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## 5E Instructional Model Among Biology Students

A Pedagogical Solution to Cell Biology Learning In Vihiga County, Kenya

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### Abstract

Biology is a science subject that provides informational foundation for advancements and innovation in critical areas of development in any nation. Biology has Cell Biology as its basic concept whose understanding is pre requisite for understanding of Biology as a whole. Despite the role of biology in development of any nation, failure rate in the subject remains high. The aim of this study was to determine the effect of 5E instructional model on academic achievement in Cell Biology concepts among students of biology in Vihiga County, Kenya. Mixed method research design that comprised of quasi-experimental design and focus-group interviews was used. A sample of 550 students and 12 teachers of biology was selected using multi-stage sampling procedure. Data was collected using two achievement tests and an interview schedule guide. The reliability of the research instruments was determined using Cronbach's alpha coefficients while validity was established through consultation with research experts and practicing teachers. Data was analysed using the independent sample t-test, at  $\alpha = 0.05$ . The main finding was that the 5E instructional model provided a pedagogical solution to the learning of Cell Biology concepts. Adoption of the 5E instructional model for effective implementation of the competency-based education (CBE) vision to realize an engaged, empowered and ethical citizen is therefore imperative.

**Key words:** Academic achievement, Cell Biology, 5E Instructional Model, Secondary Education Curriculum.

### Introduction:

Biology is an academic discipline that enables one understand nature, one self and life processes besides facilitating development of crucial skills necessary in specialized areas such as medicine, agriculture and environmental sciences. It provides the background knowledge that specialized areas of life stems from. Through biology, students can apply scientific ideas, methods, and mind-sets to solve real-world problems. Biology has Cell Biology as the basic and unifying concept for all its domains necessary to realize set objectives outlined in the secondary school syllabus. Cell Biology involves the study of cells, first described by Robert Hooke in 1665. Cells have since been described as functional and morphological units of living organisms. Cell Biology is therefore an important basic concept of modern biology whose comprehension is fundamental for academic achievement in the subject at all levels.

Studies have revealed that several Concepts of Cell Biology are difficult for students to master. Concepts related to the cell have been rated as extremely difficult to master (Sallah, Ahmad, Setyaningish, 2021). Their report specifically identified cell division, cell Structure and organization, and the chemical composition in the cell as areas of difficulty in the study of the cell life. According to Mehmet (2014), Cell division is one of the most difficult topic in Science education for both teaching and learning. Students find it difficult to understand basic knowledge about cells because the concepts are abstract and the structures are microscopic. Students are unable to perceive metabolic, biochemical and physical processes in cells using their senses. The knowledge about cells has therefore remained fragmental and inadequately integrated on the level of cells and organisms by the learners (Babayan, 2021). This greatly contributes to poor understanding of other concepts of biology by learners leading to the low performance in biology as a subject. Student comprehension of Cell Biology concepts therefore becomes an area of concern for any science educator.

The 5E instructional model is an active learner centred instructional strategy created in the mid-1980s by primary investigator Roger Bybee and his team, including Joseph Taylor, April Gardner, Pamela Scotter, Janet Powell, Anne

Westbrook, and Nancy Landes. The model exemplifies a structured inquiry learning circle approach consisting of five distinct phases: engagement, exploration, cooperation, explanation, and evaluation each with a distinct purpose in the learning process. During the 'Engage phase', the teacher assesses the students' existing knowledge and identifies any gaps in their understanding. Then at 'Explore phase', the students actively investigate the new concept, enabling them to learn through practical experience. It is followed by the 'Explain phase' during which the teacher assists the students in integrating the new knowledge and providing clarifications as needed. During the 'Elaborate phase', the learners are encouraged to apply what they have learned, allowing them to develop a deeper understanding. This aids learners in solidifying their information before assessment. Finally, the 'evaluation phase', the teacher gets the opportunity to assess if the learners have a comprehensive understanding of the fundamental ideas. 5E is a constructivism approach that places the learner at the centre of the learning process. The effectiveness of the 5E model on improvement of Science education has been supported by research conducted in schools. The effectiveness of the 5E model on improvement of various science outcome has been supported by a research that was conducted in schools.

#### The research location:

The study 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 has 754 ECD schools, 392 primary schools, 155 secondary schools, 30 vocational training centres and 1 public university. Despite the high number of academic institutions, 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. The researcher therefore sought to determine the effect of using the 5E instructional model in biology on learners' performance in the county.

#### Statement of the problem for the research article:

Despite the critical role of biology in development of any country, Performance in the subject remains low at national examinations in Kenya. Numerous research findings including those by Valverde and Schmidt (2017) in the USA, Landry (2018) in Canada, and Fonseca and Conboy (2016) in Portugal, show that low performance in biology is a global issue.

The low performance by students in biology and other science subjects has been revealed by the Kenya Certificate of secondary education (KCSE) results in the country as indicated 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 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. Unless this is addressed, the country may not realize its vision 2030 on development. Analysis of KCSE question papers for the period under study reveal the frequency at which Cell Biology concepts are examined each year as shown in Table 3:

**Table 3: Number and total score of Cell Biology questions in KCSE biology papers**

YEAR	2019	2020	2021	2022
Number of questions on Cell Biology	5	4	5	5
Total marks	35	32	29	30

**Source:** KCSE biology past papers (2019-2012).

According to Table 3, Cell Biology concepts are examined each year and account for an average of 31.5 marks out of a possible 200 marks. This is a significant mark that would contribute to overall performance in the subject. It is therefore possible that student's poor comprehension of Cell Biology concepts contributes significantly to their poor performance in biology at KCSE? The low performance in biology poses a disadvantage to the county in terms of professional empowerment.

A number of studies have been conducted on the possible cause of the difficulties in learning biology including Cell Biology. Benjamin and Emmanuel (2017) identified abstractness, misconceptions, attitude and inadequate instructional materials as key concepts responsible for difficulties in learning of biology concepts. Other research findings point to that the teaching approach employed by the teacher (Owusu, Monney, Appiah, & Wilmot, 2010). According to Shan and Khan (2015), most teaching techniques used by teachers have not been successful in improving the learning outcomes among science students due to the teacher orientation. Therefore, the study on teacher pedagogy is crucial to improve performance in biology. A number of pedagogical researchers indicate that active learning enhances students' academic performance in the classroom. According to Tatal & Yazar (2023), utilization of active learning methods positively impacted academic achievement and the retention of knowledge.

5E instructional model has been identified as one of the active pedagogies of instruction. The effectiveness of the 5E model on improvement of Science education has been supported by research conducted in schools. 5E instructional model help learners develop understanding of scientific knowledge and increases students motivation. (Bakri & Adnan, 2021; Bezen and Bayrak, 2020.) It also allows the development of critical thinking skills, argumentation skills, and the ability to apply the knowledge in practice (Amalinya et al., 2023; Ha et al., 2023). Use of 5E model exposes students to activities that foster discovering concepts using pre requisite knowledge (Nkurikiyimana et al, 2022). It is proven to develop all levels of cognitive processes captured on Blooms taxonomy. Whereas a number of studies have been carried out on the effect of 5E instructional model on various aspects of biology; studies on its effects on academic achievement in Cell Biology remain minimal.

Could 5E instructional model help improve student understanding of Cell Biology concepts? Could use of 5E instructional model improve students' performance in biology in Vihiga County? As a resident of Vihiga County, I felt indebted to use my research skills to seek answers to these questions. 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.

### **Significance of the study**

The findings of this study would be of practical and theoretical value. In terms of practical value; the findings of the study would enable teachers diversify their pedagogy by embracing the 5E instructional model-based learning approach to improved content delivery in biology. Secondly, learners would achieve deeper understanding of Cell Biology concepts through active engagement in the learning process. Improved performance in the subject would enable learners to pursue productive careers like medicine, agriculture and engineering necessary to realize the goals of biology education in the country. The Nation would realize professionals for production industries to help realize its vision 2030. In addition, curriculum developers would diversify pedagogies in use by including the 5E instructional model for active learning. In terms of theoretical value, the findings may contribute to the growth of knowledge on active inquiry through 5E instructional model.

### **Definition of key terms:**

**Cell Biology learning:** 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 centered 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.

**Pedagogy:** Method of instruction by a teacher during a lesson.

**Pedagogical solution:** Effective method of instruction that brings about learner's understanding of concepts where other methods have failed.

## Methodology

The study employed mixed method research design with quasi- experimental design as the main component supplemented by focus group interview. This was ideal since the researcher used intact classes in schools which were included in the research. Study population comprised of all form three students of biology in secondary schools in Vihiga County. Stratified random sampling, purposive random sampling and simple random sampling techniques were used to select a sample size of 505 students. Stratified random sampling was used to select schools in the four sub-counties based on the total number of schools in each sub-county to ensure even distribution in the county. Purposive sampling was used to select schools with a mean score of between 2.00 and 2.99 in biology the previous year. This would ensure homogeneity of the sample. Then simple random sampling was used to select sample schools and sample classes. The sample was then divided into two groups assigned as: experimental/treatment group and the control group. Both groups were subjected to pre-test to establish homogeneity of the groups. The two groups were then taught the concept of cell division in the topic reproduction. The experimental group was taught using 5E instruction model while the control group was taught using the conventional method of instruction. A post-test was then administered to the two groups and their scores recorded. The scores were then analysed to determine if there was a difference in achievement scores between learners who were taught using 5E instructional model and those taught using conventional approach. Interview schedules were organized for selected students from each group and their responses were also recorded. Independent group t-test was used to establish if there was a significant difference in the student's academic score in Cell Biology between the treatment group and the control group. T- Tests was used on the assumptions that there is; normal distribution of data, homogeneity of variance and independence of samples.

## Research Instruments and methods of data collection

The researcher used three instruments to collect data, namely (1) Cell Biology achievement test I (CBAT1), (2) Cell Biology achievement test II (CBATII) and Focus group interview guide. Details of each instrument are discussed in below:

### Cell Biology Achievement Test 1 (CBAT1)

Cell Biology achievement test was used as pre-test to establish students' academic entry behaviour based on Cell Biology concepts previously learnt. It was developed by the researcher after consultation with practicing teachers of biology and experts in science education from Masinde Muliro University. It was a one-hour test that was administered to all learners in in both groups before intervention. The achievement test had 12 items developed by the researcher in consultation with practicing experienced teachers of biology, based on KCSE past paper questions on the concepts of Cell Biology and in line with specific objectives outlined in the KICD syllabus. The items cut across all the six levels of Bloom's taxonomy. The test items consisted of short answer and structured questions. The test carried a minimum score of zero and a maximum score of fifty marks converted to 100% for the purpose of analysis. A score below 40% was considered poor; between 40% to 59% was considered fair while a score above 60% was deemed as good. The Cronbach's reliability was determined using the split-half method. Content and construct validity was established through consultation with experienced teachers and science educators. Pre-test scores were also utilized to establish the homogeneity of the two groups.

### Cell Biology Achievement Test 1I (CBATII)

Cell Biology achievement test II was used as post test to determine if there was a difference in academic achievement in Cell Biology when 5E instructional approach was used as compared to when the conventional approach was used. It was developed by the researcher based on KCSE past paper questions on the concepts of Cell Biology taught during the intervention and in line with specific objectives outlined in the KICD syllabus. It was a one-hour test that consisted of 12 items with a maximum score of 50 marks administered to all the learners in both groups after intervention. The items cut across all the six levels of Bloom's taxonomy. The test items consisted of short answer and structured questions. The test carried a minimum score of zero and a maximum score of fifty marks converted to 100% for the purpose of analysis. A score below 40% was considered poor; between 40% to 59% was considered fair while a score above 60% was deemed as good. Pool marking was used to mark and score the learners. Data obtained was used to determine if there was a significant difference in achievement scores when students were taught using the 5E instructional model as compared to when the conventional method was used.

## Focus Group Interviews (FGI) Guide

Twelve focus groups were the subject of a series of focus group interviews. Five randomly selected volunteer students from each sample school were interviewed, resulting in a total of sixty students. A set of guiding queries was established

prior to the commencement of the study to provide the interviewers with guidance. The guiding queries were centered on the learners' attitudes and experiences regarding the learning of Cell Biology concepts and the biology subject as a whole. The questions also addressed the student's perspective on the learning and teaching of biology, as well as their experience with the Cell Biology achievement test II. In order to assist the interviewer, probes were incorporated. The quantitative findings were further elucidated by the qualitative data collected by the instrument.

## Results and Discussion

The objective of this study was to determine the effect of using the 5E instructional model approach and the conventional teaching approach on students' academic achievement in Cell Biology concepts in Vihiga County, Kenya. Data was collected using three instruments; Cell Biology achievement test I, Cell Biology achievement test II and focus group interview guide. Cell Biology achievement test I was used as pre-test to establish students' academic score based on Cell Biology concepts previously learnt. It was developed by the researcher in line with KCSE past paper questions on the concepts of Cell Biology and the specific objectives outlined in the KICD syllabus. It was a one-hour test that consisted of 12 items with a maximum score of 50 marks administered to all the learners in both groups before intervention. The items cut across all the six levels of Bloom's taxonomy. The test items consisted of short answer and structured questions. The test carried a minimum score of zero and a maximum score of fifty marks converted to 100% for the purpose of analysis. A score below 40% was considered poor; between 40% to 59% was considered fair while a score above 60% was deemed as good. Cell Biology achievement test II was used as post test to determine if there was a difference in academic achievement in Cell Biology when 5E instructional approach was used as compared to when the conventional approach was used. It was similar in structure to the pre-test developed by the researcher. Six focus groups were established and subjected to the focus group interviews guide. Two randomly selected students from each sample school were interviewed, using a set of guiding queries established prior to the commencement of the study to provide the interviewers with guidance. The guiding queries were centered on the learners' experiences regarding the learning of Cell Biology concepts and the biology subject as a whole. The questions also addressed the student's perspective on the learning and teaching of biology, as well as their experience with the Cell Biology achievement test II. The quantitative findings were used to collaborate quantitative findings.

- Qualitative data analysis gave the results as presented in Table 4 and 5:

**Table 4: Means and Standard Deviations of Pre-test Data**

Parameter of Learning	Group	N	Mean	SD
Academic Achievement	Exp	251	18.96	4.79
	Cont	254	18.59	4.58

Table 4 indicates that the experimental and control groups had mean scores that were comparatively similar in terms of academic achievement: (experimental) 18.96, S.D. =4.79; (control) 18.59, S.D. =4.58.

**Table 5: Means and Standard Deviations of Post-test Data**

Parameter of Learning	Group	N	Mean	SD
Academic Achievement	Exp	251	23.40	3.73
	Cont	254	18.63	3.80

Table 5 indicates that the experimental and control groups exhibited discrepancies in their academic performance scores, with the experimental group achieving a mean of 23.40 and a standard deviation of 3.73, and the control group achieving a mean of 18.63 and a standard deviation of 3.80.

- Inferential analysis realized the results in Tables 6 and 7:

**Table 6: T-test results on pre-test scores**

Parameter of Learning	Group	N	Mean	S	SD	T	P
Academic Achievement	Exp	251	18.96	0.96	4.79	14.84	0.519
	Cont	254	18.59	1.00	4.58		

Critical t at 0.05=1.96, df = 50

Table 6 indicates that in the pre-test scores, there was no significant difference in the academic achievement of learners with respect to Cell Biology concepts between the experimental and control groups;  $t(1.00) = 14.84$ ,  $p > 0.05$  at  $p < 0.05$

**Table 7: T-test results on post-test scores**

Parameter of Learning	Group	N	Mean	S	SD	T	P
Academic Achievement	Exp	251	23.40	1.03	3.73	5.37	0.000
	Cont	254	18.63	1.08	3.80		

Critical t at 0.05=1.96, df = 50

Based on results from table 7, there was a significant difference in academic achievement between the treatment and control group;  $t(1.08) = 5.37$ ,  $p < 0.05$ ; p value is less than the stipulated alpha.

The results indicated that the 5E instructional model approach had a positive impact on the academic achievement of students in the Cell Biology. The experimental group, which was instructed using the 5E instructional model, achieved substantially higher scores on the achievement test than the control group, which was instructed using the conventional method. This was quite different from findings on the pre-test score analysis, which indicated that the two groups were statistically equivalent in terms of their academic achievement. These findings are in line with earlier finding by Senan (2013) who asserts that the technology-enhanced 5E learning paradigm is a highly successful tool for students and teachers to develop 21st century abilities and teach specific concepts.

Focus group interviews were conducted to collaborate the findings from quantitative data. Sampled student response from the experimental group interviewed expresses high levels of confidence to excel in the test. The students also had this to say:

**ETQIS 1:** "I understood the topic of cell division much better than topics earlier taught on the cell. All students even those who never talk in class participated. Am sure I will score all the test items well because the questions were set directly from what we. Learned."

**ETQIS 2:** "our teacher taught us reproduction well and we all enjoyed the lessons. He gave us time to work together in groups and that enabled us understand the content well. Most learners were active and happy. Am sure I will score highly in the test. The questions were ok. I hope our teacher will continue teaching us in the same was."

**ETQIS 3:** "Reproduction lessons were enjoyable. We were all engaged and interacted with one another well as we learned. The teacher was mainly guiding us and we took the active role through discussions. We were able to relate all aspects in the lessons with real life experiences. The method the teacher used made everything to be realistic unlike when we keep on listening as the teacher teaches. I understood and I know that I have passed the test. Our teacher should continue using this method to enable all students to participate."

The interview responses and score of sampled students from the experimental group clearly indicated that the 5E instructional model is an active, learner centred method that not only improved the score, but also motivated the learner and raised student efficacy. In contrast, the following responses were given by learners in the control group.

**CTQIS 1:** "Reproduction is the topic I was eager to learn though it became complicated with the cell division parts. There was a lot of confusion between types and stages. The teacher was very fast in teaching though he gave us all the notes. I did not understand the difference well. The questions in the test were also confusing though I will not fail all of them. "

**CTQIS 2:** "The topic of reproduction was complicated by the cell division part. It was confusing especially when it came to the stages of mitosis and meiosis. The teacher was also confused! The test was normal; however, biology exams are unpredictable. Sometimes marking is so strict."

**CTQIS 3:** "Reproduction lessons were boring especially the parts of cell division. The teacher was very fast and most of the students were sleeping. The exam was a bit challenging with most questions concentrated on cell division. We were also not given enough time to prepare for the exam because some questions required cramming. Some questions were difficult."

The responses from the control group students clearly indicated that the conventional approach is teacher centred with most students being passive recipients of knowledge. The approach left learners with little confidence on test performance.

### Summary of findings:

There was a statistically significant difference in student's score in Cell Biology achievement test when taught using the 5E instructional approach as compared to when taught using the conventional approach.

### Conclusion

5E instructional model approach of learning results increases students' achievement in Cell Biology concepts among secondary school biology. It enables students to attain higher scores in Cell Biology achievement tests. it is a pedagogical solution to the learning of Cell Biology concepts. The research article further revealed that the 5E instructional model also improved students' attitude towards Biology as a subject.

## Recommendation

Biology teachers should use the 5E instructional model to implement the competence-based education to help realize its vision to produce an engaged, empowered and ethical citizen' in line with the demands of the 21<sup>st</sup> century learners. Teacher educator institutions need to integrate the use of 5E model pedagogy as a learning strategy under active learning. Policy makers should enforce and support adoption of 5E instructional model approach for quality learning.

## Suggestion for further research:

The researcher proposes the following areas for further research:

- Effect of 5E instructional model on student achievement score in other areas of biology.
- Effect of 5E instructional model on student achievement score in other science subjects.
- Effect of 5E instructional model on student attitude towards science subjects.

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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 this treatise. These included; confidentiality, informed consent, anonymity and permission. On confidentiality, participants were asked to use availed codes on any response document and confidentiality of their responses was guaranteed throughout the study. With respect to permission, the researcher sought permission to carry out the research from the university after a successful defence of the research proposal first. 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 names; and this was meant 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 the research article.