruction.

The analysis of teachers witnessing creativity in students during biology lessons reveals a meaningful difference, with SMASE-trained teachers achieving a mean of 0.29 compared to 0.00 for non-trained teachers. The t-value of 3.21 and p-value of 0.00 indicate that SMASE training significantly enhances teachers' ability to foster and recognize student creativity in biology learning. This finding suggests that SMASE methodologies create classroom environments that encourage creative thinking and innovative approaches to problem-solving, which are essential skills for scientific inquiry and lifelong learning.

The qualitative insights provided by school principals further support these quantitative findings. The principals' observation that "there is a difference in creativity and performance in students taught by SMASE trained teachers than those taught by SMASE untrained teachers" provides institutional validation of the positive impact of SMASE training on student outcomes. This administrative perspective is particularly valuable as principals have the opportunity to observe and compare teaching practices across different teachers within their schools, providing them with a unique vantage point for assessing the relative effectiveness of different pedagogical approaches.

The study findings align closely with existing research literature on the effect of SMASE training in improving student learning outcomes. The corroboration with Omollo and Mboya's (2020) research in Kenya, which revealed that students taught by SMASE-trained teachers demonstrated significantly improved scores on standardized assessments, provides additional validation of the current study's findings. Similarly, the alignment with Kainyu et al.'s (2021) findings regarding higher levels of student engagement and critical thinking among students taught by SMASE-trained teachers further reinforces the current study's conclusions. The corroboration with Ndung'u et al.'s (2022) research, which found that students taught by SMASE-trained teachers not only exhibited improved test scores but also showed greater enthusiasm for mathematics and science subjects, provides additional support for the current study's findings regarding both academic performance and student attitudes. The consistency with Muriuki and Karanja's (2021) findings regarding students' reports of experiencing deeper understanding and retention when taught through SMASE methodologies provides further validation of the current study's conclusions. This convergence of evidence from multiple sources and contexts strengthens the case for the effectiveness of SMASE training in improving student mastery of biology content.

V. Conclusions And Recommendations

Conclusion

The study conclusively demonstrates that SMASE training has a profound and statistically significant positive effect on students' mastery of biology content in secondary schools in Tseikuru Sub-County, Kitui County, Kenya. Students taught by SMASE-trained teachers consistently demonstrated superior performance across all indicators of content mastery, including frequency of experimental work, involvement in experiment planning, and participation in class discussions. The statistical significance of these differences, with all p-values below 0.01, provides robust evidence that these improvements are attributable to SMASE training rather than random variation. The enhanced content mastery observed among students taught by SMASE-trained teachers reflects the effectiveness of the program's emphasis on hands-on learning, student-centered approaches, and active engagement strategies.

Recommendations

Based on the findings and conclusions of this study, the following evidence-based recommendations are proposed for various stakeholders in the education sector:

Recommendations for Education Policymakers

The Ministry of Education should prioritize the expansion and institutionalization of SMASE training programs across all secondary schools in Kenya. Given the consistent positive effects demonstrated across all measured dimensions of biology education, SMASE training should be integrated into national teacher development policies as a mandatory component of professional development for all science teachers. The Ministry should allocate adequate financial resources to support comprehensive SMASE training programs and establish mechanisms for monitoring and evaluating the implementation and impact of these programs at the national level.

Recommendations for Teacher Training Institutions

Teacher training institutions should also establish partnerships with schools that have successfully implemented SMASE methodologies to provide practical training sites where student teachers can observe and practice SMASE approaches under the guidance of experienced mentors. This practical component would ensure that new teachers graduate with both theoretical understanding and practical experience in implementing student-centered, hands-on science instruction.

Recommendations for School Administrators

School principals should prioritize ensuring that all biology teachers in their schools participate in SMASE training programs. The study's findings demonstrate that SMASE-trained teachers consistently outperform their non-trained counterparts across all measured dimensions of teaching effectiveness. Principals should advocate for their teachers' participation in SMASE training programs and provide institutional support for implementing SMASE methodologies in their schools. School administrators should also work to create supportive environments that facilitate the implementation of SMASE approaches by providing adequate time for lesson planning and material preparation, establishing systems for sharing locally available resources among teachers, and recognizing and celebrating innovative teaching practices that align with SMASE principles. Furthermore, principals should establish mentoring programs that pair SMASE-trained teachers with non-trained colleagues to facilitate knowledge transfer and skill development within their schools. This peer-to-peer learning approach can help accelerate the adoption of effective teaching practices and create a culture of continuous professional development.

Recommendations for Curriculum and Assessment Reform

Curriculum reform should prioritize depth of understanding over breadth of coverage, allowing teachers adequate time to implement engaging, experiential learning activities. Assessment systems should also be reformed to better align with SMASE teaching approaches by incorporating practical assessments, project-based evaluations, and other forms of authentic assessment that measure students' ability to apply scientific knowledge and skills in real-world contexts. Traditional paper-and-pencil tests may not adequately capture the full range of learning outcomes that result from SMASE instruction.

Recommendations for Quality Assurance and Monitoring

Education quality assurance agencies should develop specific indicators and monitoring systems to track the implementation and impact of SMASE training programs across different regions and school contexts. Regular monitoring and evaluation activities should assess both the fidelity of SMASE implementation and its effects on student learning outcomes, teacher practices, and school-level indicators of educational quality. Research institutions should be encouraged to conduct longitudinal studies that track the long-term effects of SMASE training on student achievement, career choices, and other important outcomes. Such research would provide valuable evidence for policy decisions and program improvements while contributing to the global knowledge base on effective science education practices. Furthermore, mechanisms should be established for sharing best practices and lessons learned from SMASE implementation across different schools and regions. Regular conferences, workshops, and publications should facilitate knowledge exchange among educators, administrators, and policymakers involved in SMASE programs.

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