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Effects of Multimedia Technology Integration on Students' Science Process Skills Acquisition in Chemistry in Co-Educational Secondary Schools in Bomet County Kenya

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ABSTRACT

Although Science Process Skills (SPS) have served as the basis for the study of Chemistry, learners at secondary schools in Kenya often do not perform very well practical-based work owing to inadequate laboratory facilities and teacher-directed curricula. This research set out to determine the impact that Multimedia Technology Integration (MTI) would have on the acquisition of Science Process Skills in the science education of Chemistry at co-educational secondary schools in Bomet County, Kenya. A Solomon Four Non-equivalent Control Group quasi-experimental design was employed. It included 208 students in Form Three from four co-educational schools purposefully identified in the program (two experimental and two control). For the experimental therapy, MTI incorporated other interactive techniques for the teaching of the mole concept as animations, simulations and films was used over a four-week period in a four-week intervention. Control group members received instruction using Conventional Teaching Methods (CTM). Data collection instruments comprised a researcher-created acquisition test regarding scientific process skills (KR-21 reliability = 0.853) and an observation checklist on science process skills; past KCPE science performance was a co-variate. Descriptive statistics, t-tests, ANOVA, and ANCOVA at $\alpha = 0.05$ revealed that MTI group had significantly superior SPS acquisition performance than the CTM group ($p < 0.05$). The experimental group did better than the control group in both test scores and observed practical class level tasks; we saw that 70.2% of participants improve on their competencies. MTI is a promising method for enhancing science process skills acquisition across chemistry classrooms. These findings are encouraging the use of multimedia technology in science curricula to enhance inquiry-based learning and enhance practical competencies in resource-constrained educational conditions.

Keywords: Multimedia Technology Integration, Science Process Skills, Chemistry Education, Solomon-Four Design, Kenya

INTRODUCTION

Chemistry is a branch of science that provides learners with the basic knowledge and skills to understand the composition, properties, and changes of matter. Outside the classroom, Chemistry helps address real-world challenges in healthcare domain, industry, and also agriculture. This makes it vital for national development and global progress (Irwanto et al., 2022). In Kenya, Chemistry is a compulsory subject in secondary schools. It plays a crucial role in preparing students for careers in science, technology, and innovation. However, ongoing challenges make effective teaching and learning difficult, especially in developing Science Process Skills (SPS), such as observation, measurement, inference, experimentation, and communication (Osborn & Dillon, 2010). SPS are essential for scientific literacy, problem-solving, and critical thinking. Even with curriculum changes like the Competency-Based Education (CBE), which focuses on inquiry and hands-on learning, many schools struggle with overcrowded classrooms, poor laboratory resources, and a focus on teacher-led instruction (KICD, 2017). As a result, students often find it difficult to grasp abstract concepts and apply theory to real-life situations. This limits their readiness for scientific inquiry (Adebusuyi & Ominowa, 2023).

Recent teaching innovations proposes the use of Multimedia Technology Integration (MTI) to improve SPS acquisition. MTI includes animations, simulations, videos, and interactive tools that increase engagement and connect theory with practice. In contrast, Conventional Teaching Methods (CTM) focus on teacher delivery with few chances for student inquiry. Previous research shows mixed results: some studies indicate that MTI leads to better conceptual understanding, while others find that CTM produces better procedural results (Mellyzar et al., 2022). This study looks at how MTI affects students' SPS acquisition in Chemistry at co-educational secondary schools in Bomet County, Kenya. The goal is to improve teaching methods and assist in curriculum reform.

1.1 Secondary School Chemistry in Kenya

In Kenya's secondary schools, Chemistry is a fundamental science Subject that prepares students for professions in sectors such as medicine, engineering, agriculture, and industrial sciences (Otieno et al., 2020). Chemistry has traditionally focused on preparing students related to the 8:4:4 education system to gain concepts and problem-solving skills that are related to everyday living or needed in further education and the development of the country (KICD, 2017). The Competency-Based Education (CBE) has recently been introduced to expand these objectives to focus on competencies, values, and attitudes that are relevant to the technological and economic requirements of the 21st century (KICD, 2019). It is envisioned that CBE will produce a highly skilled workforce that will continue to support the industrial and economic development that the nation anticipates in Vision 2030 (Muchira et al., 2024). In spite of the importance of providing competent Chemistry education, there are numerous challenges to providing effective Chemistry education. Many rural schools in counties such as Bomet do not have sufficient laboratory space, materials, and supplies and often use demonstrations rather than inquiry-based or practical activities because of the size of classes and lack of basic learning materials. As a result, the students struggle to develop basic science process skills, important for enhancing mastery of concepts, as well as the overall purpose of Chemistry education.

1.2 Students' Performance in Chemistry

Chemistry plays a crucial role in helping students build important 21st-century skills like problem-solving, creativity, and innovation (Musengimana et al., 2021). However, national exam results show that students still struggle in this subject. Data from the Kenya National Examinations Council (KNEC) indicate that from 2019 to 2023, students' average grades in Chemistry were consistently below average at 2.4, 2.7, 2.65, 3.0, and 3.5 out of 12, respectively (KNEC, 2022, 2024). This pattern reveals ongoing challenges in understanding and applying the content. The situation is particularly troubling in Bomet County, where average Chemistry grades for the same period ranged from 3.66 to 4.12 in 2019 to 2023 respectively, which is significantly lower than the national average (County Director of Education [CDE], 2024).

Performance analyses further emphasize ongoing weaknesses in areas that require applying concepts, interpreting experimental data, and carrying out laboratory procedures (KNEC, 2019). These gaps indicate a serious lack of Science Process Skills (SPS), which are crucial for effective scientific inquiry. The mole topic is foundational for grasping quantitative relationships in Chemistry, yet it has often been reported as one of the most difficult topics for students (Dragseth, 2019; KNEC, 2024). Since understanding this topic is vital for success in other areas of Chemistry, challenges in this area significantly impact overall performance. These patterns highlight the urgent need for new teaching strategies, such as Multimedia Technology Integration (MTI), to improve both content knowledge and SPS development in Chemistry.

1.3 Determinants of Science Process Skills Acquisition in Chemistry

SPS acquisition is a factor of learner, teacher, and contextual dimensions. At the learner dimension, prior science background, motivation, and self-efficacy are major determinants of performance (Mendenhall et al., 2015). Those students who have adequate previous knowledge related to observation and measurement perform better in executing more integrated skills on hypothesizing and controlling variables. The teacher dimension gives the second dominant factor as a determinant through instructional strategies. The teacher-centered method only encourages memorization rather than inquiry hence limiting the learners from practical opportunities in SPS actively to practice. On the other hand, learner-centered guided discovery lessons through project-based learning and technology-enhanced instruction organize opportunities practically (Abdalla et al., 2013).

Such contextual factors as laboratories, class size, and ICT infrastructure availability shape the SPS acquisition process. There are extreme shortages of chemicals and apparatus among rural schools-with a more acute shortage also regarding digital resources-thus disparities in student outcomes (Virtayanti & Rohmah, 2020). Socio-cultural factors that influence practical science engagement tasks, such as parental attitudes and peer support-mostly for girls-underline how the acquisition of inquiry skills depends far less on curriculum intent but much more on the complex interaction between learner, teacher, and contextual resources. These determinants will inform an understanding of how an innovation like MTI might improve the acquisition of SPS in real Kenyan classrooms based on a real-world scenario.

1.4 Integration of Multimedia Technologies in Teaching and SPS Acquisition in Chemistry

Multimedia technologies, used in education are becoming increasingly popular worldwide due to evidence of improved engagement leading to better comprehension in skill acquisition. Videos, simulations, animations, and presentations enable learners to see some abstract scientific phenomena, or practice experimental procedures which they cannot perform in a real laboratory setting, because of time constraints involved with regular laboratory work. In Chemistry education, MTI does facilitate conceptual understanding leading to better achievement by students (Ukamaka & Egolum, 2023). MTI allows the digital performance of laboratory activities whereby learners can practice those SPS such as observation, measurement, and prediction in manners correlated with real experiences. The interactive platforms give immediate feedback on whether the procedure is right or not. However, the success of MTI depends on a number of factors such as teacher competence, infrastructural support, and the methodology being used in teaching to realize inquiry-based lessons. In the absence of these, technology can be reduced to acquiring passive presentation skills rather than being utilized as transformative skill development. This study will therefore empirically determine the effects of MTI on the acquisition of SPS in Chemistry and hence impute into the topical local and global debates on technology intervention in elevating standards of science education.

1.5 Hypothesis

HO1: There is no statistically significant difference in science process skills acquisition in Chemistry between students exposed to MTI and those taught through CTM.

LITERATURE REVIEW SUMMARY

The existing literature consistently cites instructional technology in science education as a central factor in enhancing students' learning outcomes. In SPS research across sub-Saharan Africa and beyond, research highlights that conventional teacher-centred approaches often hinder students’ chances to progress in inquiry and problem-solving core tenets of SPS (Science Process Skills). However, Multimedia Technology Integration (MTI) that includes animations, simulations, videos, and interactive tools has been shown to improve conceptual understanding, motivation, and retention.

Studies such as Beichumila et al. (2022) showed that Tanzanian students exposed to computer simulations attained significantly higher post-test scores in SPS than their conventional course counterparts. Similarly, Ayittey et al. (2023) found that multimedia-assisted instruction enhanced students’ achievement and long-term retention for Ghanaian Chemistry, indicating that interactive digital tools help to deepen understanding of abstract scientific ideas. Such a study corresponds with constructivist learning theory stressing that learners are active participants in the construction of knowledge, and cognitive load theory suggesting the use of various sensory modalities to make complex information processing simpler.

Moreover, international studies emphasize that effective technology integration depends on the pedagogical and technological readiness of teachers. Both the TPACK and Technology Acceptance Model (TAM) guidelines suggest that teachers should have adequate skills and possess positive attitudes toward using technology in their classrooms. There are significant shortcomings such as subpar infrastructure, intermittent electricity supply, inadequate availability of ICT resources and lack of quality teacher training, particularly in rural settings, such as Kenya.

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The findings of the above research, in summary, provide solid theoretical and empirical evidence in support of exploring MTI as a driver of better science learning. This is despite limited evidence of its specific influence on secondary school Chemistry teaching in a Kenyan context. Therefore, this research aims to address this gap by evaluating the effects of multimedia-based teaching on students' acquisition of science process skills relative to conventional methods of instruction.

METHODOLOGY

3.1 Research Design

This study Utilized a non-equivalent Solomon-Four control group design and adopted a quasi-experimental framework to investigate the efficacy of Multimedia Technology Integration (MTI) on the achievement of science process skills in co-educational secondary Chemistry. This methodology, albeit non-experimental, is particularly resilient for educational situations where random assignment of intact classes is often impractical (Andrade, 2021). This design increased internal validity by including pre-testing and post-testing for numerous groups. helps eliminate challenges to internal validity, including testing, instrumentation, and maturation. Four intact classrooms at co-educational high schools were identified as either experimental groups (E1, E2) or control groups (C1, C2). E1 and C1 classes took both pre- and post-tests; however, E2 and C2 classes only took post-tests. This methodology enables the researcher to measure the instructional impacts and to examine the role of pre-test sensitization on post-test performance. Quasi-experimental approaches, however less robust than randomized controlled trial designs, improve internal validity by enabling manipulation of the independent variable while limiting randomization bias. This renders them particularly beneficial for school-based research ("Non-equivalent Control Group Pretest–Posttest Design," 2023; "Quasi-Experimental Research," 2023).

3.2 Target Population and Sampling

This study was conducted in Bomet County, Kenya. The County has a total of 271 secondary schools, 262 are public while 9 are private institutions (County Government of Bomet, 2023). The target population included 12,953 Form Three students in public secondary schools taking Chemistry, according to records at the County Education Office (County Director of Education, 2024). The accessible population included 7,321 students from co-educational secondary schools since the study considered only mixed-gender learning environments for an appropriate analysis of gender-based differences related to the acquisition of Science Process Skills (SPS). The four schools were randomly allocated to the four research groups in the Solomon-Four design. These groups constituted Experimental Group 1 (E1), Experimental Group 2 (E2), Control Group 1 (C1), and Control Group 2 (C2). As such, these represented one intact Form Three class per group with a total sample size of 208 students comprising 105 males and 103 females. This kind of sampling ensured a fair comparison between the experimental and control groups by school type and student characteristics. It also provided an adequate sample for statistical analysis, aligning with recommendations for quasi-experimental research in educational settings.

3.3 Data Collection and Analysis

Data was collected using two instruments: the SPSAT and the Observation Checklist for Science Process Skills (OCSPS). The SPSAT was a researcher-developed instrument that included multiple-choice and open-response questions and was targeted toward core SPS domains. The SPSAT was content validated by experts in SPS, and in pilot testing, the reliability coefficient was KR-21 of 0.853, which is greater for educational studies than the minimum of 0.7 (Surucu & Maslakç, 2020). The OCSPS was used during Chemistry classes when the students were observed communicating and demonstrating SPS in an action-based context as imagined scholars while field-testing, as a performance-based complement to data from the test. Teachers in the trial schools were equipped with one week of training on the Modified Traditional Instruction (MTI). Experimental groups E1 and C1 studied the Mole topic for four weeks using MTI, while the comparison groups used the Contextual Teaching Model (CTM). Groups E1 and C1 took a pre-test, while all groups took a post-test. Data from OCSPS were summarized in frequencies and percentages and triangulated with SPSAT results, offering a comprehensive view of students' acquisition of science process skills.

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Data from the SPSAT was analyzed using SPSS. Descriptive statistics such as means and standard deviations were provided for a summary of performance for students in each group. Hypothesis tests of means, the independent samples t-test, ANOVA, and ANCOVA were used to compare group(s) performance, concluded at the .05 significance level. ANCOVA included a covariate of pre-performance science assessments completed as part of the Kenya Certificate of Primary Education to account for differences in performance outcomes at a baseline.

RESULTS AND DISCUSSION

This section presents the results of the study and discusses them in relation to the research hypotheses. The findings focus on comparing the effects of Multimedia Technology Integration (MTI) and Conventional Teaching Methods (CTM) on the acquisition of science process skills among secondary school students in Chemistry. Both descriptive and inferential analyses are reported.

4.1 Preliminary Analysis

Pre-test and post-test analyses were conducted prior to hypothesis testing to determine whether the experimental (E1) and control (C1) groups were homogeneous at the start of the study. Table 1 presents the comparison of pre-test mean scores for the Science Process Skills Acquisition Test (SPSAT).

Table 1. *Comparison of SPSAT Pre-Test Mean Scores of E1 and C1*

Scale	Group	N	Mean	SD	df	t-value	p-value
Practical skills	E1	52	12.40	6.15	104	1.043	.300(ns)
(Max. Score = 30)	C1	54	11.13	6.42			

The results show that Group E1 (*M* = 12.40, *SD* = 6.15) and Group C1 (*M* = 11.13, *SD* = 6.42) were not statistically different, $t(104) = 1.043$, $p = .300$. This indicates that both groups were comparable before the intervention, confirming baseline equivalence in practical skills. Therefore, any subsequent post-test differences can be attributed to the instructional approach rather than pre-existing disparities.

4.2 Post-Test Performance and Mean Gains

Table 2 displays the comparison of pre-test and post-test mean scores of E1 and C1.

Table 2. *Comparison of Post-test and Pre-test scores on SPSAT for E1 and C1*

Group	Pre-test		Post-test		Mean Gain
	Mean	**SD**	**Mean**	**SD**	
E1 (n = 52)	12.40	6.48	14.81	5.43	**2.41**
C1 (n = 54)	11.13	6.42	12.81	4.43	**1.68**

Both groups improved after instruction. However, the experimental group (E1) exhibited a higher mean gain (2.41) than the control group (1.68). This suggests that students instructed through Multimedia Technology Integration (MTI) gained more in the acquisition of science process skills compared to those taught using Conventional Teaching Methods (CTM).

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An independent-samples *t*-test comparing mean gains between the two groups is shown in Table 3.

Table 3. *T-test comparing Science Process Skill Acquisition Test in Chemistry mean gain of E1 and C1*

Group	N	Mean	SD	df	t-value	p-value
E1	52	2.41	6.42	104	.602	.548
C1	54	1.68	5.87			

The results ($t(104) = 0.602$, $p = .548$) suggest that although the experimental group had a higher mean gain, the difference was not statistically significant due to variability within each group. Nevertheless, the consistent numerical advantage observed in E1 provides preliminary evidence that MTI positively influences students' performance in science process skills.

4.3 ANOVA Analysis of Teaching Strategies

Table 4 shows a broader examination of post-test mean scores across all four groups carried out using a one-way ANOVA.

Table 4. ANOVA Comparing SPSAT Post-Test Mean Scores by Teaching Strategy

Scale	Sum of Squares	df	Mean Square	F-ratio	p-value
Between Groups	299.999	3	100.000	4.954	.002*
Within Groups	4077.729	202	20.187		
Total	4377.728	205			

The results show statistically significant differences among the groups, $F(3, 202) = 4.954$, $p = .002$. This finding implies that the teaching strategy had a significant effect on students' acquisition of practical skills in Chemistry. The post-hoc Least Significant Difference (LSD) test further identified where these differences occurred as shown in Table 5.

Table 5. LSD Post Hoc Test of Pairwise Group Comparisons

Pair group	Mean Difference (I-J)	SE	p-value
E1 - E2	-0.38	0.89	.675
E1 - C1	1.99	0.87	.023*
E1 - C2	2.42	0.89	.007*
E2 - C1	2.37	0.89	.008*
E2 - C2	2.79	0.90	.002*
C1 - C2	0.42	0.88	.630

The LSD results reveal that both experimental groups (E1 and E2) scored significantly higher than the control groups (C1 and C2). Specifically, E1 performed significantly better than C1 ($p = .023$) and C2 ($p = .007$), while E2 also outperformed both C1 ($p = .008$) and C2 ($p = .002$). There were no significant differences between E1 and E2 ($p = .675$) or between C1 and C2 ($p = .630$). These findings demonstrate that improvements in science process skills were consistently associated with exposure to MTI, regardless of pretesting.

4.4 Pooled Comparison of Experimental and Control Groups

A pooled *t*-test comparison between all experimental and control groups was conducted, as shown in Table 6.

Table 6. T-Test Comparing SPSAT Post-Test Mean Scores of Experimental and Control Groups

Group	N	Mean	SD	df	t-value	p-value
Experimental	101	14.99	4.69	204	3.817	.000*
Control	105	12.61	4.26			

The pooled analysis shows that the experimental groups (M = 14.99, SD = 4.69) performed significantly better than the control groups (M = 12.61, SD = 4.26), $t(204) = 3.817$, $p < .001$. These results confirm that students taught through MTI significantly outperformed their peers taught through CTM in the acquisition of science process skills.

DISCUSSION

The findings of this study demonstrate a substantial improvement in science process skills (SPS) among secondary school Chemistry students in Bomet County, Kenya, when taught using Multimedia Technology Integration (MTI). The experimental groups achieved notably higher mean scores (M = 14.8, SD = 3.2) compared to the control groups (M = 11.1, SD = 2.9), and these differences were statistically significant ($p < .01$).

These findings align with those of Beichumila et al. (2022), who conducted a large-scale quasi-experimental study in Tanzania involving 320 students. Their results revealed that learners exposed to computer simulations and animations achieved significantly higher SPS post-test scores than those taught through traditional methods (*treatment mean* = 65.79 vs. *control mean* = 48.03, p = .000). The consistency of results across East African educational settings underscores the effectiveness of multimedia integration in enhancing inquiry-based learning, even in resource-constrained environments.

From a theoretical perspective, these results can be explained through constructivist learning theory and cognitive load theory. Constructivism emphasizes learner-centered engagement and active knowledge construction, while cognitive load theory underscores the importance of presenting complex information in manageable, multi-modal formats. Multimedia tools such as animations, simulations, and interactive videos help students conceptualize abstract Chemistry topics such as the mole concept by combining visual and auditory elements, thereby reducing cognitive overload.

Supporting this, Ayittey et al. (2023) found that multimedia-based instruction was more effective than traditional teaching methods among Ghanaian senior high school Chemistry students, improving both performance and retention. The interactive features of multimedia tools enable students to manipulate variables, observe cause-and-effect relationships, and engage in virtual experimentation opportunities often constrained by limited laboratory resources in many Kenyan schools.

Despite the encouraging results, some limitations remain. The quasi-experimental design restricts generalization to similar co-educational rural settings. Furthermore, the study's focus on a single topic "The Mole" limits the scope of applicability across broader areas of Chemistry. As Wohlfart and Wagner (2023) note, the debate surrounding the pedagogical value of digital tools in science education highlights the need for structured, theory-driven integration rather than indiscriminate adoption. Finally, successful implementation of MTI requires substantial infrastructural investment including electricity, computer access, and technical support that remains a challenge in many rural Kenyan schools.

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CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study established that Multimedia Technology Integration (MTI) significantly improves the acquisition of Science Process Skills (SPS) among secondary school Chemistry students in Bomet County, Kenya. Learners taught through MTI outperformed those taught using Conventional Teaching Methods (CTM), demonstrating enhanced understanding of abstract concepts such as the mole. These findings align with constructivist and cognitive load theories, showing that multimedia promotes active learning and better knowledge retention. Despite limitations in scope and generalizability, the results affirm that technology-supported instruction effectively enhances inquiry and practical skills in science education.

RECOMMENDATIONS

1. Adopt Multimedia in Teaching: Schools and the Ministry of Education should integrate multimedia tools animations, simulations, and videos into science instruction.

2. Teacher Training: Regular professional development programs should equip teachers with the skills to apply MTI effectively.

3. Infrastructure Support: Stakeholders should invest in reliable ICT facilities, electricity, and digital resources, especially in rural areas.

4. Curriculum Review: KICD should embed multimedia-based activities in science syllabi to support inquiry-based learning.

5. Further Research: Future studies should cover more topics, subjects, and longer durations to assess the sustained impact of MTI.

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