

Nexus between Application of the Nature of Science (NoS) in Biology Teaching and Achievement of Learning Outcomes: Lessons from Nairobi City County, Kenya

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DOI: <https://doi.org/10.5281/zenodo.21291888>

Published Date: 09-July-2026

Abstract: Researchers identify Biology as an important scientific discipline contributing to vital scientific innovations such as genetic engineering and medicine. However, national examination reports in Kenya from 2013 to 2023 consistently reveal sub-optimal students' achievement of learning outcomes. This suggests that there may be persistent challenges in its teaching and learning processes. This study investigated the extent to which application of Biology to everyday life context through the nature of science influences students' attainment of intended learning outcomes in Biology. The study employed a mixed-methods approach within an explanatory sequential design. The study began with a quantitative survey whose results informed the qualitative inquiry which was done in selected secondary schools. The locale of the study was Nairobi City County, encompassing 114 public secondary schools. Data collection tools included questionnaires, in-depth interview schedules, focus group discussions (FGDs) and classroom observation protocols. Participants comprised Biology teachers, students and subject matter experts from the Kenya Institute of Curriculum Development (KICD), the Centre for Mathematics, Science and Technology Education in Africa (CEMASTEIA) and Biology education lecturers from Kenyatta University. The findings revealed that application of Biology to everyday life context through the nature of science was insufficient and hence this only led to achievement of low order cognitive outcomes and basic skills and uninterested learners. This study is key to the teaching and learning of Biology in school set-ups.

Keywords: Application of Biology, nature of science, life context, achievement of learning outcomes, teaching and learning.

1. INTRODUCTION

Science has and continues to accelerate socio-economic development in all the industrializing countries of the world (Xue & Li, 2021). Productivity in health, technology, education, and energy has been realized through scientific research and innovation. Evidence from research has shown that education systems are not up to the challenge in science teaching, leading to a decline in achievement of learning outcomes in science disciplines (Fernandes, Rodrigues, & Ferreira, 2019). Further, research studies note that concerns raised regarding science teaching, including the application of knowledge into everyday life context, have not been addressed. Given the place of science in socio economic development of a country, there is need for countries to ensure that sciences are taught in a manner that exemplifies high quality (Xue & Li, 2021).

The challenge with application of Biology content knowledge into everyday-life context has been the perception that it may conflict with assessments or other systemic demands (L'Heureux, 2021). The fear of conflicting the application of the

curriculum into everyday-life context with assessments notwithstanding, the Biology teachers need to create instances for the application of biology into everyday life through the nature of science in the course of teaching. Curriculum guidelines as well should aspire to bring the Biology curriculum into a social reality in which learners can associate with. Researchers have noted a decline in achievement of learning outcomes in Biology and have pointed to the abstractness of the Biology curriculum as the main possible reason (Clark & Hsu, 2023). There is therefore a need to evaluate the application of the Biology curriculum into everyday context through the nature of science and achievement of learning outcomes among learners.

2. REVIEW OF LITERATURE

Many students have reported that Biology is difficult to understand because it has numerous abstract concepts (Chatzikiyriakidou, Tacloban, Concepcion, & McCartney, 2022). To help students understand Biology, efforts should be made to make it relevant and applicable to everyday life. Application of Biology curriculum into everyday life includes instilling Science Process Skills (SPS) in students such as observation, measurement, hypothesis-making and inference-making. Also, it involves aiding students in appreciating the nature of science in Biology and in the society where Biology is learned (Fernandes, Rodrigues, & Ferreira, 2019). These studies have done well in suggesting ways that teachers and educators can make Biology more relevant to learners. The studies have however not investigated the extent to which application of Biology curriculum into everyday life affects the achievement of learning outcomes.

Biology is not only about a body of facts, laws and theories, but the method of acquisition through the nature of science is a major component of Biology (Keengwe, 2022). The nature of science often brings the context that impacts learning, even when it is not explicitly addressed or designed for.

In the application of Biology curriculum into everyday life context, appreciating the nature of science in teaching Biology is vital. Studies have shown that Biology content knowledge in curricula guidelines ignores the nature of science (Juniar, Fardilah, & Tambunan, 2021). Indeed, these findings are pessimistic as other studies have shown that students who interact with a curriculum which appreciates the nature of science gain more from the classroom and laboratory experiences and learn Biology better (Superfine, Ko, & Goldman, 2022). For instance, the aspect of the nature of science which states that science knowledge is 'subject to change' may facilitate understanding of Biology knowledge production. According to Gatica (2024), Biology curriculum should draw on examples that demonstrate changes in theories. Teaching of Biology by separating theories from laws and linking it to real happenings is what may bring comprehension and application of Biology in real life.

According to a study by Chatzikiyriakidou, Tacloban, Concepcion, and McCartney (2022), teaching Biology as a tentative science—one in which concepts and hypotheses are frequently revised in light of fresh data—improved students' comprehension of Biology and greater engagement in science as opposed to learners who were taught depicting Biology as a static and unchanging science. Portraying Biology as unchanging can result in misconceptions and less accurate understandings of the subject. Nizomova (2023), in another study, discovered that employing imagination and creativity in Biology lessons improved students' understanding of scientific topics. According to the researchers, students can better understand abstract scientific topics by connecting them to real-world scenarios through the use of imaginative scenarios.

Another study by Toh & Zaidatun (2024) indicated that most Biology content curriculum guidelines ignore that the Nature of Science (NoS) matters in the application of Biology curriculum into everyday life context. The study states that the curriculum guidelines do not provide compelling rationales for or meaningfully promote intention to application of Biology Content knowledge into everyday life context. This shows that many curriculum developers ignore application of Biology Content knowledge into everyday life context. The study further notes that even the science laboratories in most schools fail to connect Biology to everyday life. This finding indeed is disappointing as learning in the laboratory promotes experiments that can link Biology to real life hence promoting understanding of Biology among learners. Studies have however done little investigation on the extent to which appreciating the nature of science affects the achievement of learning outcomes among learners.

Biology researchers recognize the negative implications of doing Biology in a vacuum, devoid of social context which is an aspect of the nature of science. Social context means that in as much as empirical data derives the development of

explanations in Biology, the society has a critical role in shaping how the study of Biology is done. Besides, it is also important to remember that Biologists are human beings who can develop biases (Boudry & Pigliucci, 2018). These views on society therefore should include everyday ways of knowing and teaching Biology. Boudry & Pigliucci's 2018 study noted that Biology is often taught as some facts and truths that are not part of the society. Studies have however not assessed the extent to which linking Biology into the social context may affect the achievement of learning outcomes.

3. METHODOLOGY

In this study, a mixed-methods approach was deployed using the explanatory sequential design. The mixed-methods approach was selected because it can effectively draw from both qualitative and quantitative data in response to research questions (Cameron & Golenko, 2023). It provides for both breadth and depth such that while quantitative data explores numerically measurable and to what extent the research can cover, qualitative data explores the "why" and "how". This way, the approach provides a wholesome view of the research problem. Mixed methods approach also sets out to minimize the limitations of both approaches when deployed in isolation. According to (Toyon, 2021), mixed methods is a useful strategy to have a more complete understanding of research problems/questions.

Explanatory Sequential mixed method design involved a two-phase project in which the researcher collected quantitative data in the first phase, analyzed the results, and then used the results to plan (or build on to) the second, qualitative phase. The intent of the quantitative phase was to inform of quantities such as learning outcomes; types such as the teaching and learning resources; and processes such as the teaching and learning process. The quantitative results typically informed the types of participants to be purposefully selected for the qualitative phase and the types of questions that were asked of the participants so as to gather explanations to the quantitative data.

The intent of qualitative research in this study was to understand the process of teaching Biology and the product (the learning outcomes) of the process. The researcher followed up on the schools that were identified from the quantitative data analysis. The researcher observed Biology lessons in the selected schools and sought the informants' perspectives and meanings. Qualitative approach according to (Cameron & Golenko, 2023), focuses on understanding the process that is occurring as well as the product or outcome. Qualitative approach provides for intense investigation, bringing out detailed and holistic understanding of the questions under investigation.

Mixed methods type of research posed challenges to the researcher such as the need for extensive data collection and the time-intensive nature of analyzing both qualitative and quantitative data. To this, the researcher designed a clear flow of research activities. The researcher also assigned enough time for data collection and data analysis to give credibility to the research approach and consequently the findings.

The study targeted all the 114 public secondary schools in Nairobi City County, Biology specialists from CEMASTE, KU and KICD, Biology teachers and students. For the quantitative phase, the researcher used single-stage sampling procedure using random sampling to identify 114 out of the 228 teachers of Biology. Data was collected using questionnaires in this phase. The data was analyzed and the findings used to guide the sampling and the construction of data collection instruments for the second (qualitative) phase.

For the qualitative phase the researcher used purposive sampling to select six schools for further study. Data collection involved class observations, learner FGDs and interviews from the data specialists. Data was analyzed thematically according to the objectives of the study and findings recorded. Convergent and divergent findings from the quantitative and qualitative phases were highlighted and discussed. The findings were used to draw conclusions and suggest recommendations.

4. FINDINGS AND DISCUSSION

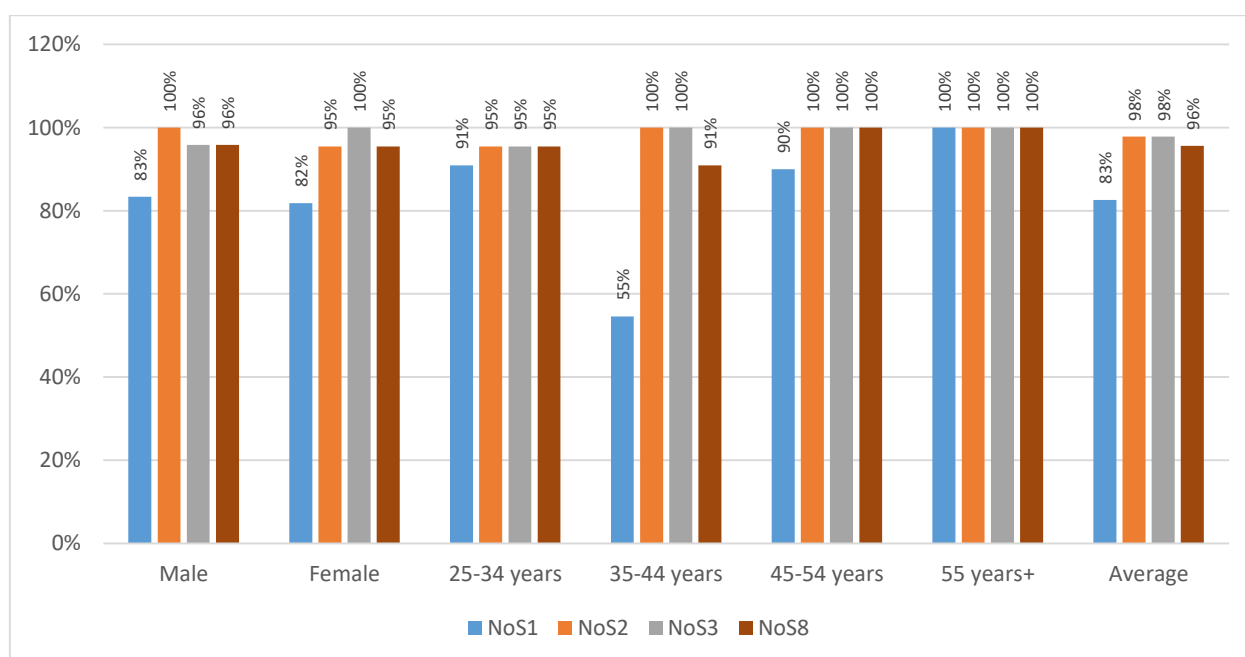
Quantitative Study on Nature of Science (NoS)

In the quantitative study in establishing the application of Biology into everyday life through use of the Nature of Science (NoS), the teachers who participated in the survey were presented with 8 statements depicting the Nature of Science (NoS) and asked if they portrayed the statements in their teaching.

Figure 4.1 shows the teachers' respondents on whether they portrayed the nature of science in the teaching of Biology.

NoS1	Portray Biology Knowledge as tentative and not final/robust
NoS2	Give room for students to use more than one method of investigation
NoS3	Give room for creativity and imagination
NoS4	Guide on clear distinction between observations and inferences
NoS5	Guide on clear distinction between theory and law
NoS6	Identify and acknowledges names of scientists associated with the Biological discovery/knowledge
NoS7	Give room for socio- cultural knowledge to influence Biology knowledge
NoS8	Give opportunities for learners to associate Biology knowledge with social realities in the society

Figure 0.1 Use of the Nature of Science



From the teachers' responses, most teachers, (83-98 out of 100; 83%-98%) teachers appreciated the usefulness of the application of Biology to everyday life using the various aspects of the Nature of Science (NoS). Majority of the respondents, 98 teachers out of 100 (98%) indicated that they give room for students to use more than one method of investigation, while the same proportion of 98% indicated that they emphasize on method of investigation in learning Biology. These findings agree with researcher Donley (2024) who states that teachers appreciate the use of the nature of science as it gives learners a better experience of Biology. These findings show that teachers understand that the use of various aspects of the nature of science is important in giving learners a rich experience in Biology. This could be an optimistic finding if indeed the teachers were to put into practice their thoughts of the nature of science in the teaching of Biology.

Further analysis was carried out to find out if there were any significant correlations between the characteristics of the teacher, namely gender, age and experience and the use of the Nature of Science (NoS). Table 4.1 shows the correlation between the teacher characteristics and NoS use.

Table 0.1 Correlation between the teacher characteristics and NoS use
Correlations

		Gen der	Age	Experi ence	NoS1	NoS2	NoS3	NoS4	NoS5	NoS6	NoS7	NoS8
Gender	Pearson Correlation	1	.174	.088	-.020	-.156	.143	-.276	-.405**	-.275	.042	-.009
	Sig. (2-tailed)		.248	.559	.895	.301	.344	.063	.005	.064	.781	.951
Age	Pearson Correlation	.174	1	.834**	-.003	.134	.134	.055	-.119	-.119	.068	.081
	Sig. (2-tailed)	.248		.000	.986	.376	.376	.715	.432	.432	.654	.591
Experi ence	Pearson Correlation	.088	.834**	1	.051	.064	.064	.058	-.081	-.122	-.011	.024
	Sig. (2-tailed)	.559	.000		.736	.671	.671	.704	.593	.418	.942	.876

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

The findings showed that male teachers tended to use NoS5 (guide on clear distinction between theory and law) more than the female teachers. This finding is contrary to reports by researchers that indicate no significant relationship between science teachers' gender and their conceptions of the NoS (Donley, 2024). However, sufficient research hasn't been carried out to warrant a conclusion regarding the influence of gender on teachers' NoS use. This finding therefore suggests that an emphasis should be made on the use of the nature of science aspect of guiding the learners on clear distinction between theories and laws of Biology by all genders so as to give learners a better experience of Biology.

After determining how teachers used the nature of science in the application of Biology to everyday life, the researcher sought to find out how the nature of science influences the achievement of learning outcomes. In the quantitative study, the teachers who participated in the survey were asked to rate in a scale of 1-5 (1 lowest 5 highest) the extent to which the NoS statements contributed to achievement of learning outcomes.

NoS1	Portray Biology Knowledge as tentative and not final/robust
NoS2	Give room for students to use more than one method of investigation
NoS3	Give room for creativity and imagination
NoS4	Guide on clear distinction between observations and inferences
NoS5	Guide on clear distinction between theory and law
NoS6	Identify and acknowledges names of scientists associated with the Biological discovery/knowledge
NoS7	Give room for socio- cultural knowledge to influence Biology knowledge
NoS8	Give opportunities for learners to associate Biology knowledge with social realities in the society

International Journal of Novel Research in Education and Learning

Vol. 13, Issue 4, pp: (8-19), Month: July - August 2026, Available at: www.noveltyjournals.com

Table 4.2 shows the responses on the extent to which Nature of science (NoS) contributes to Learning Outcomes.

Table 0.2 the extent to which Nature of science (NoS) contributes to Learning Outcomes.

Rating		NoS1	NoS2	NoS3	NoS4	NoS5	NoS6	NoS7	NoS8
Gender	Male	3.67	4.13	4.13	4.04	4.00	3.92	3.75	3.92
	Female	3.86	3.86	4.00	3.95	3.50	3.45	3.82	4.05
Age	25-34 years	3.73	4.00	4.05	4.00	3.86	3.77	3.64	4.00
	35-44 years	3.36	3.91	4.09	3.91	3.45	3.36	3.64	3.82
	45-54 years	4.20	4.00	4.00	4.10	4.00	4.00	4.20	4.00
	55 years+	4.00	4.33	4.33	4.00	3.33	3.33	4.00	4.33
	Average	3.76	4.00	4.07	4.00	3.76	3.70	3.78	3.98
Experience	4 years or less	3.75	3.63	3.88	3.63	3.63	3.63	3.63	4.00
	5-10 years	4.04	4.26	4.26	4.26	3.91	3.83	3.83	4.09
	11-15 years	2.20	3.40	3.60	3.40	3.40	3.20	3.20	3.20
	16-20 years	5.00	4.00	5.00	5.00	4.00	5.00	5.00	5.00
	21-25 years	3.25	3.50	3.25	3.50	3.50	3.25	4.00	3.75
	30 years and above	4.20	4.40	4.40	4.20	3.80	3.80	4.00	4.20
	Average	3.76	4.00	4.07	4.00	3.76	3.70	3.78	3.98

Majority of teachers rated highly (3.70-4.07 out of 5) the usefulness of appreciating the nature of science in the teaching of Biology in contributing to the achievement of learning outcomes. Giving room for creativity and imagination aspect of the nature of science was rated as the most useful, being considerably useful with a rating of 4.07 out of 5 while Portraying Biology as tentative and not robust was rated the lowest at 3.7 out 5, quite lower than other ratings by the respondents.

This finding implies that most likely Biology is taught in a static manner which does not allow room for changes. This is in agreement with Clough & Olson (2012) who state that Biology is portrayed as unchanging and this may result in misconceptions and less accurate understandings of Biology. These findings therefore suggest a limitation to the growth of Biology knowledge and consequently inadequate achievement of learning outcomes. Teachers seemed to understand the role of creativity and imagination in teaching Biology as they rated it high (4.07 out 5). This concurs with (Superfine, Ko, & Goldman, 2022) that employing imagination and creativity in Biology lessons improved students' understanding of scientific topics. This finding is encouraging if indeed teachers provide opportunities for learners to synthesis instances of Biology in relation to everyday life. This is thus likely to improve students' comprehensiveness and application of Biology.

Qualitative Study on Nature of Science (NoS)

In the qualitative study in establishing the application of Biology into everyday life through use of the Nature of Science (NoS), the researcher sought to find out from the key informants how teachers in the classrooms should apply Biology into everyday life context by use of the Nature of Science (NoS). Out of the 8 aspects of the nature of science that the researcher had outlined, the key informants talked of 4 aspects of the nature of science namely: Portray Biology Knowledge as tentative and not final/robust; Give opportunities for learners to associate Biology knowledge with social realities; Give room for creativity and imagination; Guide on clear distinction between theory and law and how they may be used in application of Biology to everyday life. The following are the responses:

KII Q: How should teachers use the nature of science in applying Biology knowledge to everyday life?

KIX

People who have gone to the university level should know that knowledge is not final. Today what you knew as the correct thing, you will find in the evening that it has changed. During my time those years, we had only two classes of naming organisms, you are either a plant or animal. If non-living we don't call it Biology. Although the relationship between nonliving and living is called ecology, you find that there is a relationship. By the time I was coming out of the system, we had how many kingdoms? 5. Monera , protocista, fungi, animalia and plantae. From the two I knew those years. The

biggest problem is how do we portray the knowledge we are teaching? Many teachers teach it as final knowledge. Teachers ought to present knowledge as tentative and not final.

The key informant X reported that scholars should know that knowledge is not final and can change. The key informant X gave an example of how living things were classified before into only two kingdoms plantae and animalia. This changed into five kingdom classification, namely: monera, protocista, fungi, animalia and plantae by the time the key informant X was coming out of the school system. The key informant therefore mainly advised on the aspect of the nature of science which states that “portray knowledge as tentative and not robust”. The informant admitted that most teachers have a problem of portraying Biology knowledge as final and often teach Biology as a body of facts. This finding agrees with (Donley, 2024)’s study who noted that Biology is often taught as some facts and truths devoid of change. This portrayal of Biology as unchanging may be detrimental to the learners as they may not have room to think outside the box and add to the knowledge of Biology. Learners may also have a closed view of Biology and fail to relate it wholly to everyday life. Failure to relate Biology to everyday happenings may make students find Biology difficult to comprehend and hence affect achievement of learning outcomes.

On the same concern of how teachers in the classrooms may apply Biology into everyday life context by use of the Nature of Science (NoS), the key informant Y had this to say:

KII Q: How should teachers use the nature of science in applying Biology knowledge to everyday life?

KIY

In the new CBC for the designs we have prepared, the learning area is related to every day's life. It is learning that you see not those theories that we were being taught like Vasco Da Gama. For example, if you teach a disease control you do not do it theoretically. We have what happened even in the recent past COVID 19. We have given room for creativity and innovation like imagination, critical thinking those are the competencies we would want them to develop from these designs so there is room for that. Through the society, the designs provide for community service learning where learners are sent to the community to do a study or research. In the 8-4-4 curriculum, NoS could have been a bit lacking but from the initial set ups there could have been such rooms. The teachers probably concentrated on assessment. For the 8-4-4 we dwelt on summative assessment especially so if there was an area to go to the community and do some activity it will be overlooked. We now have both formative and summative and hence the nature of science may now be applied.

The key informant Y indicated that in the new CBC guidelines, there is a clear relationship of knowledge and everyday life. The key informant Y mentioned of three main aspects of the Nature of Science (NoS) in the new curriculum guidelines and how they may be applied. The key informant indicated that teachers should emphasize on teaching what is happening and separating it from theories like Vasco da Gama. This statement alluded to the use of the aspect of NoS about “Guide on clear distinction between theory and law”. The key informant thus advised on the importance of separating laws and theories and relating Biology to present day happenings. If a teacher for instance teaches about a disease control method, the teacher should link it to a real disease like COVID19 which was a reality and not to teach that theoretically.

The second aspect of the NoS that the key informant Y mentioned is “Give room for creativity and imagination”. On this aspect, the key informant Y indicated that the new curriculum has allowed for imagination and creativity by outlining critical thinking as one of the competencies learners ought to attain. The third aspect of NoS that the key informant talked about is “Give opportunities for learners to associate Biology knowledge with realities in the society”. On this one, the key informant Y said that the curriculum guidelines have provided for community service learning where learners are sent to the community to do a study or research.

The key informant Y admitted that in the 8-4-4 curriculum, the Nature of Science (NoS) aspects were a bit lacking but from the initial set ups of 8-4-4, there could have been room for NoS but with time the teachers probably concentrated on assessment rather than the curriculum implementation. The 8-4-4 dwelt on summative assessment. For example, if there was an area to go to the community and do some activity, it would be overlooked and rather the time used to concentrate on learning to examinable content. These findings agree with researchers who note that the challenge with application of Biology content knowledge into everyday life context through the nature of science has been the perception that it may conflict with assessments or other systemic demands (L’Heureux, 2021). The findings of the present study therefore recommend that care should be taken to emphasize on that application of Biology knowledge through the nature of science

in the CBC curriculum guidelines lest it ends like the 8-4-4 which, despite the curriculum guidelines implying the use of NoS, was completely ignored. Besides, one of the key informants agreed that even in the new CBC curriculum guidelines, the Nature of Science (NoS) aspects are not clear and intentional. This is what the key informant W had to say about the attempt CBC curriculum guidelines are making in including NoS in the curriculum:

KIIQ: I: To what extent have the CBC guidelines included aspects of the nature of science?

KI W

I have gone through a number of designs up to grade 8 but may be it is not really standing out as nature of science it may imply the nature of science but it is not categorical that we are to have something around nature of science. But what I have interacted with I have not come across that.

Key informant W indicates that much as there has been an attempt to have some aspects of NoS in the so far designed curriculum guidelines, the intentionality is lacking. The key informant advises that the inclusion of the nature of science should clearly be addressed and be included in the curriculum guidelines. These findings therefore show that there is a need for precautions to be put in place to ensure successful utilization of the NoS aspects so as to make Biology relevant of its role in everyday life.

The researcher then sought from the learners through the FGDs ways in which their teachers applied Biology to everyday life through the nature of science. In all the schools visited, learners gave similar manner of applications among their teachers. Responses from two of the schools include:

FGD Q: How does your teacher bring out the applications of Biology to everyday life during the lesson?

School T

R1: our teacher, like in the topic of disease, tells us about the type of disease, how it is caused and refers to our daily life and how to prevent like washing hands before eating or after using the toilet and if in case we get the disease, helps us to take this type of medicine even if it's not mentioned in the text book.

School V

R3: in this topic of classification, we were studying most about animals and when the teacher was teaching he used to give examples about the animals which we see in our daily lives and also he uses the things which live around us instead of using those things that we do not even have access to

R2: in the topic 'ecology' which we have just finished, we have learnt how to prevent some of the diseases we know of like typhoid and cholera and how to know the symptoms of the diseases and how it affects human beings.

In school T, the teacher applied the knowledge of diseases to the learners' applications in everyday life of preventing the disease such as through washing hands and if they get the disease the kind of medicine they may consume apart from what is mentioned in the text book. In school V, apart from applying the knowledge of diseases, the teacher applied the knowledge on classification of animals to the learners by giving examples of the animals they experience in everyday life. From the instances of the applications of Biology knowledge to everyday life that the students mentioned, the teachers mainly used one aspect of the nature of science which was "the clear distinction between theory and law" in which case the teachers pointed out to the real happenings in life.

The researcher, through the class observations, sought to find out how teachers used other aspects of the nature of science in the application of Biology into everyday life. The following are the findings:

In school U, as the teacher was explaining about the importance of reproduction, the he asks the learner to describe a dinosaur which became extinct a long time ago. The learner describes a dinosaur as a huge animal with a big tail. The learner explains that he thinks that the dinosaur was big and that was why it became extinct because it could not run away from predators. In this excerpt, the teacher uses the NoS aspect of "Give room for creativity and imagination" by asking questions that provoke the creativity and imagination of the learner in order to make the learners understand the importance of reproduction. This finding concurs with who state that employing imagination and creativity in Biology lessons improved students' understanding of scientific topics. This finding therefore may urge teachers to give room for creativity and imagination to students for them to better understand abstract scientific topics by connecting them to real-world scenarios through the use of imaginative scenarios.

In school U and T, the teachers were observed using aspect of the nature of science “Give room for socio- cultural knowledge to influence Biology knowledge” as follows:

Class observation: use of aspects of the nature of science (NoS) in application of Biology to everyday life

School U

Lesson

T: in sexual reproduction, the nucleus of the sperm fuses with the nucleus of the ovum to form a zygote. Therefore another importance of reproduction is improvement of quality as the zygote has characteristics from the mother and father.

T: that is why in our communities it is strongly discouraged from marrying your relatives because you may have similar characteristics which can be perpetuated and even lead to occurrence of some mutations

In school U, the teacher applied the knowledge of Biology to everyday life by highlighting how the societal culture of not allowing marriage between relatives is important in contributing to deterrence of mutations which can lead to undesirable conditions.

In school T the teacher applied the knowledge of Biology to everyday life as follows:

Class observation: use of aspects of the nature of science (NoS) in application of Biology to everyday life

School T

Lesson

T: the zygote undergoes mitotic division to form a hollow structure of several cells called blastocyst. The other thing that happens after fertilization is formation of the placenta. The placenta is also called ‘after birth’. It comes out after the baby has been born. People keep the child and throw away the placenta. But in some communities the placenta is not thrown away but buried in the compound as a sign of fertility.

In school T, the teacher highlighted how some societal cultures highly valued the placenta that even after birth it was not thrown away but buried in the home compound because it was considered a sign of fertility. This application by the teacher may help the learner understand deeply the big role the placenta plays during pregnancy and in life. These findings from school U and T concur with Bwalya (2023) who notes that learners understand better concepts associated with their societal culture. This finding means that culture, being a way of the people in a society, its application is one of the best approaches to teach abstract concepts.

Application of Biology knowledge to everyday life through the aspect of the nature of science “Give opportunities for learners to associate Biology knowledge with realities in the society” was observed in school R as follows:

Class observation: use of aspects of the nature of science (NoS) in application of Biology to everyday life

School R

Lesson

T: In treatment of diseases it is important for people to complete their dosage or else they may become resistant to such medicine. Many people once they feel better they stop taking the medicine. How many of you do that? (A number of learners raise their hands). Haven’t you seen a case where one person can get cured by taking a less strong type of medicine while another cannot until they take a stronger medicine?

In school R, the teacher applied the knowledge of Biology to everyday life by highlighting the usual happenings in the social life. She mentioned that when people do not complete the dosage of their medicine, they become resistant to drugs. This application may help the learners understand why there are different drugs of different strength in the treatment of diseases. These findings from school R agree with Boudry & Pigliucci’s 2018 study which noted that Biology should not be taught as some facts and truths that are not part of the society. It is therefore important to note that the society has a

critical role in shaping how the study of Biology is done. Besides, it is also important to remember that Biologists are human beings who can develop biases.

From the learners' FGDs and the class observations, teachers mainly employed use of 4 out of the 8 aspects of the nature of science that the researcher sought to evaluate. The 4 aspects that the teachers used in applying Biology knowledge to everyday life included: Give opportunities for learners to associate Biology knowledge with social realities in the society; Give room for creativity and imagination; Give room for socio- cultural knowledge to influence Biology knowledge; Guide on clear distinction between theory and law.

The other 4 aspects of the nature of science that were neither mentioned by the learners nor observed by the researcher include: Portray Biology Knowledge as tentative and not final/robust; Give room for students to use more than one method of investigation; Guide on clear distinction between observations and inferences; Identify and acknowledges names of scientists associated with the Biological discovery/knowledge. These findings imply that even though the curriculum guidelines in use are lacking the intent of use of the nature of science in applying Biology into everyday life, the Biology teachers are trying on their own to apply Biology to everyday life through some aspects of the nature of science. These findings concur with Buffalari (2022)'s study which states that even if teachers may make an attempt, the curriculum guidelines do not provide compelling rationales for, or meaningfully promote intention to application of Biology content/knowledge into everyday life context. These findings therefore show that there is insufficient use of the Nature of Science in application of Biology to everyday life. Learners may struggle to understand Biology because the use of the nature of science in application of Biology to everyday life has not been given the seriousness it deserves in the curriculum guidelines.

The researcher sought from the experts how application of Biology to everyday life through the nature of science influences the achievement of learning outcomes. The following are the responses:

KIQ: how does application of Biology to everyday life through the nature of science influence the achievement of learning outcomes?

Key informant X

Teaching Biology as a tentative science, that is one in which concepts and hypotheses are frequently revised in light of fresh data, improves comprehension of Biology. This will also make learners want to add to the body of knowledge and therefore create or synthesize knowledge.

The key informant X stated that by portraying the knowledge of Biology as tentative, it can help the learners to comprehend Biology better and also be able to synthesize knowledge. This finding agrees with (Amoah, Emina, Ngman-Wara, & Azure, 2023) who state that teaching Biology as a tentative science improved students' comprehension of Biology and greater engagement in science as opposed to learners who were taught depicting Biology as a static and unchanging science. This finding therefore suggests that by use of the aspect of the nature of science "portray Biology Knowledge as tentative and not final/robust", learners may achieve learning outcomes such as comprehension and synthesis. Synthesis is the highest order of cognitive learning outcomes according to the Bloom's taxonomy.

On the same concern of how application of Biology to everyday life through the nature of science influences the achievement of learning outcomes, key informant Y had this to say:

KIQ: how does application of Biology to everyday life through the nature of science influence the achievement of learning outcomes?

Key informant Y

Through imagination and creativity, the students understand better abstract topics by connecting them to the real world. When you make Biology knowledge part of the culture of the society it makes Biology meaningful and interesting to study. When you separate real happenings from theory, it helps learners make hypothesis and evaluate concepts. When you make Biology as part of social life, the learners are able to improve their analysis-leaning outcomes. In the 8-4-4 curriculum some of these aspects are there but teachers concentrate on teaching exams. In the new CBC there also there but yet to come out clear.

The key informant Y indicated that by giving room for imagination and creativity it brings understanding of abstract concepts. This finding implies that the use of the aspect of NoS “Give room for creativity and imagination” may yield learning outcomes such as comprehension. By associating Biology knowledge with the culture of the society, learners may find Biology interesting and hence develop positive attitudes towards it. Thus, by use of the aspect of NoS “Give room for socio- cultural knowledge to influence Biology knowledge”, learners may achieve affective outcomes and positive approach to Biology. The key informant mentioned that when there is a separation of real happenings in learning from theories, the learners learn skills like making hypotheses and achieve evaluation cognitive outcomes. The informant also mentioned that connecting Biology to social life helps learners attain analysis cognitive outcomes.

These findings concur with researchers who state that students who interact with a curriculum which appreciates the nature of science gain more from the classroom and laboratory experiences and learn Biology better attaining high order cognitive, skills and affective learning outcomes (Chatzikiyriakidou, Tacloban, Concepcion, & McCartney, 2022). From these studies’ findings, one may conclude that use of the nature of science in the application of everyday life can help achieve all types of learning outcomes namely cognitive, skills and affective. Of greater value, use of NoS can facilitate achievement of high order learning outcomes such as analysis, evaluation and synthesis.

Convergent /Divergent Findings from the Quantitative/Qualitative Study on use of The Nature of Science

While the quantitative study portrayed wide and almost instinctive use of the nature of science, it was clear that use of the nature of science was scarce and by coincidence. According to Gatica (2024), use of the nature of science is pivotal in improving learning outcomes. The qualitative study on the same brings out optimism that the incoming CBC curriculum guidelines may provide an opportunity for the utilization of the nature of science.

Since the method of acquisition of biological content is just as important as the content itself (Gizaw & Sorsa, 2023), it is necessary for the new curriculum guidelines not only to show an attempt to include the nature of science but should be intentional so as to ensure better acquisition of learning outcomes.

5. CONCLUSION

Application of Biology to everyday life using the nature of science was not intentional in the curriculum guidelines. A few Biology teachers were trying on their own to apply biology to everyday life through some aspects of the nature of science but other aspects of the nature of science were lacking. Learning outcomes using the nature of science enhance achievement of high order learning outcomes ranging from cognitive, skills and affective such better comprehension and understanding of Biology; synthesis and evaluation. Skills like making hypothesis and achieve learning evaluation cognitive outcomes. Yet application of Biology to everyday life through the nature of science was minimal and consequently only low order cognitive, basic skills and lack of interest towards Biology may be achieved. This study therefore concludes that application of Biology to everyday life through the nature of science was poor and hence limited achievement of higher learning outcomes.

6. RECOMMENDATIONS

Even though it was reported that the new curriculum guidelines contain some aspects of the nature of science, Kenya Institute of Curriculum Development (KICD) should see to it that the curriculum guidelines have intentionality in inclusion of the use of the nature of science. KICD should further organize for INSETs for teachers and other curriculum implementers to be taken through interpretation and implementation of the nature of science and use of active pedagogical techniques.

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