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5E Instructional Model and Learners' Scientific Skills Acquisition:

A Review of Secondary School Students in Vihiga County, Kenya

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Abstract

Focussing on knowledge acquisition rather than the development of competencies required by the production industry corroborates the Kenyan government adoption of the Competency Based Education (CBE). The researcher investigates the effects of 5E instructional model on acquisition of scientific skills among secondary school students in Vihiga County, Kenya. The research adopted quasi-experimental design due to the use of intact classes in sample schools. Scientific skills acquisition tests I and II were used to collect data. Instruments Validation was established by selected experts in the field of Biology. Reliability of the test items was determined by Cronbach's reliability using split half method. Data analysis was done by using T-test at 0.05 level of significance. A significant difference in scientific skills acquisition between learners in the treatment group and the control group was observed. 5E instructional model improved scientific skills acquisition among students. Adoption of 5E instructional model would therefore be instrumental in the implementation and realization of the CBE mission of 'Nurturing every learner's potential'. The researcher recommends teacher training and support on implementation of the 5E instructional model so as to realize competent personnel needed in the production industry for the country's self-reliance.

Key words: competency-based education, Scientific Skills, 5E Instructional Model, Secondary Education Curriculum.

Introduction

Biology as a critical science gives in-depth understanding of diverse life forms and their interaction in nature. It enables learners to apply scientific concepts, principles, skills and attitudes to solve day to day life problems. It is therefore imperative for learners to acquire pre-requisite scientific skills, knowledge and values necessary in the professional fields like Medicine, Engineering, Nutrition and Agriculture for a healthy nation. In medicine, knowledge of biology is utilized in diseases prevention and control. The subject has also been found to plays a vital role in the field of biochemistry, genetics, physiology anatomy, anatomy, and ecology (Olutola et al, 2016) thereby forming a central focus in some human activities including being a solution to problem of food scarcity, hygiene, health, poverty eradication, as well as infrastructural materials. Taiwo and Emeke (2014) observes that biology exposes the students to the world of knowledge of self, the immediate and distant environment. Similarly, Aina (2013) believes that biology education is important to any growing economy. Quality academic achievement in biology at Kenya Certificate of Secondary Examination (KCSE) is therefore critical for development.

Scientific skills commonly referred to as science process skills (SPS) are a collection of cognitive abilities needed in problem-solving scientific research. They are life skills that assist people understand the nature of science and advance scientific literacy, quality, and standard of living (Mbonu-Adigwe et al., 2021). Similar to this, Ibe and Nwosu (2017) describes science process skills as potentials, capacities, and technical know-how that may be acquired via experience and are applied to scientific mental and physical processes. Mastery of science process skills therefore equips students for future acquisition of content knowledge and allows them to conceptualise the content they already know at a much deeper level. Scientific skills are key in improving creativity, understanding of the natural world and application of knowledge to solve real life challenges. It has long been acknowledged by many that science is the driving force behind

contemporary technological breakthroughs. Every country, developed and developing alike, has to strive for scientific advancements due to their application to every aspect of life.

Brickman et al. (2009) states that science literacy and skill development are both enhanced by inquiry-based learning. According to Maundu, Sambili, and Muthwii (2005), the inquiry method centers on fostering scientific process abilities and learning via discovery. In a laboratory inquiry, students work together to find the answer to a central question or problem posed by the teacher (Uno and Bybee, 2009, cited in Brickman et al., 2009). Students' proficiency with the scientific method is expected to increase through inquiry- based learning that incorporates a range of laboratory activities (Kim, 2007). This study on 5E instructional approach sought to find out how much it created opportunities for learners to develop scientific skills that naturally promote better understanding of scientific concepts and consequently improve learners' achievement in biology a science subject. Research indicates that the 5E model is more effective than other teaching strategies in facilitating students' achievement of significant learning outcomes in science. Various comparative studies have shown that the 5E strategy is superior to other methods in helping students achieve mastery in science disciplines (Akar, 2005; Coulson, 2002). Tailored Instruction in the 5E Instructional Model is grounded in scientifically-validated teaching methods, constructivist-learning theory, and cognitive psychology (Duran & Duran, 2004). Students improve their original ideas through self-evaluation, expansion, redefinition, and restructuring as part of a personalized learning process that makes use of the 5E Instructional Model (Bybee, 2009). Students are given the opportunity to take charge of their own learning through the 5E paradigm, which allows them to build their own interpretations based on what they understand conceptually.

In this research article, the researcher sought to determine whether the competence of students through development of scientific skills could be improved by teacher's use of the 5E instructional model. The skills addressed included observing, drawing, measuring and recording. The researcher also sought to unveil the effect of the 5E instructional model on students' acquisition of the scientific skills during learning of cell biology concepts. The 5E pedagogical paradigm was developed by the Biological Science Curriculum Study (BSC5) in 1987 with the objective of promoting active and collaborative learning. The five steps of learning model are as follows: engage, explore, explain elaborate and evaluate. The constructivist perspective, upon which the 5E Model is based, views learning not as a passive act of acquiring information but as an interactive and contextualized process of creating new knowledge (Richards, 2015). According to Senan (2013), the technology-enriched 5E learning model is an effective instrument for students to develop 21st century abilities. In line with the competency-based education the 5E phases would provide an effective implementation strategy. Whether 5E model could improve acquisition of scientific among students was the concern of the research that culminated into this article.

Location of the research article

The research that culminated into this article was conducted in Vihiga County, Western region of Kenya. The county lies between 34 30' and 35 0' East of the equator and between 0 and 0 15' north of the equator. The county boarders Nandi County to the east, Kisumu County to the south, Siaya County to the west and Kakamega County to the north. Vihiga county is sub divided into five sub counties; Emuhaya, Vihiga, Sabatia, Lwanda and Hamisi. Vihiga County is dominated by the Luhya community with a fair mix of other Kenyan communities such as the Luo, Kalenjin and the Gikuyu. The county has 754 ECD schools, 392 primary schools, 155 secondary schools, 30 vocational training centres and 1 public university. Vihiga County performance at KCSE has remained low as revealed in the table 1.

Table 1: KCSE performance for past 4 years in Vihiga country

Year	2020	2021	2022	2023
M/Score	4.8379	4.4559	4.6988	4.6360
M .Grade	C-	D	C-	C-

Source: County Director of Education- Vihiga 2024

The performance indicate that most learners do not favourably compete for the limited chances in public universities. This possesses a disadvantage to the county in terms of professional empowerment. Performance of students in individual science subjects is below the overall KCSE mean in the county as shown in Table 2.

Table 2: Science Subject Performance in KCSE for past 4 years in Vihiga country

	2020	2021	2022	2023
BIOLOGY	2.92582	3.0624	2.9836	3.5630
CHEMISTRY	2.36625	2.2557	2.5518	2.9180
PHYSICS	4.1931	3.4962	4.2073	3.9350

Source: County Director of Education- Vihiga 2024

From the table 3.2, the number of students from Vihiga who qualify to the prestigious science related professions like medicine and engineering is relatively low. Since resources are now being devolved to counties, locally produced professionals will be key to the advancement of each county. As a resident of Vihiga County, I felt indebted to use my research skills to seek answers to the dismal performance in key areas like biology. Being a science educator, i particularly thought of the critical area of teaching strategies with a view to make a personal contribution in an effort to improve learner performance in science education in the county,

Literature review has not revealed a study conducted in Vihiga County on effect of 5E in classroom instruction and its effect on learners' performance in cell biology. The researcher therefore sought to determine the effect of using the 5E instructional model in biology on learners' performance in the county. The low performance was the key motivator to researcher.

Statement of the problem

Despite the role biology plays in any nation, students consistently post low performance index of in the subject (WAEC, 2011; Taiwo & Emeke, 2014). A downward trend in students' achievement in biology over the years as follows: 35.74% (2010); 35.61(2011); 33.57(2012); 33.94 % (2013) and 33.87 (2014) (WAEC Reports, 2014). This trend is not different in KCSE performance by students of biology in Kenya during the period 2019 to 2022 as shown in the table 1:

Table 1 KCSE Performance in Biology from 2019 to 2022

YEAR	2019	2020	2021	2022
Mean Mark (%)	25.69	25.52	28.51	28.68
Mean Grade	D	D	D	D

Source: KNEC annual KCSE Reports, (2019-2022)

Aktamis and Ergin (2008) reported that exposing students to science process skills enhances students' achievement and scientific creativity. According to Dewey (2011) poor performance of students in science has often been regarded as symptomatic of poor learning approaches. Such approached are teacher centred pedagogies that do not develop scientific skills in the learner. Makgato and Mji (2006) argue that poor teaching methods have a direct influence on the performance of learners in the science subjects. This was emphasized by Akubuito (2004) who observes that teacher's methodology has significant effect on student's performance in biology, and that students with effective methodology are likely to come out with good performance while students not taught well will perform poorly.

Multiple pedagogical research indicate that active learning enhances students' academic performance in the classroom (Bulut & Dursun, 2019; Hendrickson, 2021; Jackson, 2002; Stephen et al., 2010; Van den Bergh et al., 2013). A number of studies have highlighted the need of fostering scientific inquiry in order to enhance students' comprehension of the subject matter (Gyllenpalm, Rundgren, Lederman, & Lederman, 2022). Amwe (2018) posits that the 5E learning circle model offers a structured sequence of instruction that prioritizes students in the centre of their learning experiences, fostering their ability to investigate, develop their own comprehension of scientific concepts, and connect these comprehensions to other concepts. The 5E learning model organizes learning experiences to enable students to develop their comprehension of a concept over time. Kallis (2024) also reveals that the 5E instructional model contributes to the development of critical thinking skills, adaptability, self-development and collaboration. This aligns with the principles integrated within the CBE curriculum. Could the 5E instructional model be the strategy to enhance acquisition of scientific skills necessary for realization of desired manpower as intended by the Competency Based Education (CBE), a holistic, skill and value-oriented education?

Research findings indicate that application of 5E Model in learning improves performance of the learner. Bybee (1997) argues that the use of this approach helps students redefine, organize, examine and change the idea they already have through peer interactions and environment. Senan (2013) reported that the technology-enriched 5E learning model is a good tool for students to acquire 21st century skills as well as for teachers to teach a specific concept. 5E therefore allows education to create a unique learning experience and helps students build a strong foundation of knowledge thus active participation. However, the 5E instructional approach has not been fully utilized in most secondary schools in Kenya in teaching of science subjects.

Significance of this research article

The findings of this research article will diversify teacher's pedagogy towards improved content delivery in biology and other science subjects. Secondly, through active engagement learners would achieve deeper understanding of cell biology

concepts and develop skills necessary for the world of work. The Nation would realize competent professionals for production industries to help realize its vision 2030. In addition, the findings would contribute to the growth of knowledge on active inquiry through 5E instructional model.

Definition of key terms:

Cell biology: study of the structure and functions of cells as the basic concept of biology in secondary school curriculum in Kenya.

Instructional model: teaching strategies, methods and activities used by a teacher during lesson delivery.

5E Instructional Model approach: Active Learning Instructional Approach that is characterized by student centred instruction where learners actively participate in knowledge construction through interactive learning guided by the 5Es; Engagement, Exploration, Explanation, Elaboration and evaluation as designed by Rodger W. Bybee in 1980s.

Scientific skills: a collection of cognitive abilities to apply knowledge in real life that assist people understand the nature of science and advance scientific literacy. They include; observing, drawing, measuring and recording.

Methodology

The use intact classes in schools allowed the researcher to use quasi- experimental design. In the quasi design, selected schools were divided into two groups, one group was assigned as experimental and the other group assigned as a control group. Scientific skills achievement test I was administered to both groups before intervention to determine whether there was a distinction in their scientific skills abilities and also to establish homogeneity of the learner in both groups. Subsequently, the two groups were then given instruction on the concepts of cell biology under reproduction. The control group was instructed using the conventional method, whereas the experimental group was instructed using the 5E instruction model. Scientific skills achievement test II was then administered to the two groups and their scores were recorded. The scores were used to determine whether there was a difference in acquisition of scientific skills acquisition of learners when the 5E instructional model was implemented in comparison to the conventional approach. Any difference would be attributed to the treatment. The research design process was schematized as shown in figure 1.

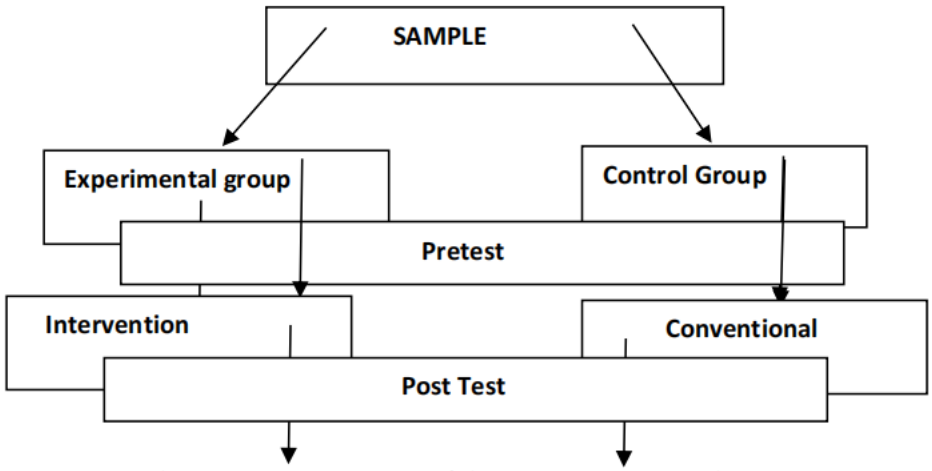

Figure 1: schematic representation of the quasi-experimental design

The target population comprised of form three students of biology in secondary schools in Vihiga County. Form threes were selected because at that level they had chosen biology as one of their examinable subjects at secondary school. Purposive sampling was used to select schools that had presented candidates in biology previously and had realized a mean of between 2.00 and 2.99. This enabled the researcher to work with a homogenous group. Stratified random sampling was used to select representative schools from each sub county to allow for even coverage in the county. Finally simple random sampling was used to select the sample schools and assign the schools into treatment and control groups. A sample size of 505 students was selected.

The results were analysed both descriptively and inferentially. Descriptive analysis generated percentages, mean, mode and standard deviation of pre-test and post-test scores. Inferential analysis involved the use of independent sample t-test at 0.05 significant levels to establish if there was a significant difference in acquisition of scientific skills between the treatment group and control group. The inferential test was used based on the assumptions that there is; normal distribution of data, homogeneity of variance, the data was continuous and the samples were independent.

Results and Discussion

The objective of this study was to determine the effect of using the 5E instructional model on students' acquisition of scientific skills in biology. Data collected with respect to this objective involved use of scientific skills acquisition test I (SSAT I) as pre-test and scientific skills acquisition test II (SSAT II)) as post-test. The null hypothesis that was formulated to address this objective was:

HO: There is no significant difference in student's acquisition of scientific skills in biology when taught using the 5E instructional approach and when taught using the conventional approach.

Independent sample t test was carried out to determine whether the differences in students' achievement in terms of scientific skills in biology was significant for the treatment and control groups.

(i) Achievement in Scientific Skills before Intervention

Findings of a t test done before intervention were as presented in table 2 below:

Table 2: T-test results on pretest scores

Parameter of Learning	Group	N	Mean	SD	T	P
Observing	Exp	251	15.07	3.12	0.39	0.593
	Cont	254	14.55	3.16		
Drawing	Exp	251	13.73	2.74	0.42	0.891
	Cont	254	13.79	3.09		
Measuring	Exp	251	9.11	2.45	0.28	0.663
	Cont	254	9.02	2.33		
Recording	Exp	251	10.47	2.77	0.36	0.610
	Cont	254	10.64	2.24		

Critical t at 0.05=1.96, df = 50

The research study findings in Table 2 revealed that the differences in means of experimental group and control group on all the parameters of learning (Observing, Drawing, Measuring and Recording) were not significant. For instance; on Observing, the experimental mean (15.07) and the control mean (14.55) were not significantly different with a p value of 0.593. Drawing had experimental mean (13.73) which was not significantly different from the control mean (13.79) with a p value of 0.891. Regarding Measuring, the experimental mean (9.11) was not significantly different from the control mean (9.02) with a p value of 0.663. In terms of Recording, the experimental mean (10.47) is not significantly different from the control mean (10.64) with a p value of 0.610.

(ii) Achievement in Scientific Skills after Intervention

The experimental and the control group were compared on scientific skills of observing, drawing, measuring and recording after the intervention and findings presented in table 4.10.

Table 3: T-test results on post-Test scores

Parameter of Learning	Group	N	Mean	SD	T	P
Observing	Exp	251	19.14	5.47	9.91	0.000
	Cont	254	12.37	4.39		
Drawing	Exp	251	17.06	3.50	14.04	0.002
	Cont	254	14.38	3.27		
Measuring	Exp	251	15.77	2.92	12.86	0.000
	Cont	254	12.46	3.13		
Recording	Exp	251	18.51	3.52	16.35	0.000
	Cont	254	12.42	3.19		

Critical t at 0.05=1.96, df = 50

From table 3; it is evident that the performance of the experimental group was significantly different from the performance of the control group. For instance, Observing had the mean of the experimental group (19.14) which was higher than the mean of the control group (12.37) with a p value of 0.000 implying significant difference. Based on finding on Drawing, the mean of the experimental group (17.06) was higher than the mean of the control group (14.38) with a p value of 0.002 implying significant difference. As regards Measuring, the mean of the experimental group (15.77) was higher than the mean of the control group (12.46) with a p value of 0.000 implying significant difference. As regards to

recording, the mean of the experimental group (18.51) was higher than the mean of the control group (12.42) with a p value of 0.000 implying significant difference.

Findings of this study are in line with findings of previous studies on the role of teaching method on student's achievement. The study by Senan (2013) reports that the technology-enriched 5E learning model is a good tool for students to acquire 21st century skills as well as for teachers to teach a specific concept. In his study on the 5E learning model Prokes (2009) observes that the students in this model were more active and motivated than students in lecture based classroom and that these students could find opportunities to share their knowledge and experiences students' prior knowledge is identified. 5E is an important model in elimination of misconceptions since it allows students to determine the misconceptions, to eliminate them through first –hand experience and to evaluate themselves (Aksoy & Gurbuz, 2013; Acish & Turgut, 2011).

Summary of findings

Based on findings on the post-test, it is evident that the performance of the experimental group was significantly different from the performance of the control group. For instance, looking at Observing, the mean of the experimental group (19.14) was higher than the mean of the control group (12.37) with a p value of 0.000 implying significant difference. Based on finding on Drawing, the mean of the experimental group (17.06) was higher than the mean of the control group (14.38) with a p value of 0.002 implying significant difference. As regards Measuring, the mean of the experimental group (15.77) was higher than the mean of the control group (12.46) with a p value of 0.000 implying significant difference. As regards recording, the mean of the experimental group (18.51) was higher than the mean of the control group (12.42) with a p value of 0.000 implying significant difference.

Conclusion

The objective of this study was to determine the effect of the 5E instructional model on students' acquisition of scientific skills. The study was carried out among form three students of biology in Vihiga County. Quasi experimental design was used where the sample selected was divided randomly into treatment and control groups. A total of 505 learners were selected using multi-stage random sampling techniques. Data analysis revealed that the 5E instructional model improved student's level of acquisition of the scientific skills of observing, drawing, measuring and recording. Students taught using the 5E instructional model demonstrated high achievement levels of these skills compared to students taught using the conventional approach.

Recommendations

The researcher recommends use of 5E instructional model in secondary schools for the implementation of the competency-based education system whose focus is on development of competencies rather than acquisition of knowledge. The model enables learners to actively construct new knowledge on the foundation of pre-existing knowledge and facilitates individualized learning in the classroom. The 5E instructional model is also recommended for teacher educator institutions to diversify the pedagogies given to student teachers to enhance their competencies as teachers. This would enable them confidently implement the Competency-Based Education to realize its mission of 'nurturing every learner's potential'. The researcher also recommends government policy formulation and support to ensure effective implementation of the 5E instructional model.

Suggestion for further research:

The researcher proposes the following areas for further research:

- Effect of 5E instructional model on students' scientific skills acquisition in other areas of biology.
- Effect of scientific skills acquisition on students' academic score in biology and other science subjects.
- Correlation between scientific skills acquisition and attitude of learners towards science-based careers.

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Ethical pledge:
The researcher confirms that all the data collected was responsibly handled and accurately documented without manipulation of any kind or bias.

Competing interest:
The researcher affirms that this research was conducted without impartially competing interests of any kind financially, professionally and personally that may have influenced the outcome of biased results or interpretation.

Disclaimer:
The views expressed in this research article are those of the author and do not necessarily reflect the official policy or position of the affiliated agencies of the author or the journal itself.

Ethical Consideration:
The researcher keenly considered ethical issues that are important in research. These included; confidentiality, informed consent, anonymity and permission. Confidentiality of participants was maintained through use of availed codes on any response document. Additionally, a statement of confidentiality of their responses was signed. With respect to permission, the researcher sought permission to carry out the research from the university after a successful defence of the research proposal. The researcher then sought Research authorization from the NACOSTI before data collection. The researcher also sought and obtained consent from the sample schools' administrators and the sample teachers who were involved in the study. The participants were made aware of the intended use of the data and confidentiality of their responses assured. The participants were also requested to remain anonymous throughout the study to guarantee privacy of the information. The data collection tools did not require respondents to indicate their actual names to ensure anonymity. The researcher therefore ensured that there was informed consent from participants and that the confidentiality of respondents was assured. Teachers who teach the control groups were later guided on the 5E instructional model approach to use the researcher also made every effort to avoid plagiarism by acknowledging all sources used in this research article.