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POST - CONFERENCE BOOK OF PROCEEDINGS

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November 15TH - 17TH, 2023

Science, Technology, Engineering and Mathematics Education International Conference (STEMEIC2023)

November 15TH-17TH, 2023

POST - CONFERENCE BOOK OF PROCEEDINGS

The Interface Between Digital Revolution and Stem: Navigating The New Frontiers.

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MESSAGE FROM DIRECTORATE OF RESEARCH AND POST GRADUATE SUPPORT

On behalf of the team from the Directorate of Research and Postgraduate Support (DRPS), I thank the participants, partners and the guests for their contributions and engagement they played in, during the 4th international STEMEIC virtual conference. The theme of the conference was "the Interface between Digital Revolution and STEM: Navigating the New Frontiers". The conference enlightened participants on frontier thematic areas such as the use of Artificial Intelligence among other subthemes. Our integration during the conferences resulted in the establishment and strengthening of collaborations and partnerships that have resulted in joint research ventures among those who participated in the conference. DRPS recognizes the importance of multidisciplinary approach to research and is using the conference as a "steppingstone" in building inter- and multidisciplinary teams for research purposes. The themes were also aligned to the Kenya Vision 2030 that aims to transform Kenya into a newly industrialized, middle-income country that provides high quality of life to all its citizens by 2030, in addition to other developmental goals. We continue to eagerly share the findings that were disseminated during the conference, as we look forward to another fruitful forthcoming STEMEIC meeting.

Thank you

Director, Research and Postgraduate Support (DRPS)
Prof. Francis Orata

PREFACE

Dear Delegates and Participants,

It is with great pleasure that I present to you the Book of Proceedings for the 4th STEM Education International Conference (STEMEIC2023), held from the 15th to the 17th of November 2023. The theme of this year's conference, "The Interface between Digital Revolution and STEM: Navigating The New Frontiers," guided our exploration of the dynamic interplay between technological advancements and STEM education.

The digital revolution continues to transform our world, presenting both challenges and opportunities for educators, researchers, and practitioners in the STEM fields. As we navigate these new frontiers, our collective insights and innovations are crucial for shaping a future where STEM education thrives in a digital age. This book of proceedings captures the essence of our discussions, research, and collaborations, providing a valuable resource for continued learning and development.

Throughout the conference, we engaged in enriching discussions, presented groundbreaking research, and fostered collaborative efforts aimed at enhancing STEM education. The diverse range of topics covered reflects the multifaceted nature of this field, from integrating cutting-edge technologies into educational practices to addressing global challenges such as environmental sustainability and public health through STEM innovations.

This Book of Proceedings is a testament to the hard work and dedication of all our contributors. It encapsulates the rich array of knowledge shared during the conference and serves as a comprehensive resource for those looking to advance their understanding of the interplay between digital technologies and STEM education. Each paper included here represents a step forward in our collective journey towards harnessing the full potential of the digital revolution to benefit STEM education. As we reflect on the rich content and diverse perspectives presented at STEMEIC2023, it is clear that the intersection of the digital revolution and STEM holds great promise

I extend my deepest gratitude to all the keynote speakers, participants, presenters, and organizing committee members whose efforts made STEMEIC2023 a resounding success. As we continue to navigate these new frontiers, I am confident that the insights and innovations documented in this volume will inspire and guide future advancements in STEM education.

Sincerely,

STEMEIC2023 Chairperson
Prof. Catherine Muhonja Aurah

PURPOSE OF STEMEIC

Our Purpose is to help institutions of learning develop and sustain learning environments and programs suitable for STEM education. STEMEIC does this by:

- Providing a forum for professional educators to share resources and information about innovative pedagogies on a national and international level.
- Stimulating practitioner research, thereby contributing to the integration of theory and
- practice, and to the improved quality of our efforts.
- Serving as a vehicle for cooperative consultation and collaboration among professionals in the field.
- Integrating the interests and concerns from a variety of areas within STEM education.
- Promoting rights of underserved students.
- Influencing institutional and public policies concerning the principles of quality practice applied to STEM education.

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ACKNOWLEDGMENTS

The completion of this **Book of Proceedings** for the **Science Technology Engineering and Mathematics Education International Conference (STEMEIC 2023)** would not have been possible without the contributions, support, and dedication of various individuals and institutions.

First and foremost, we would like to extend our sincere gratitude to the **organizing committee** members for their tireless efforts in planning and executing a successful conference. Their leadership and commitment have been instrumental in ensuring that the event provided a valuable platform for intellectual exchange.

We would also like to express our appreciation to our **academic partners**, including the **Centre for Mathematics Science and Technology Education in Africa (CEMASTEA)**, **Diversity Education Institute Texas USA**, **Sam Houston State University Texas USA**, and **Brandenburg University** for their support and contributions.

Special thanks to **Masinde Muliro University of Science and Technology** and **Brandenburg University of Applied Sciences** for sponsoring this conference, alongside **Vyxer Remit Inc.**, whose generosity has been pivotal in making this event a success.

We are equally indebted to the **authors and researchers** who submitted their papers and participated in the conference sessions. Their groundbreaking work is the foundation of this book and the broader discussions within the STEM community.

Lastly, we extend our gratitude to the various **contributors** and **reviewers** whose expertise and attention to detail ensured the high quality of the papers presented at the conference.

Thank you all for your invaluable contributions.

Sincerely,

STEMEIC 2023 Organizing Committee

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Effect Of Enhanced Self – Learning Strategy on Students' Achievement In Biology

Adedamola A. KAREEM
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Abstract

The study examined the effect of enhanced self-learning strategy on secondary school students' achievement in Biology. Pre-test posttest quasi experimental research design was used for the study. Two co-educational secondary schools from Educational District II of Lagos State, Nigeria were purposively selected for the study. One intact Senior Secondary School II (SSS II) science class was randomly selected in each school for the study. Schools were randomly assigned into experimental and control group. In all, 193 students participated in the study. The instrument used for collection of data for the study were Self-Directed Learning Instructional Guide (ESDLIG) (r = 0.75), Conventional Teaching Instructional Guide (CTIG) (r = 0.72), and Biology Achievement Test (BAT) (r = 0.87). Two research questions and two hypotheses were raised and tested respectively. Data collected were analysed using descriptive and inferential statistics (ANCOVA). Findings revealed that students exposed to enhanced self-directed learning strategy performed higher than their counterparts that were exposed to conventional teaching strategy. Based on the findings, it was recommended that teachers should encourage students to learn biology with enhanced self-directed learning, and government should ensure the provision and usage of Information and Communication Technology (ICT) laboratories with internet facilities for learning biology in senior secondary schools.

Keywords: self-directed learning, conventional, enhanced, achievement, biology

Introduction

Science is important in the development of any nation. It is the bedrock of technological development of any country. According to Ogundiwin, Asaaju, Adegoke and Ojo (2015), science is viewed as a process of enquiry about natural world, an endevour which leads to discovery and seeks explanation to man's immediate environment through scientific processes such as observation, experimentation, etc. Science is also defined as a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe (Cassimally, 2011). Application of science forms the basis of technological development which is very important for economic development of a country.

Science equally contributes to the quality of life such as health, nutrition, agriculture, energy production, etc. Science is valued in the society because application of the scientific knowledge helps to satisfy many basic human needs and improves the living standard. Due to importance of science to the development of individual lives and a country, its teaching and learning is important. These have found a place at all levels of education in Nigeria.

Biology is a natural science subject that is taught at Senior Secondary school. Inspite of its importance as a science subject, biology is a very important subject, and a requirement for further learning of many professional courses such as medicine, agriculture, pharmacy, pharmacology, physiotherapy, biotechnology, etc. The teaching and learning of the subject makes students learn and make more informed decisions about their own health and biological issues. Jubril, Bello and Abimbola (2015) remarked that biology is the most popular science subject among senior secondary school students due to its importance.

Studies (Awobodu, 2016; Ayuba, 2016; Raji, 2017; WAEC Chief Examiners' Report, 2018; Adebanjo, 2019) have shown that despite the importance of the subject, and students' large enrolment in biology, the academic performance of students in Senior Secondary School Certificate Examinations (SSCE) has been dwindling over the years. There has not been permanent improvement in students' performance. It has been zigzag in nature - some years the pass rate is below average while in few other years, it has been a little above average. Most of the problems attributed to the students' poor performance in the subject are poor teaching methods and faulty instructional strategies (Kurah, 2015, Adebanjo, 2019).

Most biology teachers were found to consistently use conventional teaching. This teaching strategy engages the students in face-to-face teaching where the knowledge is transmitted (either written or oral) from the teacher to the students. The students play the role of recipients of biology knowledge or content. This is how biology as a science subject has been taught in classroom for several years. Therefore, the students have been passive learners. This is because conventional teaching is straight forward instruction from the teacher to the learners which is typical in classroom (Okoli & Chijioke, 2019). Conventional teaching is the traditional means of delivering instruction where the teacher leads the lesson, while the students are passive in listening and taking notes.

In recent times, the use of innovative method that will engage students' involvement in search for the knowledge of biology to be learnt may add value to the process of teaching and learning of the subject. Such strategy is self-directed learning.

Self-directed learning is a process of learning in which individuals take control of their own learning with or without the help of others. When teachers are involved, act as Facilitators, the learner has personal control over learning and its process. The students initiate, diagnose their learning needs, formulate their learning goals, identify necessary resources for learning, choose appropriate learning strategies and evaluate their own learning objectives. According to LaDell-Thomas (2012), self-directed learning is an instructional strategy where the students with the guidance from the teacher decide what and how learning will take place. When students are allowed to choose different learning objectives, the students choose based on personal interests and strength. Self-directed learning is driven by intrinsic motivation to learn, with

students taken ownership in acquiring new knowledge. In this strategy, students are taught to learn through research. This is because, when students are involved in self-directed learning, students are in charge of collecting data, and performing experiments. Self-directed learning involves stages, such as: assess readiness to learn – the students conducting a self-evaluation of their current situation of study habits, set learning goals – developing a clear understanding of learning goals and communicating such with the teacher, engage in the learning process – able to understand learning needs and resources, and evaluate learning – students are to reflect and evaluate their learning goals to monitor the progress of achievement of such goals. Self-directed learning according to Tripon (2019), helps students to understand the best approach for gathering different types of information, and the development of life skills such as setting goals, reflecting on progress, problem solving, presentation and communication. Therefore, the process of learning is made better for students.

Most of the reviewed studies on independent learning strategies for students are about self-regulated learning strategy. For example, Broadbent & Poon (2015) examined self-regulated strategies as correlates of academic outcomes in higher institution. The self-directed learning is missing especially in the teaching biology at high secondary school.

Self – Directed Learning could be enhanced with the use of Information and Communication Technology (ICT) and other Technology used for learning in education. The use of ICT as a tool in teaching and learning is very common nowadays. It is used often by teachers to facilitate the effectiveness of teaching and improve students' learning. In biology, Senthikumar, Sivapragasam, & Senthamaraikannan, (2014) remarked that ICT simplifies the part of teaching as a visual representation. The visual representations of biology content could be easily understood by students. In view of these, this study enhanced or incorporated the self-directed learning with ICT. This is Enhanced Self – Directed Learning It is learning in which students are provided with ICT, modern day technologies for usage in taking charge of their own learning, develop a clear understanding of learning goals, select learning needs and resources, monitor progress of learning, etc. Students carry out Self-Directed Learning with the use of technology to enhance their understanding of the concepts to be learnt.

Knowles (1975) theory of self-learning, regards individuals as being unique, and the uniqueness calls for an individual approach to learning. The emphasis is that learning is individualistic. This theory supports self- directed learning. Students in self-directed learning take the initiative of their learning needs. The learner decides what to learn, how to learn, relevant resources for learning and implement learning. This is different from learning that defines teachers as transmitters of knowledge.

In learning, gender is an important issue of consideration in the study of students' achievement in science subjects. Various studies have submitted diverse findings on students' performance in science as relates to gender. Lawal (2015) found that gender factor has no impact on mean achievement of students in science, Okoli and Chijioke (2019) reported that female students have higher mean achievement than male students in biology.

Therefore, this study investigated the effect of enhanced self-directed learning on students' achievement in biology. The study examined the influence of gender since learning biology at secondary school is not gender biased.

Statement of the Problem

Biology is an important science subject that serves as prerequisite for many important professional courses in science field. Research report reveals that students' performances of students at examinations (especially senior secondary school certificate examinations) have not been encouraging. Various factors have been adduced to be the source of this problem such as poor teaching, laboratory facilities, students' population, etc. However, researchers have come up with various teaching strategies which may solve the problem of poor performance but the problem persists. A strategy with high involvement of students' engagement in the search for the knowledge may be of critical benefit to students' learning in the subject. It is against this background that the study attempted to find out the effect of enhanced self-directed learning strategy on academic achievement among biology students in Education District II, Lagos State.

Purpose of the Study

The purpose of this study is to:

i. investigate the impact of enhanced self-directed learning on students' achievement in biology
ii. determine the achievement of male and female students' taught using self-directed learning

Research Questions

i. Is there any difference between the mean achievement scores of students taught with enhanced self-directed learning and those taught with conventional teaching strategies?
ii. Is there any difference between the mean achievement scores of male and female students taught with enhanced self-directed learning strategy?

Hypotheses

i. There is no significant difference between the mean scores of students taught with enhanced self-directed learning and those taught with conventional strategies.
ii. There is no significant difference between the mean achievement scores of male and female students taught with enhanced self – directed learning strategy.

Instruments

Instruments used for this study include Enhanced Self-Directed Learning Instructional Guide (ESDLIG), Conventional Teaching Instructional Guide (CTIG), and Biology Achievement Test (BAT). ESDLIG consisted of guides (or steps) for enhanced self-directed learning strategy while CTIG contains guides for conventional teaching. The reliability coefficient using test-retest method was 0.75 and 0.72 for ESDLIG and CTIG respectively. BAT was made up of two sections. Section A consisted of student's demographic data while Section B contained fifty multiple choice questions items on cell division (this was the topic in the Lagos State's unified scheme of work as at the time of the study). The questions were drawn from

past paper two of WAEC and NECO May/June examinations from 2016 to 2021. The reliability was determined using KR 21 formula, a reliability co-efficient of 0.87 was obtained.

Methodology

The study adopted pretest posttest quasi experimental design.

The population of the study was made up of all Senior Secondary School II (SSS II) biology students in public senior secondary schools in Education District II of Lagos State. Purposive sampling method was used to select two schools for the study. The criteria for the selection of the schools include co-educational, presence of two biology teachers with first degree in biology education, properly equipped and functional biology laboratory and computer laboratory with internet facilities. The selected schools were far apart from each other to avoid interactions between the students during the study. In each of the schools selected, one intact SS II science class was randomly selected for the study. The intact classes were randomly assigned into treatment and control groups i.e one class being experimental group and the other, the control group. A pretest was administered on the two groups before commencement of treatment to determine their entry level.

The experimental group was exposed to enhance self-directed learning using ESDLIG while the control group was exposed to conventional teaching strategy with the use of CTIG. In the treatment group (Enhanced Self-Directed Learning), the topic was given by the teacher, but the students set their learning goals, made learning decisions with the use ICT facilities in the school's computer laboratory. In the conventional group, students were taught in the conventional way with the teacher as transmitter of the concept under consideration. The treatment was carried out over a period of six weeks. Both groups were learned Cell Division. The teaching was done by trained research assistants. At the end of the treatment period, a posttest was administered to both groups using the achievement test (BAT).

Data collected from the study were analysed with the use of descriptive and inferential statistics.

Result

The result of the study is presented according to research questions and hypotheses.

Research Question One: Is there any difference between the mean achievement score of students taught with enhanced self-directed learning and those taught with conventional method?

Table 1:

Descriptive statistics on difference between mean achievement scores of students achievement scores in enhanced self-directed learning and conventional teaching strategies

Groups	N	Mean	Standard Deviation	Std. Error
Experimental	65	11.74	1.89	.39
Control	98	10.47	1.86	.37

Table 1 shows that the experimental group achieved a higher mean score of 11.74 while the control group achieved a lower mean score of 10.47. This indicates that there is difference between the mean scores of the achievement of students in the two strategies. The students in enhanced self-directed learning performed better than those in the conventional group.

Research Question Two: Is there any difference between the mean achievement scores of male and female students taught with enhanced self-directed learning?

Table 2:

Descriptive statistics on difference between mean achievement scores of male and female students taught using enhanced self-directed learning strategy

Variables	N	Mean	Standard. Deviation
Male	37	14.34	1.36
Female	28	14.15	1.45

Table 2 showed the mean achievement scores of students according to gender. The male students had 14.34 while the female students had 14.15. Though, there is difference between the two figures, the difference is very minimal.

Hypothesis One: There is no significant difference between the mean scores of students taught with enhanced self-directed learning and those taught with conventional method

Table 3:
Analysis of Covariance (ANCOVA) of students' Mean Achievement Scores in Biology

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	14.74	5	3.14	3.14	.14
Intercept	174.33	1	194.33	108.91	.00
Pretest	8.17	1	8.17	4.58	.03
Group	4.39	1	14.35	9.35	.00
Gender	.99	2	.50	2.62	.76
Group*Gender	.17	1	.19	.13	.75
Error	94.57	53	1.78		
Total	13687.00	59			
Corrected Total	11031	58			

a. R Squared = .143 (Adjusted R Squared = .062)

Table 3 shows that the probability associated with the calculated value of F (9.35) for the effect of enhanced self-learning strategy on students' achievement in Biology is 0.00. Since the probability of 0.00 is less than 0.05 level of significance, the null hypothesis was rejected. Therefore, there is a significant difference between the mean achievement scores of students taught with enhanced self –directed learning strategy and those taught through the conventional teaching approach.

Hypothesis Two: There is no significant difference between the mean achievement scores of male and female students taught with enhanced self – directed learning strategy

Table 3 shows that the probability associated with the calculated value of F (2.62) for the effect of gender on students' achievement in Biology is 0.76. Since the probability value of 0.76 is higher than 0.05 level of significance, the null hypothesis was upheld. Thus, there is no significant difference between the mean achievement scores of male and female students taught with enhanced self – directed learning strategy.

Discussion

Results from the study revealed that there is a significant difference between the mean achievement test scores of students taught biology with enhanced self-directed learning and conventional teaching strategies. It showed that those students taught with enhanced self-directed learning performed better than those taught with conventional method of teaching. This aligned with the findings of Khiat (2015) who reported that self-directed learning has a positive effect on overall students' achievement. Tekkol and Demirel (2018) also reported that self-directed learning has a significant improvement on university students' academic achievement. In support of the findings of this study, Khodabandehlou, et al (2012) also reported that there is a big difference between conventional teaching method which is teacher-center and self-directed learning, with students in the self-directed learning performed better in academic achievement. The implication is that students learn better when the teaching strategy is individually directed by students. Hence, there is the tendency of their better performance in the subject.

In this study, the self-directed learning was enhanced with ICT, technology and internet facilities. This may have also added to the improved academic achievement of the students. This is supported by Dawson et al (2012) assertion that technology and self-directed learning have a strong relationship. This indicates that self-directed learning work well when students facilitate the learning with technology experience. This is also supported by Eyyam and Yamtan (2014) study who found that mathematics students showed improved results when taught with self-directed learning and Information and Communication Technology (ICT) compared to those who were taught without technology and with conventional teaching. Carson (2012) also reported in a study that self-directed students studying in online distance learning university achieved better academic achievement compared to regular conventional students. Mutiu and Eroz-Tuga (2013) also found that university language students exposed to self-learning with computer assisted language learning, had a better understanding of language learning. This finding supports that in self-directed learning, students learn more when learning is encouraged with computer technology.

The improvement in the achievement revealed from the study was not gender sensitive. This indicates that the strategy is good for both male and female students. This is in support of the study of Nbina and Avwiri (2014) that gender has no effect on students' achievement in science but against the submission of Mohammad (2014) who found that female students' performance in science is significantly better than the male students. However, Omwirhiran (2013) and Daluba (2013) noted that male students performed significantly than the female students which are against the findings of this study.

In line with the findings from the study, and similar findings from literature it is evident that when senior secondary school students learn biology with self-directed learning that is enhanced with ICT, the students are likely to perform better.

Recommendations

Based on the findings of the study, the following are recommended:

1. Biology teachers should ensure and encourage students to learn biology using self-directed learning enhanced with technology
2. The proprietors of senior secondary schools should ensure the provision and usage of Information and Communication Technology (ICT) laboratory with, regular internet supply. This will facilitate students' self – directed learning in biology.

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Investigating the integration of technology aided-task-based assessment methods in teaching and learning 3D geometry from selected secondary schools in Dodoma, Tanzania

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Abstract

Integration of relevant and diverse assessment methods create learning environment that actively engages students and promotes a deeper and more meaningful understanding of mathematics. This study examines the integration of task-based assessment methods assisted by technology in teaching and learning 3D geometry in some selected secondary schools in Dodoma, Tanzania. Using a mixed research methodology, the study collected information from mathematics teachers through classroom observation protocols and interviews. 58 mathematics teachers in Dodoma region were purposively selected for data collection. Thematic analysis was used to examine the data from interview and SPSS used to analyze the data from classroom observation protocols. The results indicate a preponderance of traditional assessment techniques, particularly written tasks, with a conspicuous underuse of task-based assessments such as exhibitions, game-based assessments, observations and project-based assessments. An important finding of the study is that the majority of teachers lacked experience using technology to improve assessment practices. This finding highlights the importance of providing professional development opportunities that empower teachers with the necessary skills to incorporate technology aided-task-based assessment methods in enhancing students learning of 3D geometry.

Keywords: 3D geometry, assessment methods, mathematics, mathematics teachers, technology aided-task-based assessment methods, teaching and learning

Introduction

Mathematics is an important area of study that contributes significantly to the development of students' analytical thinking and problem-solving abilities (Ahdhianto et al., 2020; Alcantara et al., 2017). Among the sub-fields in the subject, 3D geometry is a significant topic in developing students problem-solving skills (Thompson, 2013). In this context, teaching and learning 3D geometry is a fundamental component that provides students with the chance to interact with spatial ideas and its practical applications. In improving the teaching and learning of 3D geometry, teachers' methods of assessment have a significant impact on how well students learn (Omar et al., 2018). Assessment in mathematics learning goes beyond traditional testing and examinations (İbili et al., 2020) which are dominated by a teacher, the more authentic assessment advocated to improve students learning accountability is the assessment in which both, students and their teacher are actively engaging in the process of planning, leaning and assessing the learning success. According to Palm (2019), student-centered assessment practices include task-based assessment methods which encompasses a range of strategies such as hands-on activities, projects, exhibitions, self and peer assessments.

According to Venturini and Sinclair (2017), teaching and learning 3D geometry require students to perform various tasks that require students to apply their knowledge to real-world problems. Students might be required to use computer-aided design softwares to construct a 3D model, for example, as a way to demonstrate their spatial awareness and problem-solving abilities. One example of task-based assessment methods include ability to create tangible models of geometric shapes out of clay or paper is another example that may be used to gauge a student's manual and intellectual competence. Through active learning, engagement, and the application of theoretical information in practical circumstances, these strategies build a deeper understanding of 3D geometry while providing a hands-on means of assessing students' practical skills and creativeness. According to Mjenda et al. (2023b) assessment of acquisition of learning compentences can be enhanced through the use of rubrics to assess the performance level of individual student in a particular learning tasks. The study conducted by Orlando and Attard (2016) report that effective assessment is characterized by student active participation in learning and assessment activities that can be enhanced through manual activities or digital tools.

As explained by Weldeana and Sbhatu (2017), students' competence in 3D geometry is enhanced by the use of a variety of assessment techniques that are appropriate for the context. Assessment tasks specifically designed for 3D geometry assess students' application of these concepts in real-world situations in addition to their theoretical knowledge. Through the integration of task-based asassessment methods particularly technology-aided task-based assessment methods, teachers can foster problem-solving skills. This all-encompassing strategy fosters a more profound understanding of 3D geometry. According to Beatty and Gerace (2009) Technology-aided task-based assessment methods use digital tools to assess students'

skills and competencies in teaching and learning. These assessments involve interactive tasks that simulate authentic learning, allowing for a more practical and dynamic assessment of a person's abilities (Mbwile & Ntivuguruzwa, 2023). Utilizing technologies such as simulations virtual environments, and computer-based tasks enhance incorporation of pertinent assessment tasks and create an environment that is stimulating and rewarding for students' learning (Mjenda et al., 2023a). In this sense, developing a more solid and successful pedagogical approach to teaching 3D geometry requires the careful integration of assessment methods.

Educational stakeholders in developed countries use a wide range of instructional assessment methods to improve mathematics teaching and learning. The study conducted by Venturini & Sinclair (2017) on effectiveness of task-based assessment methods in teaching and learning 3D geometry with a particular focus on integrating technology revealed positive change in students learning of the topic. In addition, the study by Britten and Cassady (2012) highlighted that technology is becoming increasingly important in assessing students' acquisition of problem-solving skills in mathematics. In this view, the integration of task-based assessment methods either manually or through digital tools improve mathematics learning particularly 3D geometry. Furthermore, the study by Salend (2009) highlighted the importance of technology as a useful tool for assessing students' mathematical understanding. The studies reveal that task-based method that are enhanced by technology, give students the opportunity to work on important, challenging and relevant tasks that help them make the connection between their theoretical knowledge and practical application. This is consistent with the principles of problem-based learning, which emphasize the importance of technology-based assessments. Additionally, Chiu and Hsieh (2017) study highlights the impact of role-playing-based assessments on students' mathematics performance. The results show that the use of this novel assessment methods significantly improves students' results. Scenarios based on role play not only increased student satisfaction, but also lead to increased mathematics learning success.

Moreover, task-based assessment techniques are becoming more popular for teaching and learning 3D geometry in sub-Saharan countries as well. Ethiopia is a prime example, as evidenced the study by Weldeana and Sbhatu (2017) which shows that implementing portfolio assessment in 3D geometry instruction significantly improved student learning outcomes. Comparably, the study conducted by Salman (2009) in Nigeria emphasized the critical role that classroom assessment methods play in shaping the dynamics of teaching and learning. The study found that task-based assessment increases students' motivation and interest in the learning process while also encouraging student interaction. The results resoundingly support the incorporation of pertinent assessment techniques, highlighting their value in stimulating learning environments. The recognition of task-based assessments as catalysts for effective 3D geometry education signals a paradigm shift towards more engaging and student-centered learning experiences across diverse educational landscapes.

Apart from recognition of the importance of task-based assessment in teaching and learning 3D geometry in sub-Saharan countries, the study conducted by Agyei et al. (2023) in Ghana high schools revealed that teachers and students struggle in implementing task-based assessment assisted with technology to improve students' critical thinking and proble,m solving skills in mathematics. In addition to that, the study conducted by Barakabitze et al. (2019) in Uganda to reports that teachers find it difficult to create engaging and dynamic learning environments particulary in utilizing technology for 3D geometry assessments. Teachers and students have limited ability to manipulate models in three dimensions creatively due to limited access to digital tools. In this view due to the digital tools access, students and teachers are more reliant on conventional methods, which makes it more difficult for students to improve their spatial skills.

A major change in Tanzania's education has been the transition from a content-based to a competency-based curriculum, with an emphasis on incorporating student-centered assessment methods. Furthermore, the curriculum emphasizes integration of technology in assessment procedures. This change was enacted by the United Republic of Tanzania [URT] in 2019 to encourage direct student participation in classroom activities and enact 21st century skills to the youth (Senjiro & Lupeja, 2023). National education policy emphasizes teachers to use a range of assessment methods to instill in students a sense of ownership of their learning and to provide meaningful teaching and learning experiences. The policy emphasizes the integration of technology to improve and modernize the teaching and learning as an accountability to struggle in the global market. Application of digital tools in Tanzania is growing particular in the use of digital tools as instructional resources (Mbwile & Ntivuguruzwa, 2023a). However little has done on the part of mathematics education particularly in the area of 3D geometry, since the policy is ineffectively put into practices in the field (Lupeja & Komba, 2022; Mazana et al., 2020; William & Kitta, 2021). As effective integration of task-based assessment methods assisted by technology has positive impact on student learning, particularly in Teaching and learning 3D geometry, the study aimed at examining how mathematics teachers in Tanzania context employ task-based assessment methods assisted by technology to improve students' learning of 3D geometry. More specifically, the study aimed to fulfill the following research questions:

1. Do mathematics teachers employ task-based assessment methods enhanced by technology in Teaching and learning 3D geometry?
2. What are challenges facing mathematics teachers in integrating technology-assisted task-based assessment methods in teaching and learning 3D geometry?

Significance of the study

The significance of the study goes beyond the immediate Dodoma context and extends to the larger education system of Tanzania. Knowledge of the assessment methods integrated with technology is essential as the country struggles with poor mathematics performance, particularly in 3D geometry. In this particular mathematical area, research intended to provide a nuanced understanding of the dynamics between pedagogical assessment practices and student outcomes. Additionally, the results can serve as a catalyst for policy reform by providing evidence-based insights into the effectiveness of current assessment practices. Policymakers can develop targeted interventions to improve mathematics education nationwide by identifying areas that can be improved. Additionally, the research findings could be a useful tool for teachers, providing them with research-backed strategies to improve their teaching, particularly in the complex area of 3D geometry through the application of technology. The aim of this research was essentially to serve as a catalyst for positive change in the Tanzanian mathematics education system by creating an atmosphere in which students can develop their understanding of 3D geometry and teachers are empowered to apply efficient assessment methods cconsistent with the overall goals of the Tanzania Education curriculum.

Theoretical framework

The theoretical framework of this study is based on the sociocultural perspective, particularly Vygotsky's zone of proximal development [ZPD] (Vygotsky, 1978) and the scaffolding concept. This framework highlights the importance of social interaction for cognitive development and posits that learning occurs in a social context. The assessment methods used by mathematics teachers are essential resources for helping students navigate their zone of proximal development when it comes to learning and teaching 3D geometry. The study aimed to examine how teachers help students acquire knowledge of 3D geometry by examining these assessment methods within a sociocultural framework. It recognizes the importance of dynamic and interactive assessment techniques that not only measure students' current understanding but also provide support and guidance for their further cognitive development in this specific area of mathematics. The framework also makes it possible to examine how assessment methods might support or hinder students' ability to develop spatial thinking skills, considering the particular cultural and contextual elements of secondary schools in Tanzania.

Methodology

Study context

The study was focused on Dodoma, one of the 31 regions in the United Republic of Tanzania and is located at the central part of the country. A reason leads to decision to conduct this study to this region was the region's poor performance, particularly in Mathematics subject as shown by the results of the National Examination Council of Tanzania [NECTA] (2022) Certificate of Secondary School Examinations (CSEE). The importance of understanding assessment methods teachers use in this important subject was highlighted by the data from URT (2022) examination data. Within the Region, two districts which are Chamwino and Dodoma city were randomly selected among seven (7) districts in Dodoma to involve in the study. Furthermore, the study concentrated on the topic of 3D geometry as one among the topic in Ordinary-level Curriculum of secondary education and the topic being the worst performed in the examinations (Ministry of Education, Science and Technology [MoEST], 2022). In this view, it was felt desirable to explore mathematics teachers' integration of technology-aided assessment methods in the teaching and learning of 3D geometry, as assessment methods applied in teaching and learning play significant role in enhancing students learning.

Research approach

The methodological framework of the study was based on a mixed-methods design which is characterized by a careful fusion of quantitative and qualitative research approaches (Hall, 2013). This thoughtful decision improves the scope and depth of the study on the assessment techniques used by mathematics teachers in Tanzania. Teachers were observed in their classrooms when teaching 3D geometry to see how they integrate task-based assessment methods and integrate technology in assessment processes. On the other side, detailed semi-structured interview with mathematics teachers provided qualitative data. The interview explored the intricacies of assessment practices and explain the considerations and underlying motivations behind the selection of specific techniques. Collecting both types of data simultaneously facilitated triangulation of results and increased the overall legitimacy and rigor of the research. This methodological diversity ensures that the study captures the complex relationship between assessment methods and teaching in 3D geometry, leading to a deep understanding that can guide important recommendations for Tanzania's educational policy and pedagogical approaches.

Sampling procedures

Given the main aim of this study to examine the assessment methods employed by mathematics teachers to improve the teaching and learning of 3D geometry, a deliberate attempt was made to specifically involve mathematics teachers in the research. The decisive factor in the decision to use this purposive sampling was the responsibility of these teachers take in teaching and learning mathematics. In this view, mathematics teachers were purposively selected among all teacher in the two districts. To ensure widespread participation, consent forms were distributed to all 63 mathematics teachers in the two districts within the Region inviting them to participate in the interview and to be observed in the classes when they were teaching. Impressively, 58 teachers expressed willingness to participate in the study. Among the respondents, 15 mathematics teachers were selected through a random sampling process to participate in in-depth interview that provided valuable qualitative insights into their teaching methods. To increase the representativeness of the study, factors such as gender and the presence of special needs among mathematics teachers were carefully considered during the sampling process to ensure a diverse and inclusive representation of teachers. This careful approach aimed to gain a nuanced understanding of assessment practices across the diverse landscape of mathematics teachers in the region.

Data collection tools and procedures

In examining assessment methods mathematics teachers use in teaching and learning 3D geometry, data were collected through classroom observation protocol and semi-structured interview. The Classroom observation protocol initially comprised fifteen items. After passing the validation process, five elements were omitted because experts commented that they were not relevant to task-based assessment. All 58 teachers were observed twice by two observers. Each classroom session consumed 40 minutes. On the other hand, semi-structured interview was conducted after expert assessment of the interview questions. Before expert appraisal, the interview guide consisted of fifteen questions, experts suggested to omit three questions as seem not answering the research objectives and also two questions were seeming to be repeated. In this view, the interview guide remained with ten (10) questions that were recognized as relevant to the study. The data collection process took place for the period of two months.

Data analysis procedure

Analysis of qualitative and quantitative data were conducted independently and concurrently. For the responses from semi-structured interview, qualitative analysis, six steps as described by Braun et al. (2017) were devised for analysis. The transcriptions were read and re-read line by line to become familiar with the data. The prioritization of themes and sub-themes was enabled by the patterns and categories revealed in the analysis. To make them clear and relevant, these topics undergone a thorough review, definition and naming process. The analysis resulted to three themes: Conceptualization of assessment methods, factors for selection of relevant assessment methods and challenges on selection and integrating relevant assessment methods in teaching and learning 3D geometry.

On the other hand, the cclassroom observation protocol data were analyzed through Microsoft Excel whereby means, and standard deviations for all variables were computed. As the classroom observation were rated by two raters, the Cohen-

kappa inter-rater reliability were computed and the coefficient was 0.79 which according to Cohen's (1960) kappa this coefficient indicates substantial agreement between raters.

Findings and Discussion

The findings of the study on investigating the use of technology-aided-task-based assessment methods in assessing the teaching and learning of 3D geometry were based on two objectives: To investigate Mathematics teachers' integration of technology-aided task-based assessment methods in teaching and learning of 3D geometry and to identify the challenges faced by mathematics teachers in selecting and integrating technology-aided task-based assessment methods in teaching and learning 3D geometry.

Investigating Mathematics teachers' integration of technology-aided task-based assessment methods in teaching and learning of 3D geometry

The findings of this objective were collected through classroom observation method and interview. From classroom observation, the findings indicated teachers' low ability in integration of task-based assessment methods in teaching and learning of 3D geometry. This was indicated by an overall mean (μ) and standard deviation (δ) of $\mu = 0.30$, $\delta = 0.0116$. Which indicates the implementation of technology-aided task-based assessment methods were not observed. The summary on the indication level is presented in the Table 1.

Table 1: Mathematics teachers' level of indication of task-based assessment methods during teaching and learning 3D geometry

Assessment parameter	$mean \pm Standard\ devition$	Level of indication
Assessment methods are aligned with 3D geometry concepts and skills	0.71 ± 0.023	Slightly observed
Assessment methods are differentiated to accommodate diverse student's abilities	0.02 ± 0.038	Not observed
Provision of clear instructions and expectations for the assigned tasks	0.00 ± 0.000	Not observed
Teacher's provision of guidance and support during task implementation	0.57 ± 0.011	Slightly observed
Students actively engage with the 3D geometry tasks	0.27 ± 0.003	Not observed
There are opportunities for collaborative problem-solving during task-based assessments	0.42 ± 0.009	Not observed
Students demonstrate their understanding of 3D geometry through the tasks assigned	0.08 ± 0.021	Not observed
Teachers provide constructive feedback on students' performance in task-based assessments	0.93 ± 0.005	Slightly observed
Teachers encourage students to reflect on their learning	0.01 ± 0.006	Slightly observed
Teachers utilize technology to facilitate and assess 3D geometry tasks	0.00 ± 0.000	Not observed
Overall mean	0.30 ± 0.012	Slightly observed

The findings revealed a marginal alignment of teachers' integration of task-based assessment methods with the concepts and skills of 3D geometry. This alignment was discerned through mean (μ) and standard deviation (δ) values, $\mu = 0.71$ and $\delta = 0.023$. However, there was an absence of evidence indicating a differentiation in assessment methods to accommodate diverse student skills. Despite the commendable efforts of teachers in offering guidance and support during task implementation, there were limited instances of active student participation in assignments, and the tasks themselves were not reflected into enhanced 3D geometry learning.
The study exposed a deficiency in fostering collaborative problem-solving, an essential element for successful learning, suggesting a potential weakness in promoting cooperative learning environments. These findings resonate with the finding drawn by Weldeana and Sbhatu (2017), who emphasized that a failure to involve students in various assessment tasks hinders the development of essential 21st-century skills such as problem-solving and critical thinking. Moreover, the results support the idea, as noted by Palm (2019), that teachers struggling to plan relevant assessment tasks, resulting in the use of methods that do not align with the intended learning competencies.

The research findings underscored the limited proficiency of teachers in incorporating technological-based assessment tasks, with none of the observed teachers utilizing technological devices in the teaching and learning process. This provides alarming evidence that either teachers have limited knowledge on how to integrate technology into assessment procedures or they have no access to technological tools. These results are consistent with the findings of Agyei et al. (2023) and Barakabitze et al. (2019), who asserted that teachers grapple with the challenge of limited knowledge when effectively utilizing technology for teaching and learning 3D geometry. Based on the findings, the integration of technology-aided task-based assessment methods is still a challenge to mathematics teachers.

On the other hand, the results from the interview after in-depth analysis resulted into three themes; mathematics teachers conceptual understanding of task-based assessment methods and technology-aided-task-based assessment methods, factors to be considered in selection of types of assessment methods in Teaching and learning, and challenges facing mathematics teachers in integrating technology-aided task-based assessment methods in classrooms.

Mathematics teachers conceptual understanding of task-based assessment methods and technology-aided assessment methods

The findings indicate limited understanding on mathematics teachers' knowledge on what task-based assessment methods mean. Most of participants identified questions and answers as among the task-based assessment methods. They described it as any type of questions given to students to assess for their understanding. This was verified by the following quotations:

> Task-based assessment is the type of assessment in which students are given activities to do. It can be classroom exercises or assignments. Learning 3D geometry require assessment tasks such as solving area and volume of 3D figures require students to solve as many as possible questions in the classes (Teacher MT3, school SC9)

> Task-based assessment methods include various methods in finding out how the students are learning. This include calculating 3D geometry questions to see how students perform these activities. The students can perform activities and students assess how they have performed and assign some marks (Teacher MT6, school SC1)

From the findings it is vivid that mathematics teachers have no clear knowledge on task-based assessment methods. Having clear conception on task-based assessment methods would help them on designing relevant assessment methods to improve students learning. This is verified by the findings by Brookhart (2011) and Koh (2011) who posited that teachers' conceptual understanding on task-based assessment methods enhance the design and integration in the classroom. In this view, teachers limited understanding of the methods affects their practices.

On the other side, teachers were able to express the meaning of technology-aided task-based assessment methods. They described it as any kind of assessment that are conducted through technological tools such as computers and phones. This can be verified by the response from one of participants:

> According to my understanding, technology-aided task-based assessment methods are the kind of assessment that are conducted by technological devices such as computers, recorders or phones. These are up to date means of improving the teaching and learning however it is very difficult to apply them in our environment (Teacher MT 14, School SC7).

The response from participant indicate that teachers they have an idea on the meaning of technology-aided task-based assessment methods. The responses further indicate that teachers do not integrate technology in their assessment procedures. These findings concur with the results obtained from the reseach conducted by Fahlgren et al. (2022) that teachers might have conceptual understanding of technological pedagogies but they lack practical skills to apply them in the teachimng and learning process.

Mathematics teachers were also asked on their knowledge on factors contributing to selection of assessment methods. The findings indicate that teachers' reasons for selection of assessment methods were based on affordability of the method in

terms of material availability, time convenience as well as cost implications but not on relevance of the method in terms of the competence intended to be achieved. This was echoed by the following quotations:

> From my understanding, the factors contributing to selection of a particular assessment method include students' accessibility to accomplish the tasks at a short time and ability to mark the assignment at a manageable time. As we have a large number of students per class, it is not easy to mark about two hundred exercise books every day. So sometimes I provide exercises that I can afford to mark within a short time. (Teacher MT1, school SC 5)

> Most of the time I use to write questions on the board and students write the solution in their exercise books. Sometimes I provide individual or group assignments for students to accomplish during their extra time. I use these methods because they are the only best method I am aware of (Teacher MT8, School SC6)

Teachers' familiarity with the approach and their preference for its user-friendliness are factors in the prevalence of methods for assessment. Teachers choose methods for assessment based on how easily they can provide prompt feedback. Thomas (2012) asserts that teachers ought to consider employing assessment strategies that motivate students to participate actively in the process of teaching and learning. Based on the teachers' insights, it is vivid that teachers do not consider relevance of the assessment method based on how productively it can enhance students learning.

To identify the challenges faced by mathematics teachers in integrating relevant assessment methods in teaching and learning 3D geometry.

Teachers identified various challenges affecting them in integrating task-based assessment methods in the in teaching and learning 3D geometry. The major reasons mentioned were knowledge on particular methods. They mentioned other factors as time in planning the tasks, monitoring students when practicing the method and feedback provision. This can be verified by the following quotations from participants:

> I get challenged in the use of other methods apart from that I always use. The reason behind is that I have no idea about other assessment methods. Most of the time, after teaching I provide questions to students to assess their understanding. The challenges I get from this method is that sometimes I fail to mark all exercise books as we have a large number of students in classes, it is hard to mark all works all the time (Teacher MT2, School SC4)

> I am aware that in a revised curriculum which is competence-based curriculum we are emphasized to employ student-centered teaching and learning methods that encourage students to engage in the learning process. It is evidently that even assessment methods should be student centered. The problem of not involving students in assessment is that it is time consuming to engage students in planning such as preparation of assessment materials and supervision of activities (Teacher MT5, School SC2)

From teachers' responses it shows that most of mathematics teachers do not employ task-based assessment methods due to limited knowledge on a wide range of assessment tasks. Teachers claim that they are aware of few methods and hence they use them in teaching all topics. This claim concurs with the findings with Kyaruzi et al. (2018) that knowledge on assessment methods promote its practice in teaching and learning. In this view teachers limited knowledge promote low practice in teaching and learning. In addition, teachers claimed on limited time in implementing task-bases assessment methods in teaching and learning and hence they avoid integrating relevant assessment methods. The study by Salamoura and Unsworth (2016) incouraged teachers in utilizing necessary resources such as time, materials and infrastructures to ensure students are actively engage in the learning process.

In addition, participants complained about the lack of technological infrastructures such as shortage of computers and unstable power supplies in their educational settings. They further reported limited knowledge on designing technological-aided assessment tasks. This can be evidenced through the following quotations captured from participants:

> It becomes a challenge to me in using technology in planning or delivering a lesson in class. In our school we do not have electricity, so it is difficult to use computer or any other technological tool as they need a source of power (Teacher MT3, School SC9)

> It is very hard to me to use technology such as computers to develop task-based assessment methods since I have no knowledge on how to use technology to assess students. Most of the time I use to write question on the blackboard and students copy on their exercise books to respond (Teacher MT2, School SC3)

Participants responses indicate that mathematics teachers do not integrate technology in assessment processes. Their claims about limited knowledge on using technology in assessment and limited access to technology facilities concur with (McCulloch et al., 2018) Britten and Cassady (2012) that teachers struggle in using technology for planning classroom assessments due to limited access in terms of facilities such as computers and internet. Insufficient resources hinder the adoption of digital tools in developing assessment activities through the use of digital tools.

Conclusion

The aim of the research study was to investigate teachers' practices in integrating technology-aided task-based assessment methods in the teaching and learning of 3D figures. The study employed classroom observation and semi-structured interview to teachers. The main finding from both methods of data collection indicate that teachers are faced with limited knowledge and skills in integrating technology in classroom assessment practices. Teachers reported lack of knowledge on the use of digital tools, limited access to digital tools and other technological devices as among the challenges faced them in integrating technology-based assessment methods. Theys could not use any kind of technology apart from traditional ways of teaching and assessment such as paper and pencil tasks. Apart from technology use, mathematics teachers run challenges of employing task-based assessment methods in general. Teachers did not engage students in diverse learning activities such as engaging them in hands-on activities, exhibitions of projects as the learning of 3D figures involve various 3D objects manipulations.

Recommendations

To improve mathematics teachers' knowledge and skills in designing effective assessment methods the research recommends targeted training programs for mathematics teachers to enhance their proficiency in implementing diverse assessment methods, with a particular emphasis on task-based assessment approaches. Creating interesting assessments becomes labor-intensive without digital tools, which restricts inventiveness and students' active engagement in learning. Using technology to plan relevant assessment tasks requires a sophisticated knowledge of the competence to be achieved, the available digital tools and the competence to operate a particular technology. It could be difficult for teachers who have not received wide-ranging training in this area to design assessment tasks that accurately reflect students' grasp of 3D geometry. These difficulties highlight the critical need for extensive professional development programs that equip teachers with the necessary technological know-how and techniques to smoothly incorporate digital resources into the assessment landscape, guaranteeing a more engaging and productive learning environment for students. Teachers are advised to undergo professional learning that could equip them with skills to deliver engaging and dynamic lessons.

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Observations And Proposals from The Pilot Implementation of Universal Health Coverage With Reference To Machakos County And Its Implication On The Digitization Of Healthcare In Kenya

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Abstract

Universal Health Coverage (UHC) is amongst the key global initiatives adopted by the United Nations as a part of the Sustainable Development Goals (SDGs) and is an agenda entrenched in the World Health Organization's constitution. The global initiative aims to ensure that communities have access to health services without undue exposure to financial hardship. To implement this agenda, the United Nations General Assembly passed a resolution on 12th December 2012 urging member countries to prioritize access to affordable and quality healthcare cutting across curative, promotive, palliative, and rehabilitative health services with expected positive general well-being and socio-economic outcomes. The government of Kenya, a member-state of the United Nations, thereto, has identified UHC as one of Her 'Big 4' Agendas and a key pillar to national development. Consequently, the Ministry of Health (MOH) with the involvement of the National Hospital Insurance Fund (NHIF), the Kenya Medical Supplies Agency (KEMSA) and the Council of Governors (COG) initiated a pilot program that envisaged to learn lessons that would aid a countrywide roll-out of UHC by 2022. Four counties were selected on the basis of varying social and health dynamics. Kisumu was selected for prevalence of infectious diseases such as HIV and TB; Machakos owing to injuries arising from road accidents; Nyeri for non-communicable diseases such as diabetes and finally; Isiolo due to nomadism. The project was launched on the 13th December 2018. Against this background, this paper outlines the challenges, strategies and interventions used by NHIF in conjunction with Pharm Access Kenya, a private consulting company; to sensitize and subsequently register members from the target population in Machakos County. The article highlights the successes and challenges encountered in piloting the program and makes recommendations on key areas that need to be improved in up-scaling UHC in the entire country. In response to the COVID-19 pandemic, the research proposes several innovations that can be implemented to serve as a valuable source of good practices and lessons learned for future policymaking in Universal Healthcare.

Keywords: Covid-19, digitization, Machakos County, NHIF, Universal Health Coverage

Introduction

According to Barasa et al, (2018), most developing countries are increasingly adopting and prioritizing their health policies toward UHC. With Kenya committed to achieving UHC by 2022, concerted efforts are being made to achieve UHC through the expansion of a wide range of health services to a larger population encompassing all citizens regardless of their socio-economic status. Chacha (2012) and Barasa et al, (2018) observe that Kenya is among a few other sub-Saharan countries such as Ghana, Nigeria, Rwanda, and Tanzania in up-scaling its contributory and/or prepaid public health insurance scheme through the NHIF.

The NHIF is a public institution established in 1966 to provide compulsory health insurance. It is a non-profit facility whose mandate since 1988 incorporates the provision of health care to both employees and citizens in formal and informal sectors. The NHIF is managed and run by the Government. The board of management is representative of key stakeholders that include, among others; the Kenya Medical Association (KMA), the Federation of Kenya Employers (FKE), the Kenya National Union of Teachers (KNUT), and the Central Organization of Trade Unions (COTU).

Membership to the NHIF is statutory for employees in the formal sector who contribute on a graduating scale depending on salary ranking. The highest monthly deduction is 1700 Kenyan shillings (17 USD).

Informal sector and/or self-employed membership is voluntary with a monthly contribution of 500 Kenya shillings (5 USD). The informal sector contributors include small and micro-enterprise industry members such as those in the Juakali, matatu, and the construction industry.

The NHIF also establishes partnership programs whereby individuals, corporates, and companies sponsor to support indigents such as orphans, vulnerable children, poor elderly persons, the disabled; and destitute families (NHIF, 2017).

NHIF is the major healthcare insurer providing 16% of healthcare coverage to Kenya's population of 45 million people (KNBS, 2010).

Theoretical issues

Colquhoun et al, (2013) emphasize that collaborations between various stakeholders can lead to improvements in addressing communication and research challenges within the health sector leading to stronger institutions among communities. These community and institutional synergies bring together stakeholders with diverse experiences in dealing with public health issues that includes its funding.

Although Colquhoun et al, (2013) mainly addresses common challenges facing community and university research collaborations, it informs this analysis in that the piloting and implementation of a program of such global magnitude like the UHC requires collaboration among many stakeholders.

The UHC is a major component of the implementation of Kenya's Big Four Agenda aimed at providing universal healthcare at affordable rates. The UHC is not free health coverage for all possible interventions and health care needs but rather an

intervention managed by the government through a sustainable national health insurer and the Ministry of Health. The UHC is aimed at alleviating the health burden by pooling resources to ensure that citizens are "not exposed to financial hardship in the event of severe or long-term illness.' (NHIF: 2019).

Despite several challenges in the operations of the NHIF which cites poor communication, poor management, political influence, unclear objectives, and lack of monitoring and evaluation programs among others (K. J. Wanjiru, 2014): this article focuses on observable successes and challenges that may have to be put into consideration during the implementation of the UHC program nationally. It specifically aims at harnessing the positive aspects for continued improvement and learning from the challenges.

Methodology

The study made observations in the field during the initial stages of piloting the UHC program in Machakos County. These observations were augmented with secondary data containing literature on the NHIF, the Ministry of Health and the government's Big 4 Agenda which are food security, provision of affordable housing, improvement of the manufacturing sector, and provision of affordable universal healthcare.

Literature was gleaned through use of various keywords elicited through Google Scholar search engines. Further primary data was collected through oral interviews with the implementing teams during the Pilot Implementation Phase of the UHC program in Machakos County.

The interview questions sought to find out how the target communities were mobilized to participate and enroll for the UHC and the methods used by the implementers to communicate with the stakeholders and prospective clients; with an aim of getting responses to provide further information on the challenges, success and/or failures in the piloting of the UHC. The information emanating from this analysis guided and informed the way forward in the countrywide rollout of the UHC.

The data collected for analysis included raw field data, oral information and statistical figures. The data was collected between November 2018 up to the end of March 2019 and the results presented through descriptive analysis.

Machakos County population data

Machakos County spans 5,953 km2. The 2009 Kenya Population and Housing Census put the Machakos County population at 1,098,584 people. The UHC implementation team projected the current population at an estimated 1,289,200 people.

SUBCOUNTY	LIVES REGISTERED	HOUSEHOLDS REGISTERED
Kangundo	100,201	42,517
Kathiani	102,038	38,190
Machakos Central	232,991	101,821
Masinga	111,675	40,643
Matungulu	116,335	49,038
Mavoko	127,849	51,849
Mwala	144,639	61,815
Yatta	129,079	54,083
Total	1,064,832	439,965

Observations and challenges in the implementation

Community Health Volunteers (CHVs)

This is an invaluable network as far as health programs in Kenya are concerned. They provide health education and services to families that may otherwise lack access to healthcare.

For purposes of implementing this project, the CHVs served their units of scope at the sub-location level under the guidance of the community health workers (CHEWs) who are mainly nurses and clinicians.

This arrangement worked positively as per the already existent design of the Ministry for Health whereby the CHEWS and CHVs synergize to deliver improved health outcomes within communities.

The challenge was that the importance of health care duties for the clinicians which are of paramount put pressure and extra tasks on the workers since they had to run the program concurrently with their normal duties.

Recruitment of agents

This was done by Pharm Access, a digital platform contracted by the NHIF with the support of the County Government of Machakos through its Department for Health. The advantage was that the County has access and goodwill with the citizenry thus affording Pharm Access goodwill within the communities.

The challenge was that the agents had to be trained on the job with slow take off that led to low registration outcomes within the first days. However, high literacy levels amongst the youth in the county ensured ease in outcomes once the program took off.

The Provincial Administration's support

This category comprising the County Commissioners office, Village/Ward Administrators took up the role of mobilizers in their respective villages through a door-to-door campaign strategy. They provided an invaluable input in implementing the pilot project leading to mobilization being successfully done at the household and church levels. This grassroots sensitization approach extended to Chief's barazas and market places.

At times they faced slight challenges because this was the same role taken up by the CHVs and reporting lines are different for the groups.

Card Printing, distribution and issuance

Card printing was an enormous task for NHIF which had to grapple with normal routine printing for her clientele and for the UHC. The officers had to work around the clock to meet deadlines. The downside was that some of the normal printing had to be delayed. The advantage is that alternative methods of member identification are applied with deepening of technological interventions within the rural set up through use of an existent NHIF portal.

Every printed card was delivered to the office of the Chief Officer-Public Health and Community Outreach for dispatch. This proved overwhelming for the County's resources and logistics to make deliveries alongside grappling with their other tasks. However, the NHIF Machakos office which collaborates closely with the county network in health assisted the Machakos county public health office to ensure timely delivery of cards to the clients.

It was further noted that whereas the collection of cards is a continuous task for the NHIF, it has a few challenges and bottlenecks because some clients collect their membership cards when they have a pressing need to utilize it when seeking health services.

Resources

The Machakos County Government, the NHIF and Pharm Access provided resources to ensure the smooth running of programs to support the project. These resources included, but not limited to; transport, human resource, mobilization tools such as radio and mobile phone messaging advertisements, barazas, meetings and posters.

Findings

During interviews with implementing teams, it was observed that various challenges emerged. Most of these challenges occurred due to misinterpretation of the government's purpose for the UHC registration resulting in citizen apathy and mistrust during the initial stages of the recruitment, collection of bio-data and subsequent registration.

For instance, some people claimed that the information would be used to aid political and electoral manipulations in the future. This was swiftly countered by the County government through mobilization of various strategies that corrected the misinformation. The use of local vernacular radio stations, conversations in barazas, churches, advertisements, mobilization of vans mounted with sound systems that voiced intention, packaged messages distributed to interest groups created awareness and rectified the misconception that the UHC had ulterior motives.

It was observed that some political voices misinformed supporters affiliated to them that the program belonged to their opponent; owing to an electoral dispute that was in court and was yet to be ruled upon. This was successfully dismissed within a short while even as the electoral matter was resolved in court. Further to this, the project enjoyed immense support from the County governor and government.

Part category of the target population was skeptical arguing that the government can neither provide free service nor offer quality services that meet the bar of acceptable healthcare. Other citizens were of the view that 'free' services can never be good enough and are just a gimmick to make government look better. This was countered by personal experiences of the early majority that registered and accessed quality services. This information was quickly communicated through word of mouth thus changing the narrative within a span of barely a week following commencement of the exercise.

The situation above could initially not be countered and was sometimes exacerbated by Community Health Volunteers (CHVs).The reality that many of them initially had a poor grasp of their mandate and little conceptualization of UHC despite being the link persons with communities caused a poor head start. This was countered with close collaborations with team leaders who ensured that knowledge loopholes were sealed.

Some setbacks also emanated from an underdeveloped road network in some regions in the interior of Machakos County leading to high overheads and difficulties in reaching some households. The teams used various modes of transport such as motor vehicles, motorcycles, and walking on foot resulting in time wastage to reach some critical populations. Some stakeholders, facilitators, and volunteers complained about poor facilitation hence feeling that they ought to have been paid more for their role in the implementation.

A low level of computer technology penetration was noted in some regions. The M-Tiba platform that was used to record information though deemed simple and easy to use; wasn't necessarily perceived as such by some villagers and was treated with some level of indifference. However, it was noted that the government is reorganizing the NHIF through digitization and by extending services through its 37, 000 bank agents. This will open Medicare to more customers at entry level including in towns and cities.

The pilot project mainly used locals to conduct registration allowing relative ease in gathering of information. There was easy flow of conversation that was freely conducted in the Kamba language which served to create rapport, infuse warmth and hence fostered buy-in. The few implementers that couldn't communicate in the local languages used Kiswahili, one of

Kenya's national languages whose syntax is close to Kamba and thus easy to communicate as a lingua franca.

Despite the cited challenges experienced in initiating piloting of the UHC in Machakos County, it was noted that the there are certain advantages of implementing the program through the NHIF. For instance, the NHIF enjoys immense goodwill among the rural communities in Machakos County. There is a notable positive impact on those who have enjoyed the benefits offered by the NHIF due to its brand penetration and recognition at the grassroots. This observation was reported in other counties during the piloting in Isiolo, Kisumu, and Nyeri and is an indication that there are many Kenyans who are sick and in need of medical care. The UHC aimed at ensuring that such people are not left out. On the other hand, however, the PharmAcess agents working alongside the NHIF implementing team were not as recognizable from the onset.

The Community Health Volunteers' (CHVs) network within communities is equally excellent. There is acceptability of the volunteers as they are familiar members of the community and that it is employment in the face of high levels of unemployment in Kenya.

There were job opportunities for unemployed youth who found purpose to participate in the exercise as agents or CHVs. They felt included, valued and engaged. The youth should generally be encouraged to take up the opportunities when UHC will be implemented in the rest of the country. Moreover, the program has advantages for the literate youth as well as for providing an opportunity to further entrench the NHIF brand across the country.

Further opportunity to leverage health programs for UHC on CHVs exists as evidenced by the role of the CHVs in the subject discussed in this paper. For instance, the Kenya Quality Model for Health (KQMH), training course for health sector workers; is considered excellent and relevant by health practitioners in Kenya. The KQMH training manual was developed by the Ministry of Health and development partners for the training of health managers and practitioners. It outlines the training and health service delivery needs at all levels of training and health management. This is a good starting point for utilizing the CHEWs who have undergone training to induct the CHEVs before launching the UHC countrywide.

Another opportunity noted is that the Community Health Volunteers' (CHVs) reach within communities they serve is excellent with underlying opportunity to leverage on the KQMH. More collaboration between communities, the Ministry of Health and other government agencies would deliver an excellent model for UHC.

Owing to changes in the management of health services and devolvement oh health services to the County level, the NHIF has strengthened insurance services to the grassroots with marked improvements in the payment of claims. Moreover, the referral system allows easier access to basic healthcare and within where citizens reside with cases that specialized care being escalated to more advanced hospitals.

It was initially noted that there was a lot of negativity emanating from people who are critical of the status quo. Prospective clients had a poor grasp of what was being done. Some did not understand that the pilot was meant to make interventions that correct ills associated with the status quo. These negative attitudes slowed down the activity because it took a long time to explain to the population.

It is imperative that in the future, reliable outcomes must come from a controlled environment as per the implementation design with a view to understanding more about the population dynamics of each county and hence design interventions based on her uniqueness.

Residents of neighboring counties sought to register to benefit from the 'free' services hence posing the risk of distortions to the number of households as recorded by the National Population database and registered households was a delicate affair. This phenomenon was also observed in Kisumu County when the pilot project was launched. Gatonye Gathura (2019) echoes this observation by reporting that the "six-month free universal health care piloting [had exposed the fact that] a lot of Kenyans do not seek healthcare even when sick mainly because they cannot pay."

The engagement of multi-agencies such as the MOH, NHIF, Pharm Access, and the County Government of Machakos, the Ministry of Education, and the Provincial Administration had some advantages and disadvantages. For instance, the teams developed synergy through the diverse sharing of ideas and rich experiences. This approach culminated in constructive mobilization. The implementation strategy and period provided an avenue for the project implementers to bond. However, the process slowed down decision-making owing to cross-consultation on various issues.

Although the NHIF holds vast experience in distributing membership cards, the project was design was that the County Government Department of Health takes up the role. The resultant effect of this were hiccups in distribution that especially were a result of heavy work load for staff therein. However, owing to a cordial work relationship the departments worked together to ensure delivery as NHIF gave assistance to curb slow outcomes.

The printing of cards was an arduous task with targets with a short period. NHIF had to do all the printing as the other stakeholders have no experience in that part of the exercise. The CHEWs for instance, are trained in handling patients and not doing general administrative duties. Supervising requires more dedication into their training and preparation for the task as most of the work was new to them.

Recommendations

The UHC piloting in Machakos County targeted 1,289,200 lives spread out in 315,102 households. NHIF registered 1,064,832 people during the piloting launch. The implementing team worked closely with the county government of Machakos, the Ministry of Health as well as other enabler ministries and departments to register 82.6% of the targeted population. Multi-pronged strategies involving multiple agencies were used to achieve this success rate.

Despite this success, several challenges were observed. That Machakos County continues to register members at health facilities is evidence that the target to provide affordable healthcare for all by 2022 is achievable. This includes, but is not limited to training and incorporating community health workers for accelerated community participation in future.

Consequently, this paper recommends that lessons learnt from the implementation of the UHC in Machakos County should be adopted and applied in designing implementation programs in the rest of the country.

What kind of innovations in Universal Healthcare can be put in place in response to the COVID-19 pandemic to serve as a source of good practices and lessons learned to inform policy in the post-pandemic future?

Here are some key areas where innovations can be put in place:

1. Telemedicine and digital health: The pandemic has highlighted the importance of telemedicine and digital health solutions. Increased investment in remote consultations, virtual clinics, and digital health platforms can facilitate better access to healthcare services, reduce the burden on physical facilities, and improve patient outcomes. These technologies can be further developed and integrated into universal healthcare systems to provide efficient and convenient healthcare delivery in the post-pandemic future.

2. Data-driven decision making: Leveraging data analytics and artificial intelligence to monitor healthcare systems, predict outbreaks, and identify areas of intervention has proven crucial during the pandemic. Enhancing data collection, interoperability, and analysis capabilities can enhance the ability of universal healthcare systems to respond promptly to future health crises. Developing robust data infrastructure and implementing privacy safeguards will be essential for the effective utilization of health data.

3. Collaborative research and development: The pandemic has demonstrated the significance of global collaboration in research and development. Encouraging partnerships between governments, academia, and the private sector can facilitate the quick development and dissemination of vaccines, therapeutics, and diagnostics. Strengthening international cooperation frameworks and investing in research infrastructure can ensure the availability of adequate resources to combat future health emergencies.

4. Public health infrastructure and workforce readiness: The pandemic has exposed the vulnerabilities of public health infrastructure and highlighted the need for a well-prepared healthcare workforce. Building a resilient healthcare infrastructure with sufficient hospital beds, medical equipment, and testing capabilities is crucial. Furthermore, investing in the training and capacity building of healthcare professionals, both in terms of technical skills and crisis management, will be essential to respond effectively to future outbreaks.

5. Health literacy and community engagement: Effective communication and health literacy campaigns play a critical role in controlling the spread of infectious diseases. Emphasizing health education, promoting accurate information, and engaging with communities through various channels can improve public understanding and compliance with preventive measures. Investing in public health messaging and fostering community partnerships can enhance trust and cooperation during future health crises.

6. Supply chain management: The disruption of global supply chains during the pandemic revealed vulnerabilities in the availability of essential medical supplies. Strengthening domestic production capabilities and diversifying supply sources can ensure a more resilient and responsive healthcare system. Developing contingency plans, establishing strategic stockpiles, and improving coordination and transparency in the supply chain are vital in mitigating future risks.

By implementing these innovations, universal healthcare systems can not only respond effectively to the challenges posed by the COVID-19 pandemic but also serve as a repository of good practices and lessons learned for informing policy in the post-pandemic future. Embracing technological advancements, promoting collaboration, strengthening public health infrastructure, and empowering communities are key steps toward creating more resilient and equitable healthcare systems that can withstand future crises.

On whether or not the UHC rollout created any synergies and solutions in the area of Open, Distance, and Online Learning in Machakos or Kenya for that matter. In the context of Universal Healthcare in Kenya, Open, Distance, and Online Learning (ODL) can play a critical role in addressing various challenges and enhancing healthcare provision. Here are some areas of synergies and potential solutions:

1. Online healthcare education: ODL platforms can be utilized to offer specialized and accredited healthcare programs, such as nursing, pharmacy, or public health, to equip a larger number of individuals with the necessary skills and knowledge to contribute to the healthcare system. This can help address the shortage of healthcare professionals in Kenya.

2. Continuing professional development: ODL can serve as a platform for continuous training and education for healthcare professionals. Online courses and webinars can be conducted, focusing on emerging healthcare technologies, best practices, and updates on treatments and diagnoses. This can ensure that healthcare providers have access to up-to-date information, ultimately improving the quality of care delivered.

3. Telemedicine training: With the increasing adoption of telemedicine in Kenya, ODL can provide training programs for healthcare professionals on the effective use of telemedicine platforms, virtual consultations, and remote patient monitoring. This will enable healthcare providers to offer quality healthcare services remotely, especially in rural and underserved areas, bridging the healthcare access gap.

4. Public health campaigns: ODL can be utilized to educate the general public on preventive healthcare measures, such as proper hand hygiene, vaccination awareness, or disease prevention strategies. By spreading awareness through online platforms, ODL can empower individuals to take proactive steps toward maintaining good health and preventing illnesses, leading to improved overall public health outcomes.

5. Health information management: ODL can contribute to the development of skilled professionals in health information management systems. With the implementation of electronic health records and data analytics in healthcare facilities, trained personnel will be crucial in managing and analyzing health data effectively, supporting evidence-based decision-making, and improving healthcare outcomes.

6. Health promotion and behavior change: ODL can be leveraged to offer health promotion programs targeting specific population groups, focusing on healthy lifestyle choices, disease prevention, and behavior change. Through online platforms, interactive modules, and virtual counseling sessions, individuals can be empowered to make informed decisions regarding their health, leading to improved overall health outcomes.

To maximize the potential of ODL in the context of Universal Healthcare in Kenya, it is crucial to ensure access to the necessary technological infrastructure, affordability of internet services, and digital literacy among the target population. Collaboration between educational institutions, healthcare providers, and the government is also essential to develop and implement sustainable and context specific ODL initiatives.

What kind of innovations in Universal Healthcare can be put in place in response to the COVID-19 pandemic to serve as a source of good practices and lessons learned to inform policy in the post-pandemic future?
In response to the COVID-19 pandemic, several innovations in Universal Healthcare can be implemented to serve as a valuable source of good practices and lessons learned for future policymaking. Here are some key areas where innovations can be put in place:

1. Telemedicine and digital health: The pandemic has highlighted the importance of telemedicine and digital health solutions. Increased investment in remote consultations, virtual clinics, and digital health platforms can facilitate better access to healthcare services, reduce the burden on physical facilities, and improve patient outcomes. These technologies can be further developed and integrated into universal healthcare systems to provide efficient and convenient healthcare delivery in the post-pandemic future.

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By implementing these innovations, universal healthcare systems can not only respond effectively to the challenges posed by the COVID-19 pandemic but also serve as a repository of good practices and lessons learned for informing policy in the post-pandemic future. Embracing technological advancements, promoting collaboration, strengthening public health infrastructure, and empowering communities are key steps toward creating more resilient and equitable healthcare systems that can withstand future crises.
Did the UHC rollout create any synergies and solutions in the area of Open, Distance, and Online Learning in Machakos or Kenya for that matter? What can be done and not what's been achieved so far? In the context of Universal Healthcare in Kenya, Open, Distance, and Online Learning (ODL) can play a critical role in addressing various challenges and enhancing healthcare provision. Here are some areas of synergies and potential solutions:

1. Online healthcare education: ODL platforms can be utilized to offer specialized and accredited healthcare programs, such as nursing, pharmacy, or public health, to equip a larger number of individuals with the necessary skills and knowledge to contribute to the healthcare system. This can help address the shortage of healthcare professionals inKenya.

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Conclusion

At a time when the government aims to increase universal health coverage from the current 36% to 100%, the lessons from the other pilot projects in Isiolo, Kisumu, and Nyeri must be collated to inform the national UHC program. The lessons could also be taken into account to further inform ongoing reforms at the NHIF as it transforms itself into an organization that can adequately handle universal and sustainable healthcare.
To maximize the potential of ODL in the context of Universal Healthcare in Kenya, it is crucial to ensure access to the

necessary technological infrastructure, affordability of internet services, and digital literacy among the target population. Collaboration between educational institutions, healthcare providers, and the government is also essential to develop and implement sustainable and context-specific ODL initiatives.

As at the time of presenting this paper, the NHIF Act had been repealed drastically and replaced by SHIF (Social Health Insurance Fund). This new fund incorporates a digital element as well as the utilization of Community Health Promoters (CHPs) thereby equipping the grassroots health providers with the digital ability to identify and keep track of the health needs of the community members. However, this attest development falls outside the scope of this paper.

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The Mathematics-Language Proficiency: The Learners' Perspective

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Abstract

Mathematics is considered a difficult school subject by majority of learners. For many learners, mathematics is a series of hurdles and challenges-a task made with continued failure and seeming irrelevance in spite of the value that mathematics plays in society. The effect of this has been unwilling class participation, disinterestedness, haphazard solving of mathematical tasks, plus low achievements and failure to communicate mathematics. The latter effect is important in application of mathematics in occupations such as building, construction, engineering and accounting. This state of affairs propagated the topic of the paper: "The Mathematics-Language Proficiency: The Learners' Perspective". The objective was to find out the nature of the relationship between proficiency in mathematics vocabulary and conceptual understanding of mathematics. The study drew on Vygotskian Socio-Cultural Theory (SCT) and used a multiple-case study design. The sample size of the study was 1353 participants comprising of 1339 form three learners and 14 mathematics teachers in Bungoma South Sub-County. Data were collected by questionnaires, classroom observations and interviews. The study found out that there exists a strong positive relationship between mathematics vocabulary and conceptual understanding. Further learners were unable to interpret the meaning of some mathematics solutions after solving the question correctly. The study concluded that proficiency in mathematics vocabulary is necessary but not sufficient for conceptual understanding of mathematics. The study recommends learners to be supported in communicating mathematics ideas both verbally and in writing during mathematics lessons to broaden their conceptual understanding of mathematics.

Keywords: Mathematics, mathematics vocabulary, Proficiency, Conceptual Understanding

Introduction

The importance of integrating language aspects into school mathematics has been advocated by researchers and educators (Prediger & Zindel, 2017; Heller & Morek, 2015; Dale, 2015). Eidelwein & Mottin (2021) note that language consists of words which are labels for ideas that may suggest different meanings to different people. Hence words acquire meaning within a particular discourse community of people without which every individual has to form their own meaning from the environment.

Learning of mathematics is concerned with acquisition of concepts, which in most cases are stated in the learning objectives. Knudsen et al. (2017) point out that learning of concepts is expressed in words, phrases, labels or symbols. While these words or phrases have specific meaning in mathematics, their meanings in other contexts may be diverse. The variance in meanings between usage of mathematical words in lay talk and in Mathematics context is a source of misconception for some learners.

Further insight into the place of language in learning mathematics comes from Thompson and Rubenstein (2010). They state that language is the tool for most learning and communication in the mathematics classroom. Thompson and Rubenstein argue that mathematics literacy should be an essential and regular component in the mathematics lessons. Conceptual understanding is attained when appropriate language of mathematics is used for communication in mathematical learning contexts because concepts are conveyed through language.

Riccomini et al. (2015) not only contend that language is a critical issue in learning mathematics but also notes that most learning is achieved through oral language. They note that language and communication are vital in learning, understanding and applying mathematics. They also write that in order to communicate using mathematical language, several elements must be present; these include sound mathematical vocabulary, numerical fluency and comprehension skills. Without the necessary mathematical language and vocabulary skills to access mathematics, students can be faced with barriers in understanding of the subject.

Wilkinson et al. (2018) make it clear that the dilemma facing students is the overlap between ordinary language and the language of mathematics. She notes that mathematics language is used to convey concepts that have little relevance to and have no correlation with lay-talk. She asserts that learning mathematics language is a challenge to students since it can only be learned in schools. Empirical evidence demonstrates that learning and using the language of mathematics is not an easy task (Chow et al., 2021) more so to English language learners (ELL), also referred to as L2, who have to learn the language of instruction first. The ELL are expected to interpret the meaning of the ordinary English first before delving into mathematical English. Thus language plays a vital role in mathematics learning and demonstrating these competencies in a second language (or third) language is a challenging endeavor.

More studies in the use of language in mathematics classrooms have commented on the need for classroom talk to move from every day to more technical use of language (Han, 2013; Riccomini et al., 2015). Riccomini et al argue that Mathematical language has to be taught in classrooms just like any other school subject such as Geography and Economics. He brings to the limelight Mathematical language as a system of communication with vocabulary, grammer, syntax, and people

who use and understand it.

Umeodinka and Nnubia (2016) delve into the components of mathematical language: (i) A vocabulary made up of symbols or words (mathematics vocabulary). Symbols like π, ∑ and ≥ are used in mathematical language; (ii) Syntax. A grammar that has the rules of how these symbols and words may be put into use; (iii) Semantics. Words with mathematics meanings that are different from their everyday meanings and (iv) Lexical words. (p.12).

Semantics constitute of words with precise meaning in mathematics context but have diverse meaning meanings in non-mathematical situations. Such words include simplify, power, similar, side, right, compound, singular, base, characteristic, complementary, supplementary, determinant and evaluate. Everyday words are imbued with mathematics meaning as illustrated in Table 1.

Table 1: ***Examples of Semantics Used In Secondary Mathematics Syllabus***

Word	Meaning in Everyday Life	Meaning in Math
Singular	One thing, remarkable, great	A matrix without inverse (as in singular matrix)
Similar	Looking alike in appearance	Exactly the same shape
Origin	The beginning, as in origin of man	Point of intersection between x and y axis (0,0)
characteristic	Feature	Whole number part of logarithm
Mean	(adj.) stingy, (v) to intend	Average
Root	the underground part of a plant	The quantity raised to the power 1/r
Table	Furniture	An arrangement of numbers, symbols or words to exhibit facts or relations
Point	Idea, statement	Dot(.) delineating whole number and decimals
Area	a space or surface	The quantitative measure of a plane or curved surface
Expression	a look indicating a feeling	A symbol representing a value

Syntax in mathematical language refers to rules of grammar in mathematics. Challenges of understanding a concept arise when a concept is made up of the relationship between two words. Examples of relationships are given as follows: Prime numbers less than 9; A father is 4 times as old as his son; Nekesa is as tall as Otieno and Anindo earns £ 6 more than Juma. Lack of direct correspondence between symbols and words is also part of syntax. For example, the number x is 6 less than the number y is not: $x = 6 - y$ but it is $x = y - 6$.

The mathematics vocabulary component is made up of terminologies specific to mathematics subject; these may also be referred to as technical terms/terminology, mathematics terms or simply mathematics words. Mathematics vocabulary as argued by Freeman (2018) include words such as polygon, hypotenuse, integer, logarithm, surds among others. Regardless of the learner's first language, the meanings of these words must be known in international mathematics community circles. Research studies have shown that mathematics words used in mathematics curriculum are generally difficult for learners to comprehend irrespective of their linguistic and cultural circumstances. Hence learners struggle to cram algorithms but fail to see mathematics as sensible and useful in everyday life (Abu & Amit, 2022).

Objectives of learning Secondary Mathematics point out five out of twelve competencies embedded in Mathematical language. They state that learners should be able to: Think and reason precisely, logically and critically; Communicate mathematical ideas; Concretise, symbolise and use mathematical relationships in life (Ministry of Education, Science and Technology, 2002). Studies reveal that learners do not know how to explain concepts, a key feature of conceptual understanding (Gurefa, 2018; Mberia & Mwangi, 2018; Venesa, 2019) which created a gap for this paper.

This state of awareness has necessitated this paper which addresses one out of four objectives of a larger study which sought to explore learners' proficiency in mathematical language and their conceptual understanding of mathematics in secondary schools in Bungoma County, Kenya.

2. Theoretical Framework

The theory that guided this paper is that of Vygotskian Socio-Cultural Theory (SCT) which emphasises the importance of using a language in social situations, as a necessary herald to individual learning (Vygotsky, 1987). Vygosky's perspective on the role of language in learning can be explained in two ways: First, language accommodates a medium of learning. This means that learning can basically take place in a social context and social interaction is the essence of learning. Second, language is an instrument that assists a learner to think. A learner conceives and perceives a mental picture through a familiar language before it is verbalised or expressed in signs (Perez & Alieto, 2018).

In the case of learning mathematics, native speakers of a language of teaching and learning are assumed to have advantage over their peers, L2 and L3 because they already have the register of the language and hence can visualise a variety of mental pictures easily. SCT posits that when a learner is familiar with the academic language s/he can learn individually through interaction with peers and even by reading text books. It becomes apparent that language of mathematics (which comprises of both technical and non-technical words) is pivotal as a channel of mediation on both social level and individual level.

Vygostsky strongly claims that concepts cannot be acquired in conscious form without language and a child cannot have a conscious understanding of concepts before they are explained in a related context using language (Vygotsky, 1987). SCT has been applied by Huang and Normandia (2007) in a study to examine linguistic features of students' written discourse in secondary school mathematics in Central New Jersey in United States of America. Similarly, Semeon and Mutekwe (2021) applied SCT to explore Perceptions about the use of language in classrooms in South Africa.

The Vygotskian socio-cultural approach to classroom promotes effectiveness in teaching and learning and it is for this reason that this study adopted the socio-cultural perspective as the theoretical framework. Learners receive information through lexical language (a variable in objective i). They interpret mathematical idea in the information by use of specialised and mathematics language of mathematics (variables in objective ii and iii). They finally present the idea on paper in symbols or diagrams displaying conceptual understating (dependent variable).

3. Method

The empirical enquiry employed a multiple-case study. The context for the study was form three mathematics classes in secondary schools in Bungoma South Sub-county, Bungoma County in Kenya. Data were collected through classroom observations, teacher and student interviews and questionnaires.

3.1 Sample

The sample of the study comprised of 1339 form three L2 students and 14 mathematics teachers drawn from Sub-County Schools (SCS) (695), County Schools (CS) (424) and Extra-County School (ECS) (220) with fourteen (14) teachers, two each from ECS and CS and 10 from SCS.

3.2 Instruments

Data were collected through classroom observations, teacher and student interviews and questionnaires. A total of 17 lessons of 40 minutes in length were observed and the researcher took field notes during classroom observation. Observations helped the researcher to get a feel of how students use mathematical language in general and capture the context in which learning took place. This paper focusses on objective three of the study: learner' proficiency in mathematics vocabulary and conceptual understanding of mathematics and reports findings from student questionnaire.

4. Findings and Discussions

An interesting finding across cases is that students faced same challenges in interpreting mathematics words as shown by equal number of vocabularies with a score of zero in the column for CORRECT meaning as presented in **Tables 4.1, Table 4.2 and Table 4.3.**

Table 4.1: ***Students' Level of Proficiency in Mathematics Words (SCS)***

S/N	List of Vocabulary	Meaning of the Word			Give a symbol, mark, picture or drawing/example		
		Correct	Confused	Blank	Correct	Confused	Blank
1	Index	22(4.0%)	35.9	60.1	35(6.3%)	65.7	28
2	Logarithm	0(0%)	44.0	56.0	0(0%)	59.5	40.5
3	Mantissa	0(0%)	14.7	85.3	0(0%)	43.1	56.9
4	Equation	77(13.8%)	37.2	49.0	115(20.4%)	58.6	21.0
5	Co-ordinate	0(0%)	18.3	81.7	4(0.8%)	30.2	69
6	Isosceles triangle	217(38.5%)	19.0	42.5	233(41.4%)	48.6	10.0
7	Perpendicular	118(20.9%)	32.3	47.1	114(20.2%)	64.8	15
8	Cartesian Plane	59(10.6%)	38.0	51.4	141(25.0%)	54.3	20.7
9	Vertex	0(0%)	41.7	58.3	5(0.9%)	8.0	91.1
10	Diagonal	0(0%)	73.7	36.3	171(30.3%)	53.6	15.1
11	Bisector	40(7.1%)	40.9	52	111(19.7%)	66.0	14.3
12	Angle	45(8.0%)	32.0	59.1	121(21.5%)	45.0	33.5
13	Linear Scale Factor	0(0%)	0	100	0(0%)	0.1	99.9
14	Pythagoras theorem	117(20.8%)	49.2	30	228(40.4%)	52.6	7
15	Hypotenuse	93(16.5%)	40.5	43	123(21.9%)	49.1	29
16	Obtuse angle	155(27.5%)	30.5	42	175(31.0%)	59	10
17	Polygon	11(2.0%)	48.7	49.3	158(28.0%)	53.6	18.4
18	Integers	16(3.0%)	14.4	82.6	0(0%)	30.1	69.9
19	Transversal	36(6.5%)	30.5	63	0(0%)	49.5	50.5
20	Prime number	176(31.3%)	30.7	38	226(40.0%)	34.5	25.5
21	Square number	1(0.1%)	20.9	79	8(1.5%)	30.4	68.1
22	Standard form	0(0%)	37.5	62.5	1(0.1%)	58.9	41
23	Convex quadrilateral	0(0%)	0	100	0(0%)	3.2	96.8
24	Inequality	0(0%)	29.6	70.4	9(1.7%)	47.3	51.0
25	Cuboid	39(7.0%)	44.2	48.8	74(13.2%)	49.0	37.8

Results in Table 4.1 indicate that learners in SCS hardly stated the meaning of logarithm, mantissa, coordinate, vertex,

diagonal, linear scale factor, square number, standard form, convex quadrilateral and inequality, as displayed by a score of 0(0%). Correlation coefficient between variables was positive and strong (0.798) implying direct dependence of variables and further implying that learners were proficient in mathematics words therefore attaining conceptual understanding of mathematics. Results of CS mirror SCS given a strong positive correlation of 0.778 between variables as depicted in table 4.2.

Table 4.2: ***Students' Level of Proficiency in Mathematics Words (CS)***

S/N	List of Vocabulary	Meaning of the Word			Give a symbol, mark, picture or drawing/example		
		Correct	Confused	Blank	Correct	Confused	Blank
1	Index	30(9.1%)	32.0	58.1	31(9.5%)	59	30.5
2	Logarithm	0(0%)	67.0	33.0	301(90%)	90.5	9.5
3	Mantissa	0(0%)	39.8	60.2	0(0%)	73.1	26.9
4	Equation	56(17%)	23.4	59.6	118(35.5%)	42	22.5
5	Co-ordinate	0(0%)	22.4	77.6	6(1.9%)	35.1	63
6	Isosceles triangle	200(59.8%)	20.2	20	229(68.4%)	30.0	1.6
7	Perpendicular	82(24.7%)	35.3	40	91(27.2%)	63.8	9
8	Cartesian Plane	71(21.2%)	56.1	32.7	87(26.0%)	63	14
9	Vertex	0(0%)	49.4	50.6	10(3.0%)	7.1	89.9
10	Diagonal	0(0%)	76.5	23.5	140(41.8%)	29.2	29
11	Bisector	54(16.3%)	60.7	23	163(48.7%)	51	0.3
12	Angle	43(13.0%)	47.5	39.5	149(44.5%)	31.5	22
13	Linear Scale Factor	0(0%)	0.1	99.9	0(0%)	19.6	80.4
14	Pythagoras theorem	144(43.2%)	31.8	25	222(66.3%)	33	0.7
15	Hypotenuse	82(24.6%)	41.4	34	164(49%)	22.0	29
16	Obtuse angle	155(46.3%)	31.7	22	130(39.0%)	58	3
17	Polygon	26(8.0%)	69.2	22.8	157(47.0%)	27.6	22.4
18	Integers	23(7.1%)	18.9	74.0	0(0%)	35.3	64.7
19	Transversal	46(14%)	41.0	45	0(0%)	51.5	48.5
20	Prime number	165(49.4%)	33.6	27	177(53.5%)	22.5	24
21	Square number	134(40%)	34.2	35.8	151(45.1%)	31.9	23
22	Standard form	0(0%)	56.7	43.3	0(0%)	69.0	30.9
23	Convex quadrilateral	0(0%)	0	100	0(0%)	3.5	96.5
24	Inequality	0(0%)	87.5	12.5	16(5%)	47.5	47.5
25	Cuboid	43(13.1%)	63.9	23	81(24.2%)	51	24.8

The terms most confused were the same as in SCS except that in CS the vocabulary 'square number' was not among the list of confused words. The findings imply same level of challenges in interpreting mathematics terms across cases. Findings in ECS also portray the same pattern of interpretation of mathematics vocabulary as indicated by a strong positive correlation of 0.709 between variables in Table 4.3.

Table 4.3: ***Students' Level of Proficiency in Mathematics Words (ECS)***

S/N	List of Vocabulary	Meaning of the Word			Give a symbol, mark, picture or drawing/example		
		Correct	Confused	Blank	Correct	Confused	Blank
1	Index	25(12.5%)	37.5	50	25(12.5%)	50	37.5
2	Logarithm	0(0%)	37.5	62.5	0(0%)	87.5	12.5
3	Mantissa	0(0%)	50	50	0(0%)	50	50
4	Equation	50(25%)	12.5	62.5	125(62.5%)	25	12.5
5	Co-ordinate	0(0%)	62.5	37.5	(5025%)	62.5	12.5
6	Isosceles triangle	200(100%)	0	0	175(87.5%)	12.5	0
7	Perpendicular	75(37.5%)	37.5	25	175(87.5%)	12.5	0
8	Cartesian Plane	75(37.5%)	37.5	25	75(37.5%)	50	12.5
9	Vertex	0(0%)	37.5	62.5	25(12.5%)	12.5	75
10	Diagonal	0(0%)	62.5	37.5	125(62.5%)	12.5	25
11	Bisector	75(37.5%)	50	12.5	125(62.5%)	37.5	0
12	Angle	50(25%)	37.5	37.5	125(62.5%)	12.5	25
13	Linear Scale Factor	0(0%)	0	100	0(0%)	50	50
14	Pythagoras theorem	125(62.5%)	12.5	25	175(87.5%)	12.5	0
15	Hypotenuse	100(50%)	25	25	150(75%)	12.5	12.5

16	Obtuse angle	125(62.5%)	25	12.5	0(0%)	50	0
17	Polygon	25(12.5%)	75	12.5	125(62.5%)	25	12.5
18	Integers	25(12.5%)	25	62.5	0(0%)	37.5	62.5
19	Transversal	50(25%)	37.5	37.5	0(0%)	62.5	37.5
20	Prime number	125(62.5%)	25	12.5	125(62.5%)	12.5	25
21	Square number	100(50%)	25	25	150(75%)	25	0
22	Standard form	0(0%)	50	50	2(1%)	62.5	25
23	Convex quadrilateral	0(0%)	0	100	0(0%)	37.5	62.5
24	Inequality	0(0%)	37.5	62.5	100(50%)	37.5	12.5
25	Cuboid	25(12.5%)	62.5	25	50(25%)	50	25

The same terms that challenged learners in CS were also noted in ECS. Overall, correlation coefficient across cases was strong implying that mathematics words are a preserve of mathematical contexts where students interact with them only in mathematics classes or while reading mathematics textbooks hence proficiency is not affected with contextual factors. The coefficients for objective iii are presented in

Table 4.4

Table 4.4: ***Pearson Correlation across Cases***

	SCS	CS	ECS
Mathematics words	0.798	0.778	0.709

All the above correlation tests were carried out with an N=25 cutting across to the multiple data present. Two tailed test was used for all the tests with a level of significance of 0.01.

The findings indicate that Pearson correlation coefficient across cases is positive implying that proficiency in mathematical language directly affects conceptual understanding. Furthermore, the findings reveal a strong positive correlation in objective iii ($r>0.7$) across cases giving two implications. Firstly, that there is a direct congruence between mathematics vocabulary and conceptual understanding. Secondly, the range of r is 0.089, a very small difference, implying that mathematics words are context free thus pose same challenges to learners irrespective of their linguistic background.

5. Conclusion

This paper arose from the need to find a way to help students communicate mathematics concepts clearly and precisely. Mathematics is communicated by mathematical language thus the paper explored a relationship between mathematics vocabulary and conceptual understanding. The paper recorded a strong positive relationship between mathematics vocabulary and conceptual understanding. The finding implies that mastery of mathematics vocabulary is necessary for conceptual understanding of mathematics which is an inescapable resource in communicating mathematics concepts. The study recommends learners to be supported in communicating mathematics ideas both verbally and in writing during mathematics lessons to broaden their conceptual understanding of mathematics. Such support will cut across pedagogy in mathematics, choice of tools and materials to be used in lessons and decision on the type of assessments that inspire learning mathematics for conceptual understanding.

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APPENDIX

Questionnaire of Mathematics Words

List of words	Give the meaning of the word	Give a symbol, mark, picture or drawing/example
Index		
Logarithm		
Mantissa		
Equation		
Co-ordinate		
Isosceles triangle		
Perpendicular		
Cartesian plane		
Vertex		
Diagonal		
Bisector		
Angle		
Linear scale factor		
Pythagoras theorem		
Hypotenuse		
Obtuse angle		
Polygon		
Integers		
Transversal		
Prime number		
Square number		
Standard form		
Convex quadrilateral		
Inequality		

Are Collective Bargaining Agreements Compromising Equity In Grade Promotion Of Post-Primary Teachers In Extra-County And National Schools?

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Abstract

The use of two different implementation approaches for the 2017-2021 Collective Bargaining Agreement of post-primary teachers casted doubts on equity in grade promotion because each union was affiliated to its own approach. Given that there were two unions at post-primary level, the purpose of this study was to compare equity accruable between them in Kakamega County. The objective was to determine the difference in equity between the use of scheme of service and the career progression guideline approaches based on Teacher Performance and Appraisal Development tool for 2017-2021. It was guided by a socialist economics of education theory. A comparative research design with a sample of 1,569 respondents from 5,923 was used. Systematic random sampling was used to select teachers in each union, purposive sampling for principals and saturated sampling for sub-county directors of education and union secretaries. The study enhanced content validity with internal consistency reliability of instruments at 0.877. In data analysis, gini permutation test found promotion to be marginally equitably allocated in Kenya Union of Post-Primary Education Teachers than in Kenya National Union of Teachers through 0.0567 and 0.0698 coefficients respectively. However, the pairwise correlation established plausible interactions between study variables at $\alpha = 0.05$ with membership in Kenya Union of Post-Primary Education Teachers being statistically insignificant to promotion ($p>.05$). The logistic regression analysis found a statistically significant difference ($p\leq.05$) between the two unions with an extra TPAD score in 2017, and teaching in extra-county and national schools reducing the odds of promotion to the next grade.

Keywords: Equity; Grade Promotion; Collective Bargaining Agreement; Trade Union; Scheme of Service;Career Progression Guidelines; Teacher Performance and Appraisal Development

Labour unions began and rose because of exploitative labour practices by employers after the industrial revolution (Hipp & Givan, 2015; Levi, Melo, Weigast, & Zlotnick, 2015). Labour unions were established to aid workers in identifying, airing and solving work related grievances such as low wages & salaries, unsafe working conditions, long working hours and career progression through CBAs. These issues set the stage for the formation of labour unions, with the Working Man's party being the world's first labour party to be formed in 1828 (Jensen, 1956).

The main aim was to anchor Collective Bargaining Agreement (CBA) as a panacea for grade promotion. The CBA concept got into international obligation as law, with the International Labour Organization (ILO) coming up with three conventions linked to the need for enhancement of peace and harmony in industrial labour relations. These are, Freedom of Association and Protection of the Right to organize Convention, 1948 (No. 87), Right to organize Collective Bargaining Convention, 1949 (No. 98) and the Collective Bargaining Agreement Convention, 1981 (No. 154). The conventions bore a common milestone resolution between employers and labour unions of adopting the right to bargain collectively and have legally binding CBAs that would be addressing issues of career progression of workers through grade promotions through the use of a single implementation approach for any given CBA.

As a result, in 1957 in Kenya, the Kenya National Union of Teachers (KNUT) was allowed by the colonial government to form and officially got registered as a trade union in 1959 (Mader, 2012). Kenya Union of Post-Primary Teachers (KUPPET) union was registered in 1998 for teachers in Post-Primary Education (PPE) institutions like secondary schools and other tertiary institutions whose employer was Teachers Service Commission (TSC). The Kenya Union of Special Needs Education Teachers (KUSNET) signed a recognition agreement with TSC as the third union on 3rd March 2021 and therefore did not take part in the operationalization of the 2017-2021 CBA. Further, the Universities Academic Staff Union (UASU) was registered in 2003 as a trade union for lecturers teaching in public universities in Kenya (Republic of Kenya, 2004).

The philosophies and ideals behind the formations of these teacher trade unions in Kenya were deeply rooted in the challenges, successes and lessons learnt by the early labour movement organizations, especially in the western world with the main focus on better remuneration and career progression through collective bargaining processes (Jensen, 1956). The adoption and use of scheme of service (SoS) approach as a single tool of implementation of CBAs on grade promotion of teachers from the onset of CBA criterion on promotions in Kenya since 2005 easily accounted for high equity levels (Code of Regulation for Teachers, 2005). The same tool was transcended into PPE in 2011 as the single approach in CBA implementation on grade promotions.

However, in 2016 following a new job evaluation exercise in the public teaching sector conducted jointly by both Salaries and Remuneration Commission (SRC) and TSC, a recommendation for an inevitable paradigm shift in policy from the "scheme of service approach" to a "career based strategy approach" was made (CBA Reference Manual, 2018). This

necessitated the signing of a new CBA between TSC and the teachers' unions, mainly KNUT and KUPPET on 25th and 26th October 2016 respectively. This new CBA was to be implemented with a new single implementation approach known as the Career Progression Guidelines (CPG) (Code of Regulations for Teachers, 2015).

Nevertheless, KNUT successfully protested in court for their members to be reverted back to SoS approach (KNUT Strike notice for 2nd January 2019; TSC petition no. 151 of 2018 dated 31st Dec 2018) while KUPPET continued preferring CPG as its single implementation approach for promotion of its members based on their respective Teacher Performance and Appraissal Development (TPAD) scores for the 2017-2021 period of the CBA. This resulted into the creation of two different, independent and parallel approaches implementing the same CBA to same teachers thus complicating the achievement of equity in promotion especially at PPE level where both unions were domiciled concurrently.

It is not easy to ascertain any statistically significant difference in equity in grade promotion of teachers at post-primary level in Kenya due to the application of the SoS as well as the CPG approaches in the implementation of the 2017-2021 CBA. Whereas CPG was rejected by KNUT on the basis of causing career stagnation, it was preferred by KUPPET on the basis of its strength in enhancing career progression of their members in PPE institutions. On the other hand, whereas SoS was preferred by KNUT on the basis of enhancement of equity in grade promotions of their members, it was rejected by KUPPET.

Compounded by the annual decline in the rate of access to teacher promotions witnessed in secondary schools from 12.9% in 2016 to 5.2% in 2020 in Kenya (Republic of Kenya, 2019b), Kakamega county led with a job stagnation of 15.7 years per grade (Republic of Kenya, 2020b) which is far beyond the ILO recommendation of a baseline of 3 years per grade through recommendation no. 154 of 1981 ILO convention further casting doubts on the effectiveness of the 2017-2021 CBA. The county further had the highest unionized members in both unions KUPPET and KNUT among the counties with the highest stagnation levels in Kenya.

The objective of the study was to ascertain the difference in equity in grade promotion of post-primary teachers between the application of the scheme of service and the career progression guideline approaches of the 2017-2021 Collective Bargaining Agreement, based on TPAD performance of teachers.

The study was guided by the Socialist economics of education espoused by Louis Blank (Colander, 1994) which in this study, revolved about cumulative distribution of teachers promoted in each grade from 2017-2021 to the cumulative distribution of the predictor TPAD performance in percentage scores from lowest to the highest while the conceptual framework depicts the effect of the implementation approach of the CBA (based on TPAD scores) on the outcome variable (equity in grade promotion measured by gini coefficient) controlling for teacher and school variables, as represented in Figure 1 for the interaction of the variables.

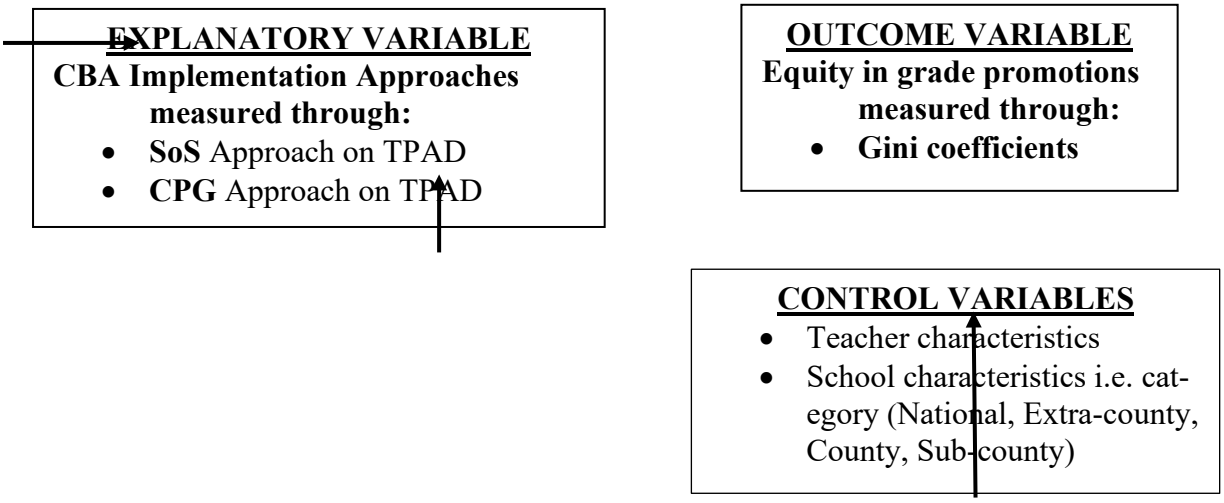

Figure 1: Conceptual Framework of CBA Implementation Approaches on Equity

Literature review

The Labour Relations Act (2007) defines a Collective Bargaining Agreement (CBA) as a foundational legal agreement made and signed between an employer and employees represented by the respective trade union on all matters related to salary, other benefits, and grade promotion for a specific period of time (Republic of Kenya, 2007). It operates on the principle of "equal pay for equal value of work done" hence becomes a common point of reference in case of any labour

dispute arising between employers and employees on grade promotions.

To ensure its smooth operationalization, a CBA gets attached to a single specific approach of implementation for grade promotion of workers (Lindy, 2011; Labour Relations Act, 2007). Most studies worldwide reveal that the strength of a given CBA lies with its implementation approach on career progression of its subjects (Jordhus-Lier, 2012). Indeed, in United States of America, case studies by Jones-White (2004), Fuller, Mitchell & Hartmann (2000) and Terry (2010) which targeted specific states of Miami-Dade County (Florida), Minneapolis and New York respectively found a direct positive relationship between the negotiated CBAs and the progression of tutors in their teaching cadres in the 19th century due to the application of a single tool per CBA. However, Nana (2017) established that as of 2014 the union density in United States had contrastingly dropped compared to the 1950s due to redundancy in career progression of tutors as a result of change in CBA implementation mode which from single approach to multidisciplinary approach in award of grade promotions through CBAs. This was during the advent of liberalization in education in the various states which impacted directly on the teaching sector giving rise to a wide range of variations in equity in grade promotions of tutors with the inability to determine the one with the most equitable distribution of grade promotions.

In Australia, there is a bi-partisan approach to award of grade promotions of teachers in the post early-childhood education system (Baccaro and Benassi (2017). One approach, the Modern Awards approach, is affiliated to the small-scale sectorial bargaining agreements whose promotions are structured in regular (annually) and equal intervals of awards with minimal wage increaments administered automatically within grades while the other approach which operates in freelance mode for both unionized and non-unionized teachers, known as the external regulator approach, is majorly controlled by the state without involvement of the unions and has no specific timelines for promotions. Traxler (1995) established that the two approaches complicate the ability to determine the exact levels of equity in grade promotions of teachers due to lack of a specific unified approach in the country. The study found 36% of teacher employees as being covered by Modern Awards through unions, 23% directly covered by the awards without any affiliation to unions while the remaining about 41% catered for promotions through the state-provided approach. That is, around three-fifths of total employees have wages and grade promotions not determined by the employer and employee, despite the Awards having been structured on skill level.

In Germany, total lack of implementation approach in CBAs on grade promotions of teachers complicate the ability to ascertain the exact levels of equity in grade promotions attributing such ambiguity to open clauses in the CBAs that are deliberately inserted for non-commital engagements and are usually contingent upon an initial agreement between the signatory social partners in the education sector (Haipeter and Lehndorff, 2014). There is always some leeway in designing the clause on career progression in the CBAs to allow for time to time negotiations.

However, there are high levels of equity noted in career progression of tutors in some countries in European Union due to lack of ambiguity in CBA implementation approaches. For instance, Smit (2014) asserts that there is high rate of grade promotions in teaching profession in Philippine largely attributed to CBAs that are implemented by a single approach. The approach is strongly anchored on tutor professional development tool that favours regular short term courses at the expense of the initial academic qualification that one joins the teaching profession with during recruitment.

Additionally, New Zealand realized high levels of equity in career progression of teachers from early 1991 (Peetz and Rasmussen, 2018) after the adoption of a single hybrid approach in implementation of its CBA that was tailored towards combining the ‘length of service’ and ‘academic qualifications’ in grade promotions of teachers.

In Africa, a case study of Southern African Development Community (SADC) countries by Zvobga (2019) undeniably argues that the use of International Labour Instruments found relevance in boosting equity in career progression of its employees when a legislation limiting the implementation of existing domestic CBAs in all member states to a single tool of approach was passed. This legislation on international treaties for workers in both monist and dualist legal systems in every jurisdiction process around SADC was a major boost that accounts for over 70% of equity levels in grade promotions of teachers in Madagascar.

In Kenya, the initial use of SoS approach only as a single approach of implementation of CBAs on grade promotion of teachers from the onset of CBAs as a criterion on promotions since 2005 easily accounted for high equity levels (Code of Regulation for Teachers, 2005). The same tool was transcended into Post-Primary Education (PPE) institutions in 2011 as the single approach in CBA implementation on grade promotions through the KUPPET union with similar ease in accountability in promotions in successive CBAs.

However, the combined use of two approaches upon the signing of the 2017-2021 CBA with SoS approach serving the interests of KNUT affiliated teachers and the CPG serving the interests of the KUPPET affiliated teachers complicated the ability to determine the equity levels in the grade promotions.

Methods

The study adopted a comparative research design since the design essentially compares two different groups to determine either similarities or differences between them for revelations on a common phenomenon (Lodico et al., 2006) which in this case were SoS versus CPG approaches on the same 2017-2021 CBA.

The study had a total population of 5,923 out of which a sample of 1,569 respondents were drawn for this study using a formula prescribed by Cochran (1977). Primary data was collected using questionnaires and interview schedules while secondary data was collected using the document analysis guide as guided by the Addendum to the Collective Bargaining Agreement (CA NO. 296 of 2016). The study adopted content validity while internal consistency method was used to test the reliability of the instruments with a Cronbach alpha co-efficient of 0.877.

In data analysis, the variables of the study were all measured on the interval scale. Pairwise correlation was used to establish plausible interactions between the variables while logistic regression analysis was done to depict the odds (likelihood) of a teacher getting promoted by virtue of belonging to a particular union (either KUPPET or KNUT) for comparison purposes (Greene, 2012; Sturdivant, 2013, Todaro & Smith, 2006)). Then gini coefficient was used to measure and determine the aggregate values of equity accruable in grade promotion for the two unions for comparison purposes. The Lorenz curve was used to show the graphical representation of the two promotion distributions for the two unions for purposes of comparison.

Results and discussion

Data for this study was collected in post-primary education institutions in Kakamega County from unionized teachers with the aid of Questionnaires. A response rate of 93.44 % of questionnaires was realized.

Descriptive Statistics

The distribution of TPAD scores among the respondents were as shown in Table 1.

Table 1: Distribution of Respondents' TPAD Scores

Variable	Mean	Std. Dev.	Min	Max
t51a2017	70.42144	8.667917	4	99
t51b2018	72.76782	96.01121	4	8181
t51c2019	72.43025	11.46462	6	766
t51d2020	74.45535	94.37813	45	7972
t51e2021	73.25815	9.695425	7	381

Note; t51a2017=2017 tpad score; t51b2018=2018 tpad score; t51c2019=2019 tpad score; t51d2020=2020 tpad score; t51e2021=2021 tpad score

Table 1 show that the highest mean TPAD score for the respondents was 74.46 in the year 2020 while the lowest was 70.42 in the year 2017. However, the highest standard deviation in the TPAD scores was 96.01 in year 2018.

Pairwise Correlation for the variables

In order to determine the plausible interactions (association between variables) that could be pursued further in the regression models involving TPAD scores, a pairwise correlation between grade promotion, union membership and TPAD scores for 2017-2021 at alpha = .05 was done and the correlation gave the results in Table 2.

Table 2: Correlation Matrix Between Promotion, Union Membership and TPAD Scores for 2017-2021

	t24dy	t29x	t51a2017	t51b2018	t51c2019	t51d2020	t51e2021
t24dy	1.000						
t29x	-0.045*	1.000					
	0.025						
t51a2017	-0.149	0.044*	1.000				
	0.000	0.000					
t51b2018	-0.012	-0.009	0.058*	1.000			
	0.555	0.416	0.000				
t51c2019	-0.128*	0.024*	0.454*	0.012	1.000		
	0.000	0.042	0.000	0.301			
t51d2020	-0.061*	0.015	0.039*	0.004	0.038*	1.000	
	0.002	0.209	0.001	0.755	0.001		
t51e2021	-0.072*	0.046*	0.448*	0.037*	0.295*	0.554*	1.000
	0.019	0.014	0.000	0.042	0.000	0.000	

The results in Table 2 show that union membership and TPAD scores 2017-2021 were statistically significant to teacher promotion ($p \leq .05$) at alpha = .05. Consequently, Pairwise correlation was done while controlling for teacher-level and school-level variables and results were as shown in Tables 3 and 4 respectively.

Table 3: Pairwise Correlation Results (Controlling for Teacher-Level Characteristics)

	t24dy	t62	t65
t24dy	1.000		
t62	-0.002	1.000	
	0.922		
t65	0.181*	-0.009	1.000
	0.000	0.440	

Note. t24dy=grade promotion; t62=gender; t65=designation

Table 3 shows that TPAD score was significant to promotion. The pairwise correlation results while controlling for school-level variables are shown in Table 4.

Table 4: Pairwise Correlation Results (Controlling for School-Level Characteristics)

	t24dy	t69	t610b	t71
t24dy	1.000			
t69	-0.032	1.000		
	0.111			
t610b	-0.051	-0.216*	1.000	
	0.010	0.000		
t71	0.016	0.021	-0.001	1.000
	0.478	0.112	0.933	

Note. t24dy=grade promotion; t69=sub county; t610b= school category; t71=designation in school

Table 4 shows that school category variable was significant to promotion. Since ($p \leq .05$) in both Table 3 and Table 4, then both union membership and TPAD scores were statistically significant to promotion hence pursued further in the regression.

Logistic Regression Analysis for Grade promotion and TPAD Scores

As a Consequence, three logistic regression models were developed. The first one was model 1 whose intention was to determine the effect of TPAD scores of 2017-2021 on grade promotion. The second model was model 2 which sought to find out the effect of TPAD scores 2017-2021 on grade promotion while controlling for teacher-level variables. The third regression model which was model 3, while controlling for both teacher-level and school-level variables, sought to find out the effect of TPAD scores 2017-2021 on grade promotion of teachers. The results of the three models are presented as model 1, model 2 and model 3 in a summarized format as Table 5.

Table 5: Logistic Regression Odds for the Association Between TPAD Scores (2017-2021) and Promotion

		Model 1 (t24dy)			Model 2 (t24dy)			Model 3 (t24dy)		
Variable	Variable label	OR (Std.Err)		*P*	OR (Std.Err)		*P*	OR (Std.Err)		*p*
t29x	1=KP;0=KN	.79	(.15)	0.195	1.08	(.14)	0.553	.84	(.10)	0.148
t51a2017	Tpad score	.97	(.02)	0.047	.96	(.01)	0.000	.95	(.01)	0.000
t65	3=C3 grade				.02	(.04)	0.029	.14	(.15)	0.056
t610b	3=EC school							.63	(.13)	0.031
	4=N school							.65	(.13)	0.037
Constant		3.70	(.34)	0.158	12.82 (19.22)		0.089	5.33	(2.5)	0.000
N		1,032			2,423			2,405		
LR chi2(df); Value		(5) 19.20		0.002	(10) 212.80		0.0000	(5) 73.56		0.000
Pseu-doR^2		0.0233			0.1089			0.0383		

Note. KP=KUPPET; KN=KNUT; t24dy=grade promotion; t29x=union membership; t51a2017=2017 tpad score; t65=designation; t610b= school category; EC=Extra County; N=National school

Results in Table 5 model 1, model 2, and model 3 show that membership in KUPPET was statistically insignificant on

promotion while controlling for teacher-level and school-level variables (p>.05) as shown by .195, .553 and .148 respectively. The final regression model was model 4 which sought to find out the effect of union membership on promotion while controlling for both teacher-level and school-level variables. The results were as shown in Table 6.

Table 6: Logistic Regression Odds for KUPPET Membership on Promotion Controlling for Both Teacher- Level and School-Level Characteristics

Logistic regression — Number of obs = 2,405; LR chi2(5) = 73.56; Prob > chi2 = 0.0000; Log likelihood = -923.07469; Pseudo R2 = 0.0383

Variable	Label	Odds Ratio	Std. Err.	Z	*p*>	|z|	[95% Conf. Interval]
t29x	1=KP;0=KN	.84	.10	-1.45	0.148	.659	1.06
t51a2017	TPAD	.95	.01	-6.88	0.000	.940	.966
t65	3=C3	.14	.15	-1.91	0.056	.019	1.05
t610b	3=EC	.63	.13	-2.15	0.031	.418	.959
	4=N	.65	.13	-2.08	0.037	.435	.975
	Cons	5.32	2.53	3.52	0.000	2.09	13.5

Note. _cons estimates baseline odds; KP=KUPPET; KN=KNUT; t29x=Union Membership; t51a2017=2017 TPAD Score; t65=Designation in school; t610b= School Category; EC=Extra County; N=National School

The results in Table 6 further show that, an extra score in TPAD in 2017 and teaching in extra county and national schools reduces the odds of promotion to the next grade.

Gini Permutation Test for Union Membership and Grade Promotion Based on TPAD Scores 2017-2021

Based on the null hypothesis for the objective;

H_O: There is no statistically significant difference in equity in grade promotion of post-primary teachers between the application of the scheme of service and the career progression guideline approaches, based on teacher performance.

Using the data provided in Table 5 on union membership and grade promotion for 2017-2021 and the data provided in Table 2 on TPAD scores for 2017-2021, the Gini Permutation Test was performed for this objective based on TPAD scores with the set seed 7227.

The results for the Gini Permutation Test for TPAD scores 2017-2021 were as shown in Table 7.

Table 7: Gini Permutation Test Results Based on TPAD Scores 2017-2021

Variable	*p*GiniPerm 2017	*p*GiniPerm 2018	*p*GiniPerm 2019	*p*GiniPerm 2020	*p*GiniPerm 2021
*P*val	.022	.034	.001	.002	.024
Stat	.0001	.0001	.0001	.0001	.0001

Based on Table 7, since $p \leq .05$ for each year for 2017-2021, the null hypothesis of equality of the two promotion distributions was rejected.

Furthermore, the Gini Permutation test results for the two unions are as shown in Table 8.

Table 8: Gini Permutation Test Results for Unions 2017-2021

Union	Gini coefficient
0=KNUT & Others	0.069759
1=KUPPET	0.0566518

From Table 8, the graphical presentation of the tabulation for the gini coefficients of the two unions is shown in the Lorenz curve in Figure 2.

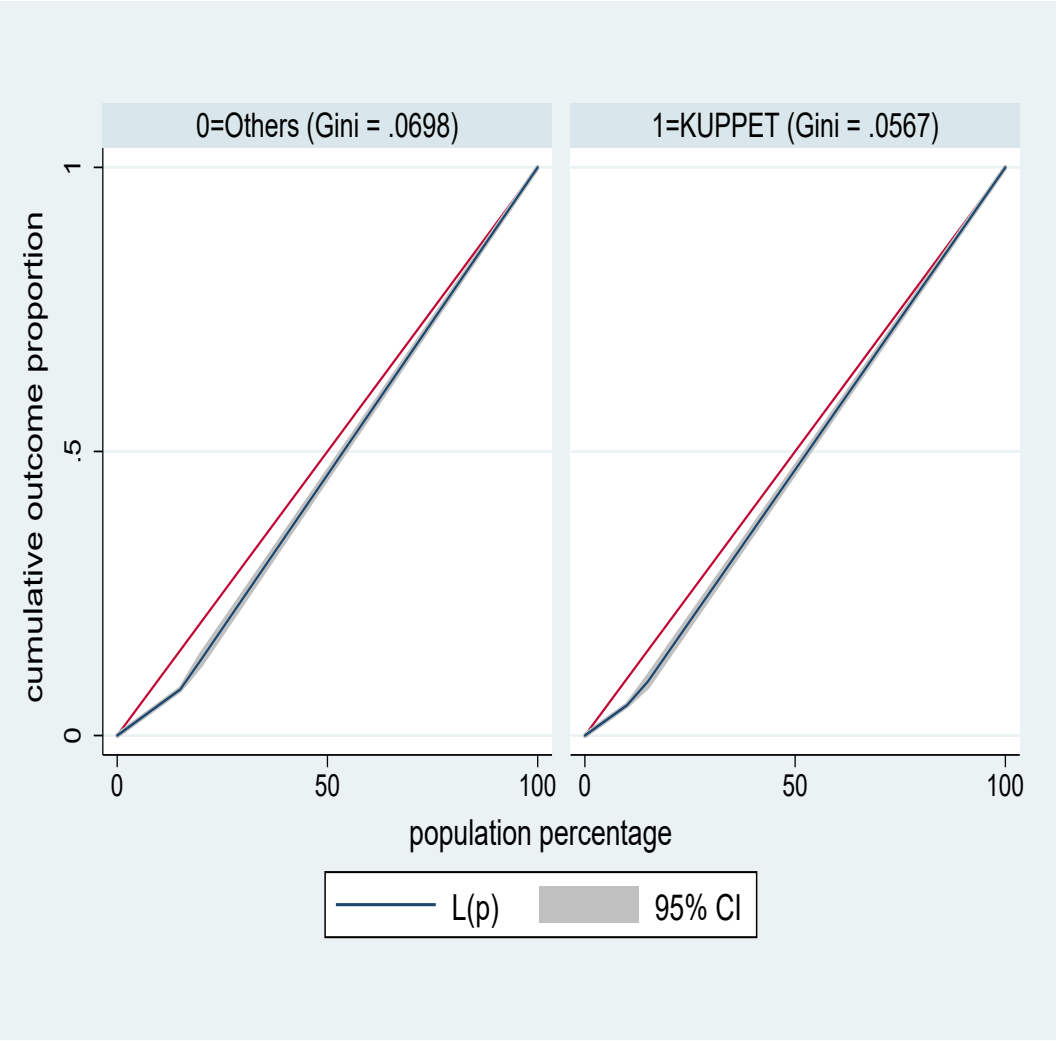

Figure 2: Lorenz Curves of Grade Promotion for Unions in Post-Primary

Figure 2 Compares the Lorenz curves for the grade promotion in the two unions side by side, showing that promotions in KUPPET (gini=.0567) appears marginally equitable than Others (gini=.0698). Others are KNUT, KUSNET and KUTT, which is basically KNUT since the other two were not subscribed to the 2017-2021 CBA during the period of its implementation. Therefore, based on Tables 7 and 8, we reject the null hypothesis of equality of the two promotion distributions since $p \leq .05$.

Conclusions and Recommendations

This means that the difference in equity in grade promotion of post-primary teachers between the application of the scheme of service and the career progression guideline approaches is statistically significant based on teacher performance in TPAD ratings. Grade promotion in KUPPET is found to be marginally more equitably distributed than in KNUT, with an extra score in TPAD in 2017, and teaching in either extra-county or national schools reducing the odds of promotion to the next grade in KUPPET union.

The study therefore recommends for the harmonization of the two approaches into one hybrid one to implement grade promotions among post-primary teachers for equity purposes based on any given CBA. The study further recommends for the establishment of a demarcation policy in which post-primary teachers can be limited to being members of one given union at a time.

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Sustainability and Innovation: The Intersection of Green Chemistry and the Digital Revolution - A Review

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Abstract

The convergence of the digital revolution and STEM disciplines has opened up exciting opportunities in the field of Green Chemistry. Since its birth (early 1990s), the green chemistry paradigm has reached an imperative status in the chemistry field; in this sense, many educational institutions and industries around the world have implemented the green chemistry principles to contribute to sustainable development goals. This review paper explores how digital technology, data analytics, and STEM advancements are being leveraged to drive innovations in sustainable chemistry. It also examines the role of interdisciplinary collaboration and discusses industry case studies, challenges, and future directions for the development of eco-friendly products and processes. Additionally, this paper addresses the importance of sustainability metrics, policy support, and education in promoting the intersection of Green Chemistry with the digital age. Although challenges persist, such as scaling up eco-friendly processes, sourcing sustainable feedstocks, and navigating complex regulatory landscapes, the future of Green Chemistry looks promising. The paper envisions a future where green materials, circular economy principles, and sustainable product design will play key roles in reshaping industries and mitigating environmental impacts
Keywords: Digital Revolution, Innovation, Molecular Design, Synthetic Chemicals, Eco-Friendly, Chemistry Impact

Introduction

The 21st Century has witnessed a great transformation in science and technology, driven by the digital revolution and STEM(Science, Technology, Engineering and Mathematics) advancements. In this era, the domain of Green Chemistry has emerged as a critical catalyst for addressing environmental concerns and sustainability. Green chemistry is the design of chemical products and processes that reduce and/or eliminate the use or generation of hazardous substances (Zimmerman et al., 2020). Green chemistry offers a platform for introducing creative approaches to address chemical challenges and integrating sustainability into molecular design. Chemists possess the capacity to create goods and procedures that minimize their effects on both people and the environment, consequently establishing eco-friendly chemical foundations for materials and products within our society. The scientific dilemma that is currently confronting the chemical industry as it envisions the future of our planet is not centered on the necessity of chemical products, as their importance is undeniable. Instead, the crucial question revolves around the attributes, qualities, and manufacturing methods of synthetic chemicals essential for fostering a sustainable civilization and development (Bukchin & Kerret, 2020). Throughout its history, chemistry has demonstrated a remarkable ability to develop key and beneficiala products and processes with great effectiveness. The remarkable inventiveness, imaginative prowess, and innovative spirit of chemists have left an indelible mark on every aspect of our lives. This influence varies from the vibrant garments we don to the constantly evolving electronic gadgets we interact with on a daily basis, from life-saving pharmaceuticals combating perilous diseases to synthetic fertilizers that bolster global food security, and from the soaring count of skyscrapers to the

relentless acceleration of transportation methods. However, this technological advancement has frequently been achieved within a limited functional scope that neglects potential negative repercussions (Li & Anastas, 2012). This paper delves into the interface between the digital frontier and Green Chemistry, highlighting the transformative potential of their synergy.

Fig. 1 : Green chemistry and its impacts(source: Saudi Pharma, Accessed 23rd Oct,2023)

Research Method

To conduct the literature search, we utilized several databases, including SciFinder®, Scopus, Google Scholar, and ResearchGate. This search encompassed the period from the release of the inaugural green chemistry textbook by Anastas and Warner in 1998 up to the contemporary period. We employed the following keywords as search queries:

- Green chemistry methodology
- Assessment of green chemistry
- Metrics for green chemistry
- Parameters for green chemistry
- Quantifying environmental friendliness
- Comparative greenness evaluation
- Synthesis greenness
- Chemistry sustainability assessment

Results and Discussions

The Digital Revolution in Green Chemistry

Technological advancements have had a significant impact on teaching methods, student learning approaches, and the conduct of chemical research. Swift technological progress has notably enhanced laboratory equipment, data gathering and analysis processes, and has greatly empowered the field of Green Chemistry. Digital technology has revolutionized the field of Green Chemistry. The application of computational chemistry, machine learning, and data-driven insights has enabled a more efficient and sustainable approach to chemical design and analysis (Martínez et al., 2022). Computational chemistry, in particular, has emerged as a powerful tool for predicting the properties and behavior of molecules without the need for time-consuming and resource-intensive laboratory experiments. Computational chemistry is the branch of chemistry that utilizes computer simulations, mathematical models, and algorithms to investigate and understand chemical phenomena and solve complex chemical problems. It involves the application of various computational techniques to study the behavior of molecules, atoms, and chemical reactions. Computational chemistry allows researchers to simulate chemical reactions, predict reaction pathways, and optimize the properties of chemical compounds. It is especially valuable in the design of novel catalysts, materials, and processes(Goh et al., 2017). Machine learning techniques, on the other hand, have revolutionized the way we approach data analysis, especially when dealing with enormous datasets. Their capacity to process and extract valuable insights from these extensive pools of information has become an invaluable asset in various fields, including the design of more sustainable chemical processes. Through the application of machine learning algorithms, we can unveil intricate patterns, hidden correlations, and previously unnoticed relationships within the data, shedding light on novel strategies for enhancing the sustainability of chemical processes. This data-driven approach not only expedites the identification of more eco-friendly and efficient methods but also allows for the fine-tuning and optimization of existing processes, thereby contributing to a greener and more environmentally responsible chemical industry (McArdle et al., 2020).

Innovations in Sustainable Chemistry

In recent years, the field of Green Chemistry has undergone a transformation in almost all aspects, characterized by an upsurge of remarkable innovations in sustainable synthesis, catalysis, and materials science. The primary goal of sustainable synthesis methodologies is to curtail or completely eliminate the reliance on hazardous solvents, lower energy consumption, and curbside waste generation (Sheldon, 2018). These innovations have sparked a significant shift in the landscape of chemical research and industry, paving the way for the emergence of greener, more sustainable, and highly efficient chemical processes that stand at the forefront of environmental responsibility. By focusing on these transformative developments, we not only make substantial strides in minimizing the ecological footprint of the chemical sector but also enhance the prospects of a more harmonious coexistence between industry and nature.

Catalysis plays a central and indispensable role within the of Green Chemistry movement, serving as a fundamental tool for promoting environmentally sustainable practices. It plays a pivotal role in facilitating chemical reactions to take place under milder and more benign conditions, thereby diminishing the energy demands and curtailing the generation of wasteful byproducts (Sheldon, 2020). The ongoing progress in the field of catalysis has yielded groundbreaking developments, with the unearthing of novel catalysts designed to not only boost the selectivity and efficiency of chemical transformations but also to substantially mitigate their overall environmental footprint. These innovative catalysts are instrumental in steering chemical processes toward a path of heightened sustainability and eco-friendliness, contributing significantly to the broader mission of promoting greener, more responsible chemistry practices. Enzymes represent essential biological catalysts renowned for their remarkable selectivity, operating efficiently under mild conditions. They find widespread applications in diverse industries, including pharmaceuticals, biofuels, and food production, enabling the facilitation of reactions while minimizing waste generation and energy consumption (de Marco et al., 2019). Heterogeneous Catalysts, such as zeolites, metal- organic frameworks, and nanoparticles, offer sustainable catalytic solutions. These materials can be easily separated

and reused, thereby reducing both waste and energy costs. For instance, zeolites play a crucial role in catalytic converters, effectively decreasing emissions from automobiles. Organic Catalysts, including quaternary ammonium salts and phase-transfer catalysts, possess the ability to catalyze a broad spectrum of chemical reactions. Notably, they often exhibit lower toxicity and more environmentally friendly characteristics compared to traditional inorganic catalysts. Photocatalysts harness the power of light, primarily sunlight, to initiate chemical reactions. Titanium dioxide, for example, finds application in self-cleaning surfaces and water purification processes, utilizing sunlight to catalyze reactions and degrade pollutants. Biocatalysts encompass whole cells or cell-free systems capable of catalyzing intricate reactions. Prominent examples involve the utilization of algae or bacteria for converting carbon dioxide into valuable products, or employing enzymes for the synthesis of biofuels. Biomimetic Catalysts are meticulously designed to replicate natural processes. Synthetic molecules have been developed to emulate the catalytic properties of natural enzymes, merging the selectivity of enzymes with the stability of inorganic catalysts, yielding promising prospects for innovative catalytic applications.

In the ever-evolving field of materials science, the paradigm shift toward sustainability is ushering in a wave of innovative and environmentally responsible alternatives to conventional materials. This transformative movement encompasses a diverse range of strategies aimed at mitigating the ecological footprint of materials production and usage. One prominent aspect of this evolution is the growth of the use of biodegradable polymers. These polymers are designed to break down naturally, offering an eco- conscious alternative to their non-biodegradable counterparts, which often remain in the environment for extended periods of time (Sheldon, 2017). As these biodegradable materials gain traction, they hold the potential to alleviate the burdens of plastic waste and contribute to a cleaner, greener future. Additionally, the utilization of renewable materials has gained considerable momentum. These materials are sourced from readily available and rapidly replenishing resources, such as plant-based materials, e.g. bamboo and water hyacinth, or sustainably managed forests. The emphasis on renewability in materials sourcing aims to reduce the environmental strain associated with the depletion of finite resources such as mineral resources and environmentally important resources such as trees. Sustainable composites have also emerged as a cornerstone of this transformative shift.

These composites, crafted from a combination of materials that are both environmentally friendly and durable, have the potential to supplant less sustainable options in various applications (Ruiz-Mercado et al., 2016). By embracing a combination of renewable resources, recyclable components, and advanced engineering techniques, sustainable composites exemplify the harmonious coexistence of performance and environmental responsibility. As environmental concerns continue to loom large in Africa, and by extension, on the global stage, the integration of these sustainable materials approaches into materials science is not just an option; it is a vital imperative that must be done now. They hold the promise of addressing environmental challenges and contributing to a more ecologically conscious and responsible approach to material development and usage. In addition to this, they also bring on board numerous economic benefits thus making products derived from them accessible to all classes of people (Boyle et al., 2021).

Bridging Theory and Practice in Green Chemistry

The effective realization of Green Chemistry principles relies on fostering extensive collaboration that goes past the disciplinary boundaries. Embracing an interdisciplinary approach, this collaborative effort unites the collective strengths and insights of chemists, engineers, and data scientists, forging a dynamic synergy that bridges the chasm between theoretical understanding and practical application. Within this interdisciplinary framework, chemists contribute their knowledge of molecular interactions and chemical reactions, striving to formulate innovative approaches and greener methodologies. Engineers, on the other hand, apply their mastery of process design and optimization, harnessing these skills to ensure that sustainable processes are not just theoretical ideals but practical and scalable solutions. Their proficiency in the intricate workings of equipment and systems is key in translating green chemistry concepts into real-world operations. Simultaneously, data scientists play an increasingly important role in this collaborative tapestry. Their expertise in data analytics, machine learning, and modeling provides invaluable insights for optimizing and fine-tuning sustainable processes. By leveraging the vast amount of data generated in the quest for eco-friendly solutions, data scientists help guide decision-making, expedite the development of green technologies, and enhance their overall efficiency. The synthesis of these varied areas of expertise facilitates the design and development of processes that are not only environmentally responsible but also viable on a large scale. This collaboration, rooted in a shared commitment to sustainability, empowers researchers to navigate the intricate landscape of Green Chemistry, unlocking the potential for long-term positive impacts on the environment and society at large. It is through this interconnected web of knowledge and collaboration that we pave the way for a greener and more sustainable future. This collaboration is crucial in addressing the complex challenges of Green Chemistry. Whether designing novel materials, optimizing reaction conditions, or developing new catalytic systems, the synergy between chemistry, engineering, and data science is key to successful implementation. This will bring the concepts and principles of green chemistry from mere ideas on papers and books to real world solutions to the modern problems facing mankind such as climate change, wars and military conflicts, water contamination, global health issues, poverty, children's poor access to healthcare, education and safety and lastly access to food and hunger.

Industry Case Studies

Numerous industries have embraced Green Chemistry principles, integrating digital technologies to drive sustainability. Case studies from companies exemplify how they have reduced waste, improved energy efficiency, and gained a competitive edge while adhering to environmental standards. For instance, pharmaceutical companies have adopted Green Chemistry principles to design more efficient and environmentally friendly synthetic routes to pharmaceuticals. The reduction of hazardous reagents and waste in the pharmaceutical industry not only benefits the environment but also enhances the cost- effectiveness of drug manufacturing. Over the past decade, a significant number of major pharmaceutical companies, including our own company, Amgen, as well as others such as the Merck Group, Abbott, Johnson & Johnson, and Roche, have transitioned towards incorporating green chemistry principles into their drug discovery, development, and manufacturing processes. In recent developments, both Merck and Amgen have successfully embraced green chemistry principles in their drug manufacturing processes. Merck, for instance, implemented a more environmentally friendly approach to produce molnupiravir, an antiviral medication for COVID-19, leading to reduced solvent waste, a 1.6-fold yield increase, and a streamlined three-step process. Their commendable efforts were acknowledged by the U.S. Environmental Protection Agency, which granted them the Greener Reaction Conditions Award in 2022. Likewise, Amgen adopted green chemistry practices to create LUMAKRAS™, an innovative treatment for specific non-small cell lung cancers. This green synthesis not only eliminated a purification step that generated substantial solvent waste but also resulted in substantial annual savings of £3.17 million, all while increasing the yield. In recognition of their dedication to sustainability, the U.S. Environmental Protection Agency also honored Amgen with the Greener Reactions Condition Award in 2022. Notably, there are established rating systems like the Dow Jones Sustainability Indices and the Pacific Sustainability Index1 that gauge the environmental performance of these firms, highlighting their commitment to sustainability (Barone et al., 2021; Braun et al., 2020; de Marco et al., 2019; Nalley, 2023). This transformative shift is primarily motivated by the recognition that processes that are both cost-effective and environmentally sustainable offer a competitive edge in the pharmaceutical industry. However, the successful adoption of green chemistry practices hinges on more than just implementing technical changes. It necessitates the cultivation of a sustainability-oriented corporate culture that permeates every facet of the organization. This includes imparting a comprehensive understanding of green chemistry principles to personnel at all levels, from management to laboratory scientists, underscoring the mutual benefits of such an approach. It is essential to have a clear vision of the future advantages that stem from substantial operational changes. Committing the necessary resources and funding to support this transition is crucial, even though the positive outcomes may not be immediately evident. In essence, the pursuit of green chemistry in pharmaceutical endeavors demands a holistic commitment to sustainability that extends beyond mere technical shifts and into the heart of the organizational ethos.

The automotive industry provides another example, with companies adopting eco-friendly materials in vehicle design and implementing sustainable manufacturing processes. These green initiatives are driven by consumer demand for more sustainable products and lower emissions. Chemistry plays a pivotal role in the composition of various elements of automotive exteriors, including paints and coatings, windows, windshields, and door handles. Similarly, automotive interiors, such as airbags, seatbelts, seating materials, and dashboards, are all intricately intertwined with the principles of chemistry (Gohoungodji et al., 2020). By adopting eco-friendly energy sources, such as hydrogen or electricity, electric vehicles effectively tap into stored chemical energy to initiate an electrochemical reaction, resulting in emissions-free operation. This reduced release of tailpipe emissions not only benefits the ozone layer but also eliminates the need for fossil fuels to power these vehicles. In the past, the automotive industry rarely considered the issue of waste in the design of new vehicles. However, this perspective is now outdated. A new initiative led by Circularise in collaboration with Porsche and innovative material suppliers, including Borealis, Covestro, and Domo Chemicals, has been introduced. This project aims to employ blockchain technology to monitor the plastic materials used in manufacturing processes. This tracking system enables the precise recording of carbon emissions associated with the production of specific components, as well as the quantification of water usage, among other important data points. Dow has taken a groundbreaking step by unveiling the development of innovative polyurethane solutions, derived from a circular feedstock obtained from waste materials within the mobility sector, effectively replacing traditional virgin fossil-fuel-based resources. These newly engineered polyurethane foam systems not only retain the same advantageous qualities as existing automotive polyurethane foams but also contribute to a noteworthy reduction in the overall carbon footprint of car components, from production to end-use (Gohoungodji et al., 2020; Ruiz- Mercado et al., 2016).

Challenges and Future Directions

The potential of Green Chemistry and the digital revolution to revolutionize industries and mitigate environmental impact is undeniably promising, but as with any transformative shift, several challenges must be navigated to achieve these lofty goals. In this intricate landscape, we encounter a host of complex issues that necessitate continuous attention and innovative solutions.

One of the primary challenges pertains to the scaling up of eco-friendly processes. While laboratory-scale experiments often yield impressive results in terms of sustainability, replicating these successes on an industrial scale poses a substantial challenge. The

logistics of optimizing and transitioning processes to efficiently operate on a larger, more practical scale can be fraught with obstacles. It requires the alignment of technological advancements, infrastructure, and supply chains, among other factors, to achieve true scalability. Another pivotal issue revolves around the accessibility and availability of sustainable feedstocks. Green Chemistry champions the utilization of renewable and environmentally benign raw materials, such as biomass or waste materials, in place of conventional, finite resources. However, sourcing these sustainable feedstocks in a consistent and economically viable manner is an intricate puzzle that the industry continues to address. The conversion of these feedstocks into valuable chemical products also requires innovative technologies and processes. Additionally, regulatory complexities pose an ongoing challenge. The regulatory framework governing chemical processes is intricate and varies globally, which can hinder the rapid adoption of sustainable chemistry practices. Finding common ground and harmonizing regulations across regions and sectors is a demanding task that requires international cooperation and dedicated efforts.

Despite these challenges, the future of Green Chemistry is incredibly promising, with several intriguing directions on the horizon. One notable area of development is green materials. The quest for sustainable materials, be it biodegradable plastics, environmentally friendly coatings, or innovative construction materials, remains a vibrant field of research. These materials aim to provide a greener and more sustainable alternative to conventional counterparts while maintaining or improving performance. The concept of a circular economy is gaining traction in Green Chemistry. By designing products and processes with end-of-life considerations in mind, the industry seeks to minimize waste and ensure the efficient recycling and reuse of materials. This approach holds the potential to significantly reduce the environmental impact of chemical products and manufacturing. Sustainable product design is another compelling avenue for the future. The integration of sustainable design principles into product development involves a comprehensive assessment of the entire lifecycle of a product, from raw material extraction to disposal (Bányai & Zaher Akkad, 2021). This approach can lead to more efficient and sustainable products, from electronics to packaging materials.

Conclusion

In conclusion, the promising fusion of Green Chemistry and the digital revolution illuminates a path and the journey towards a more ecologically responsible and sustainable chemical industry. While the future is indeed bright with the potential to transform and mitigate environmental impacts, it is imperative that we confront and overcome the persistent challenges that have proved to be major hurdles in our pursuit of greener practices.

The task of scaling up green processes from laboratory to industry, while maintaining efficiency and sustainability, is a formidable venture. It demands a holistic approach that unites technological advancements, infrastructure enhancement, and the streamlining of supply chains. Likewise, the quest for sustainable feedstocks, such as biomass and waste materials, presents challenges in sourcing and converting these resources into viable, eco-friendly products. Addressing the complex regulatory landscape further compounds these challenges, urging us to seek harmonization and cooperation on a global scale.

Yet, as we navigate these challenges, the future of Green Chemistry beckons with a world of possibilities. The development of green materials, whether biodegradable plastics, eco-conscious coatings, or innovative construction materials, is set to revolutionize industries, offering alternatives that champion sustainability without compromising on performance. The concept of a circular economy, transforming the way we design, use, and recycle products and materials, holds the potential to drastically reduce waste and environmental impact. Meanwhile, the incorporation of sustainable design principles into product development ensures that every facet of a product's lifecycle is environmentally responsible.

In essence, Green Chemistry, intertwined with the digital revolution, paves the way for a future that is not only more sustainable but also less environmentally impactful. The evolving landscape of the field is marked by collaboration, innovation, and a shared commitment to reducing our ecological footprint. Together, these endeavors represent an ongoing evolution toward a greener, more sustainable, and ultimately less environmentally impactful future for the chemical industry.

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A Critical Review of Microbial Fuel Cells For Wastewater Treatment in Africa

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Abstract

The African continent grapples with ensuring access to clean and sustainable water resources while maintaining the ecological balance of its natural environments. Wastewater treatment is critical in this pursuit. This research investigates the potential of microbial fuel cells (MFCs) as an eco-friendly solution to treat wastewater, while bridging the gap between the increasing human demand for water resources and the imperative to protect the ecosystems that provide these resources. Microbial fuel cells effectively treat wastewater while generating electricity, offering a sustainable and environmentally friendly solution.This review delves into the current status of MFC applications in wastewater treatment throughout the African continent. A comprehensive analysis of the existing literature was conducted to identify the latest innovations, and the challenges and drivers associated with MFC adoption in Africa. The viability and sustainability of MFC technology in diverse African environments was evaluated to identify the socio-economic and environmental factors that influence its adoption. This review illuminates the path towards sustainable, eco-friendly wastewater treatment solutions in Africa, offering invaluable insights to stakeholder, future researchers, and contributing to the broader advancement of engineering and environmental sciences while upholding the principles of a circular economy.

Keywords: ecological balance, microbial fuel cell, waste water

Introduction

Falkenmark's water stress indicator indicates that, when a country's per capita water consumption falls below 1000 m3, it is considered to be experiencing water scarcity, and if it dips below 1700 m3 per capita, it is considered as water stress. (Musse, 2021). As Africa's population escalates and climate change continues to prevail, it is predicted that by 2025, close to 230 million Africans will be facing water scarcity(Musse, 2021).According to a report by the United Nations,wastewater is critical in meeting the growing water demand. Yet a huge percentage of wastewater is still released into the environment without being either collected or treated. This is particularly true in many African countries, which on average only treat 8 % of domestic and industrial wastewater(Unesco et al., 2017).

Microbial fuel cells emerge as a remarkable and sustainable solution. MFCs are a unique subset of biological fuel cells that treat wastewater while generating bioelectricity simultaneously by converting the chemical energy in organic or inorganic matter into electrical energy via a series of electrochemical reactions. This unique capability is what makes them especially valuable in regions without electricity access. Initially developed for bioelectricity generation, MFCs have recently gained attention for their potential in treating wastewater efficiently while harnessing renewable energy (Nawaz et al., 2022a). The electricity generation typically involves the biodegradation of organic materials with the help of a suitable microbial substrate. Initially, glucose, acetate, or other simple substrates were used as substrates at a laboratory scale to determine the behavior of electrode materials, membranes, and such others, as well as the reactor architecture or microbial activity. In 2004,The study using real wastewater as a substrate began(Tsekouras et al., 2022a).Wastewater, the primary substrate in microbial fuel cells, provides both the necessary microbes and organic matter. MCFs are effective in treating Various types of wastewater , including sanitary wastewater, food processing wastewater, domestic, industrial, agricultural, and urban wastewater. Today, wastewater is the most popular substrate for an MFC operation due to its high percentage in organic load and zero cost, especially the agro-food wastewater is very suitable due to its high biodegradability(Tsekouras et al., 2022a).

Wastewater treatment already consumes a significant percentage of Africa's electricity load. MFCs can be utilized to address both the wastewater treatment challenge and energy needs, while reducing the carbon footprint. MFCs are effective at removing various pollutants, such as sulfides, up to 90 percent of the chemical oxygen demand (COD), and contaminants like hydrocarbons, organic matter, microbes, endocrine disruptors, and heavy metals like arsenic, cadmium, chromium, zinc, iron, nickel, lead, and mercury. The key advantages of MFCs include mild operating conditions, the use of biodegradable substrates as fuel, high operational sustainability, low material costs, and a low carbon footprint.

Within the African context, the adoption of MFCs for wastewater treatment is influenced by various drivers and barriers. The major drivers include their adaptability to decentralized wastewater treatment, the production of lower sludge volumes, and their ability to self-generate microorganisms, which eliminates the need for periodic bacteria placement. Additionally, MFCs generate electricity using wastewater as fuel, which is cost-effective and environmentally friendly. However, barriers to MFC adoption in Africa include high material costs, unstable performance when treating real wastewater, and challenges related to scaling up the technology, which can lead to decreased power output. Despite being in their early stages of adoption in Africa, primarily due to design complexities and material costs, MFCs offer a promising solution to address wastewater treatment and energy challenges in the region while simultaneously producing electricity.

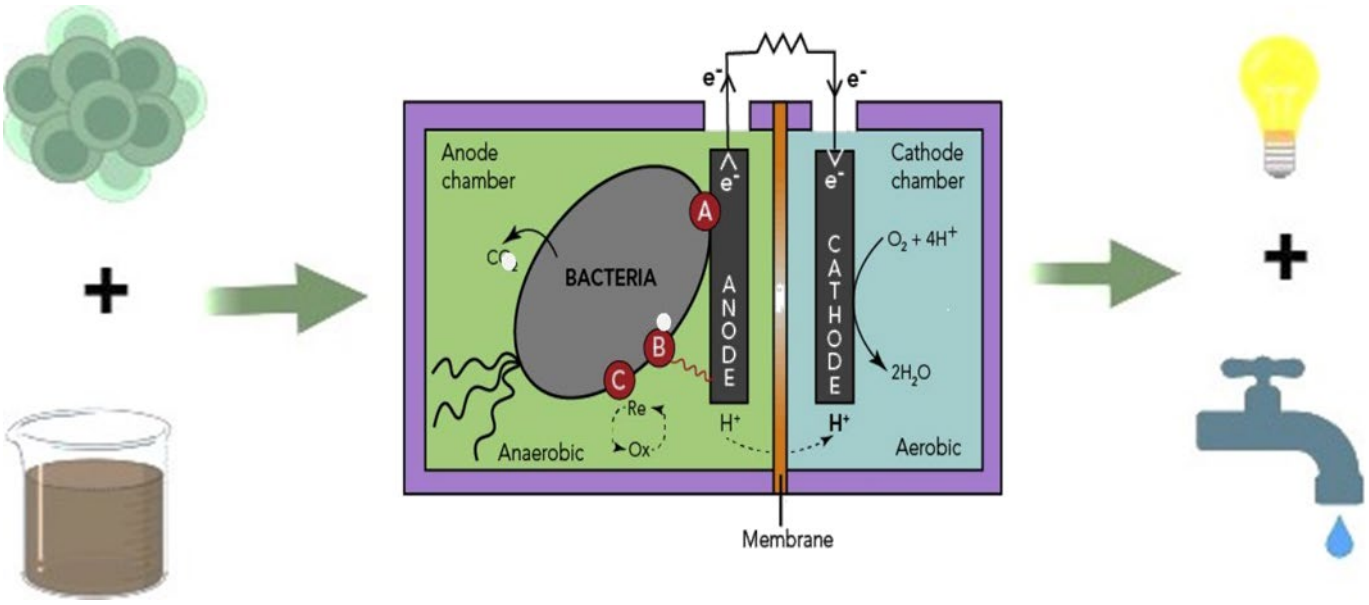

Figure 1 Basic Operation of a Microbial Fuel Cell

2. Microbial Fuel Cell Technology

2.1 Microbial fuel cell components

2.1.1 Anode compartment

The anode compartment contains an anode electrode, typically made of a conductive material like graphite or carbon. This electrode serves as the site where microorganisms, known as electrogenic bacteria, oxidize organic matter in the wastewater. As they do so, they release electrons, which form the basis for electricity generation. The electrons then transfer to the external electrode or anode. The design of the anode compartment is crucial to providing the bacteria with the necessary environment and surface area for growth. In addition to the production of electrons, oxidation of organic pollutants to generate protons together with electrons, formation of biofilm, and production of hydrogen occur in anode compartment.

In order to enhance the MFC performance, the selection of suitable material for anode is key. The material employed should possess high electrical conductivity(Nawaz et al., 2022b). While metals such as copper, platinum, and stainless steel are conductive and can be considered suitable for the anode and ideal for electroconductivity, they are not so good for the microbial activity. Some metals such as platinum and titanium stand out due to their ability to carry electrons over long distances and their effectiveness in large-scale operations. However, using such precious metals increases the system cost and introduces new research areas for finding alternative materials when scaling up a typical MFC .

Previous research on anode development was based on two philosophies. The earlier study aimed to increase anode surface area to accommodate more biofilm. In contrast, the concept worked well in small-scale operations or lab studies. However, a scaled-up system or stacked MFC requires more than increasing electrode surface area. It requires proper electron migration between anode and cathode [16]. Recent research has focused on long-distance electron transport from anode to cathode rather than small-scale operation.

There are several techniques to modify the properties of the carbon-based anode, such as treatment with acid, electrochemical treatment, coating with polymer, etc. The main focus behind these techniques is to increase the surface area and perturb the surface chemistry, which improves the adhesion of biofilm on the surface of an anode(Banerjee, Calay, & Mustafa, 2022)

2.1.2 Cathode compartment

The cathode electrode is usually made of materials like platinum, carbon, or air cathodes. It is located in the cathode compartment, where reduction reactions occur. The cathode electrode is a receptor for electrons and protons generated at anode. Oxygen or other electron acceptors in the cathode compartment combine with electrons transferred through an external circuit from the anode to produce water or other reduced compounds. Efficient cathodes have a large active surface area and great catalytic capabilities for reduction reactions. An MFC cathode can be made of biocatalysts (enzymes or microbes) for the oxygen reduction reaction, abiotic catalysts (carbonaceous materials such as activated carbon, carbon nanotubes and

graphene(Mahurede et al., 2023)Depending on the design of the MFC, there are variations in cathode electrodes. In a double-chamber MFC, the cathode is separated by a selective membrane, while in a single-chamber MFC, an air cathode is used to receive the generated electrons.

Electrons are reduced through interactions with electron acceptors in the cathode on reaching the cathode. The materials utilized for constructing cathode electrodes include carbon cloth, graphite fiber brush, graphite rod, carbon paper, graphite felt, and stainless steel .Oxygen is the most preferred electron acceptor because of its high redox potential. However, its use is limited due to insufficient electrode contact and increased power consumption for its supply(Nawaz et al., 2022b). Efficient cathodes have a large active surface area and great catalytic capabilities for reduction reactions. An MFC cathode can be made of biocatalysts (enzymes or microbes) for the oxygen reduction reaction, abiotic catalysts (carbonaceous materials such as activated carbon, carbon nanotubes and graphene(Mahurede et al., 2023)

While cathode electrodes have improved over the years, challenges still persist. These include high cost, surface toxicity of microbes, and insufficient re-oxidation,

necessitating the routine maintenance of the catholyte. These challenges have led to research into better alternatives to increase MFC power output. These alternatives include materials with a carbon basis, metal oxides and complexes(Shabangu et al., 2022).

2.1.3 Proton exchange membrane

A membrane, often made of materials like Nafion, separates the anode and cathode compartments. This membrane allows protons (H+ ions) produced during the anodic reaction to pass through it while preventing the physical interaction of the anodic and cathodic materials. This separation is critical in maintaining the electrochemical gradient necessary for electricity generation.

The performance of a membrane depends on its physical and chemical properties. In the case of a membrane with pores in its structure, its performance is the function of the pore size and the number of pores(Ramirez-Nava et al., 2021). Proton conductivity is also a key property when assessing the potential material for membranes, especially for electricity generation applications. Resistive losses are dependent on the proton conductivity and ionic resistance of the membrane. Various studies have been conducted to analyze the effect of the thickness of the membrane on the output performance of MFC. The experiments were done for three different thicknesses 2.5, 5, and 10 mm of the membrane made of fine fire clay material. The maximum absolute power around 2.1 mW was obtained using a 2.5 mm thick membrane since a thinner membrane has lower ionic resistance than the thick one. Another study was also conducted to analyze the effect of the thickness of the Nafion membrane used in an iron-chromium redox flow battery with thicknesses of 50, 126, and 178 μm. The maximum utilization of electrolytes was observed with a thickness of 126 μm. The outcome of the research work implies that the thinner membrane has less internal resistance and higher permeability to electro active species(Banerjee, Calay, & Eregno, 2022)

The major factors affecting membrane performance are proton conductivity, permeability to water, ion transport number, biofouling, internal resistance and, mechanical strength, chemical resistance and

oxygen diffusion. The surface of the membrane also has an effect in the membrane performance and the power generation in MFCs systems(Borja-Maldonado & López Zavala, 2022).

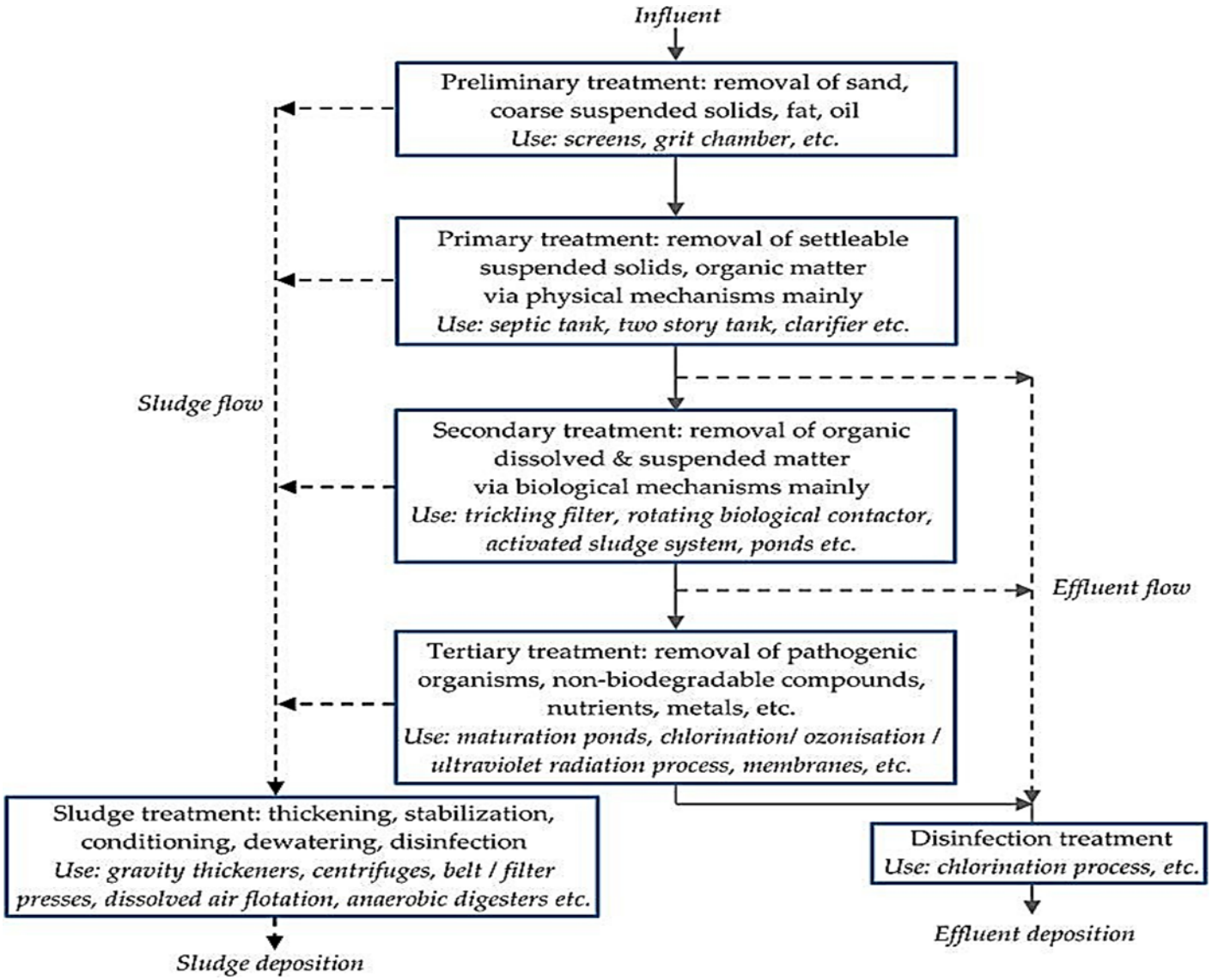

Figure 2 Flowchart for Wastewater Treatment using MCFs(Tsekouras et al., 2022b)

3. Adoption in Africa

3.1 Barriers to Adoption

3.1.1 High cost of materials

The initial cost of MFC technology, including electrodes and proton exchange membranes, and the cost of maintenance is a barrier to adoption of MFCs in many African countries. The capital cost of wastewater based

MFC is nearly 30 times more than the conventional activated sludge treatment (Roy et al., 2023).

The high cost is due to the expensive electrode materials and separator materials. The abiotic electrode catalyst (platinum) and electrode binders (Nafion) that are currently used in the MFCs are cost-prohibitive. To upscale the MFC technology and implement on an industrial scale, there is a need for the development of bioelectrodes. The bioelectrodes should be cost-effective and possess the potential to improve the power density and waste treatment capabilities. The cost involved in wastewater based MFCs can be reduced by adopting decentralized wastewater treatment. Decentralized wastewater based MFCs reduces the transportation cost of wastewater and energy consumption(Venkatramanan et al., 2021). Also, it is necessary to use scalable materials, that is the anode, cathode and membrane, with high efficiency and low cost(Obileke et al.,

2021)

3.1.2 Instability when treating wastewater

MFCs can exhibit performance instability when treating wastewater due to the complexity and variability of wastewater composition. Also, the chemical oxygen removal rate is still low. Various studies show that the organic removal rates for MFC range between 0.0053 and 5.57g COD/l/day (Moran, 2018).However, for an MFC to be economically profitable, the organic removal rate should range at 5-10 g COD/l/day .There is a gap between actual and expected organic removal rates(Venkatramanan et al., 2021). Majority of the studies that have been conducted on wastewater based MFCs are vulnerable to uncertainty. They are mostly based on batch-fed and laboratory-scale operating conditions. There is a need for further research to gauge the potential of wastewater based MFCs in large scale operating conditions to reduce the element of uncertainty(Venkatramanan et al., 2021).

This uncertainty also extends to the efficiency of the MFC system. Over time, it decreases. This is due to factors such as :

- Variations in the electrochemical activity of the anode biofilm-the wastewater substrate is affected by several factors such as; the wastewater composition, substrate concentration, solution electric conductivity, solution temperature. These factors are not yet fully predictable, there is need for further research to understand the complex nature of wastewater to stabilize the system.
- Cathode behavior has been observed to deteriorate over time due to the deactivation of oxygen reduction catalysts: especially for catalysts based on metals and the contamination of the biofilm cathode(Tsekouras et al., 2022b)

3.1.3 Other factors

Many African regions lack the awareness and expertise required for the successful implementation of MFCs for wastewater treatment. There is need to build the capacity and knowledge not just among researchers but also to stakeholders and the indigenous people to ensure widespread adoption. MFCs also require routine maintenance and monitoring to ensure optimal performance. Developing capacity for maintenance and troubleshooting among local people is crucial for long-term sustainability.

Conclusion

MCFs utilize microorganisms to treat wastewater while simultaneously generating electricity. Although this technology holds great potential in solving water scarcity in Africa, there are several challenges that hinder its adoption. Issues related to scalability, substrate utilization, and overall efficiency must be addressed to realize their full potential in real-world applications. Understanding and mitigating these limitations is essential to ensure the successful implementation of MFCs in water treatment facilities across the continent. There is need for continued research and development in this field to propel the large-scale implementation of MCFs. The insights provided in this review can inform stakeholders and future researchers on the gaps in this area. These applications can significantly contribute to sustainable water management and environmental protection. The implications of this review paper suggest the need for further research into the improvement of MFC technology. Future studies should focus on scaling up MFC systems, exploring novel electrode materials, and investigating the potential for harnessing different types of microorganisms.

Recommendations

- Invest in research to explore cost- effective electrode materials that balance conductivity and microbial compatibility.
- Investigate the potential of different microbial species to enhance MFC performance and stability in varying environments.
- Further develop bioelectrodes to replace expensive materials like platinum, reducing initial setup costs.
- Promote decentralized wastewater treatment to cut transportation costs and energy consumption.

- Research methods to achieve higher organic removal rates within economically viable ranges for improved MFC profitability,
- Keep sustainability at the forefront, ensuring that MFC adoption aligns with long-term environmental, economic, and social goals for water resource management in Africa.

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Inception of Competency Based Curriculum - Do Secondary School Teachers Possess the Required Pedagogical Competencies?

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Abstract

With many countries of the world adopting Competency Based Curriculum, Kenya being part of the global village, could not afford to be left behind. To keep abreast with the socio-economic changes, the government through the Ministry of Education has made changes in the curriculum with emphasis on seven core competencies; communication and collaboration, critical thinking and problem solving, creativity and imagination, citizenship, digital literacy, learning to learn and self-efficacy. This is to ensure that students graduating from the secondary level of education possess the necessary competencies essential to meet societal needs. Accordingly, the competencies acquired should be dynamic instruments of positive change. They are expected to affect or condition the social behavior of the person being educated. This change in social behavior should be the desired one, continuous and lifelong. For the students to acquire the intended competencies, the teachers and educators must possess certain critical pedagogical competencies. These pedagogies must embrace twenty first century teaching approaches which are student centered. However, according to most research findings, educators tend to agree that most teachers in secondary schools still use teaching approaches that are teacher – centred instead of student – centred. This hinder students from achieving lifelong learning and application. A desk research was performed to evaluate if secondary school teachers possessed the pedagogical competencies necessary for implementation of Competency Based Curriculum. This study examined secondary data from the internet and the library on secondary school teachers' pedagogical competencies. The study documented different approaches used by secondary school teacher. The study established that secondary school teachers did not possess the required pedagogical competencies as recommended in the teachers' guides and syllabus. The major factors documented to be hindering the use of required pedagogical competencies, were lack of resources and equipment, inadequate teacher preparation and training.

Keywords: **Competency Based Curriculum, Content Based Curriculum, Pedagogical Competencies**

Introduction

Competency-based education (CBE) is surging in popularity globally as schools around the world scramble to implement their own versions of competency-based curricula (Ash, 2012; Mulder & Akkermans, 2011; Nederstigt & Mulder; Wong, 2008, (cited in Griffith and Hye-Yeon, 2014). Bowden (cited in Griffith and Hye-Yeon, 2004), noted that, throughout its evolution, CBE has been known by a variety of names including performance-based learning, criterion-referenced learning, and capabilities-driven instruction.

According to Kenya Institute of Curriculum Development (KICD), the change of the curriculum was inevitable due to globalization of labour market and demand for acquisition of the twenty first century skills by the present society (KICD, 2016). To make the Kenyan citizens globally relevant and to meet the societal needs especially developmental as envisioned in the vision 2030, the Kenya Government, through the Ministry of Education initiated the change of the school curriculum from the Content Based Curriculum, popularly known as 8-4-4 to Competency Based Curriculum (CBC) in 2016. The move was welcomed due to long-standing concerns over the content based curriculum which was characterized with examination oriented, heavy workloads and a teacher-centric instructive approach. The new Content Based Curriculum is intended to be learner-centred. It is based on the premise that children learn best when they can construct their own knowledge and skills through being exposed to different challenging scenarios and helped to find real-life solutions (Alicia, 2023). The competency-based education has its roots in the Behaviorist theories of learning which were popularized in the United States during the 1950s by educators such as Benjamin Bloom (Griffith and Hye-Yeon, 2014). Smith and Patterson [cited in Griffith and Hye-Yeon, 2014), argue that due to lack of conclusive evidence showing a link between knowledge about a subject and the ability to use that information in context, CBE expressly focuses on what learners can do rather than on what they know. The basic idea is to focus on objective and observable outcomes which can be easily measured. CBE requires that students demonstrate value-added skills which are assessed by looking at outcomes rather than process (Bowden, 2004; Guskey, 2005).

The focus on competencies or learning outcomes underpins the curriculum framework and syllabus specification, teaching strategies, assessment and reporting. Instead of norm-referencing assessment, criterion-based assessment procedures are used in which learners are assessed according to how well they can perform on specific learning tasks.

What is a competency?

According to Learning Designs Inc., Richards & Rogers (cited (Griffith and Hye-Yeon, 2004), a competency refers to

"critical work functions" or task in a defined setting. Successful completion of each specific, task involves a set of skills and knowledge which must be accurately applied. Vichita and Jintawe (cited in Abdelnaser and Akram, 2017), defined a competency as a motive, trait, skill, self-concept, body of knowledge, or an attribute that allows an individual to perform a task or activity within a specific function or job. According to International Atomic Energy Agency (no date), a competency is a combination of skills, knowledge, attributes and behaviours that enables an individual to perform a task or an activity successfully within a given job. Competencies are observable behaviours that can be measured and evaluated.

In Kenya, the Competence Based Curriculum, emphasizes seven core competencies; communication and collaboration, critical thinking and problem solving, creativity and imagination, citizenship, digital literacy, learning to learn and self-efficacy (KICD, 2017). One of the most remarkable differences between Competence Based Curriculum and the traditional curriculum, is that, in competency-based learning, students are expected to master competencies aligned to college and career-ready standards with clear, transferable learning objectives and on the other side, in the traditional system of education, students are required to master grade level college and career-ready standards. In Competence Based Curriculum, the emphasis is on acquisition and use of the skills and knowledge (Das, 2019).

Change of Curriculum and Implications for Pedagogy, Policy and Practice

The change from the Content Based Curriculum to Competency Based Curriculum has necessitate the re-conceptualization of education in Kenya. This paradigm shift has implications in terms of pedagogy, policy and practice.

In Competency Based Curriculum, learning is personalized. The main focus is on the learner and how she/he attains and masters the prescribed competencies. Some of the major differences between the traditional curriculum; (8-4-4) and Competency Based Curriculum are well illustrated by Knowledgeworks.com. The divergence is in core areas such as school culture, learning continuum, learning pace, instruction, assessment and grading policies.

"….School culture in traditional education, learning happens inside a traditional classroom, little to no accommodation of student interests or learning needs. In personalized, competency-based learning, students have an equitable range of learning experiences at school, online and in the community. Schools foster a sense of belonging, embrace growth mindset and the importance of relationships for meaningful, relevant learning experiences.

Instruction

In traditional education, every classroom has one teacher who designs and delivers instructional curriculum with very little differentiation. In personalized, competency-based learning, educators work collaboratively with community partners and students to develop a unique learning plan for each student based on interests, learning needs and real-time data. Individual learning pathways accommodate student interests and learning needs.

Assessment System

In traditional education, assessments at set times to evaluate and classify students. One opportunity to take the summative assessment at the end of the year. In personalized, competency-based learning, a comprehensive assessment system is an essential part of the learning system. Formative assess¬ments guide daily instruction. Students partner with their teachers to decide when and how to show what they have learned, and they have multiple chances to demonstrate mastery.

College and Career Readiness

In traditional education, students are expected to master grade level college- and career-ready standards. In personalized, competency-based learning, students are expected to master competencies aligned to college- and career-ready standards with clear, transferable learning objectives.

Learning Pace

In traditional education, students advance at educator's pace regardless of mastery or needing additional time. In personalized, competency-based learning, students access customized supports both in-school and out-of-school to ensure they get what they need, when they need it.

Grading Policies

In traditional education, grades are norm-referenced, reflect course standards and are typically based on weighted quarters and a final exam. In personalized, competency-based learning, grades reflect the degree of mastery of competencies. If students do not earn course credit, records indicate competencies that need to be re-learned instead of the entire course (Knoledgeworks.com, 2022)."

As observed by Jeng'ere (cited in Isaboke et al, 2021), the change from Content Based Curriculum to Competency Based Curriculum requires change in the orientation of the instruction process. As noted by Knoledgeworks.com, (2022), Competency Based Curricullum requires a change in instructional methodologies. Teachers and educators must work collaboratively with community partners and students to develop a unique learning plan for each student based on interests, learning needs and real-time data. Isaboke et al, (2021), noted that the change in pedagogical approaches necessitates training of teachers to assist them understand the paradigm shift so that they adopt teaching approaches that can help them implement the Curriculum effectively.

The Competency Based Curriculum emphasizes the attainment of competencies. This forces the teachers to drastically change from traditional pedagogies which are teacher centred and adopt synergetic ones. The teachers' role become more inclined towards facilitation, diagnostic, mediatory and liaising. The teachers are compelled to embrace technology to support learning due to ever evolving technology. This is necessary to make education to prepare students for the real world outside school. Alicia (2023) noted that teachers in junior secondary were facing a novel challenge teaching this higher level, in a learner-centric way. This was due to lack of training to implement the new curriculum. To address this challenge, Teachers Service Commission (TSC) has been in-servicing (retooling) some teachers to enable them effectively implement the Competency Based Curriculum.

Statement of the Problem

The core tenets of Competency Based Curriculum are entrenched in the four pillars of education as advocated by United Nations Educational and Cultural Organization (UNESCO). These are: learning to know, learning to do, learning to be and learning to live together (Wanjala et al., 2019). This is well stated in the seven competencies outlined in the Competency Based Curriculum. These are: communication and collaboration, critical thinking and problem solving, creativity and imagination, citizenship, digital literacy, learning to learn and self-efficacy (KICD, 2017).

Kenya being part of the global economy, the government through the Ministry of Education, initiated a change in educational curriculum from traditional Content Based Curriculum (8-4-4) to a Competency Based Curriculum. This was to enable the graduates acceptable and competitive in the global labour market, apart from possessing the twenty first century skills which are relevant in the present society (KICD, 2016). This change in curriculum calls for child-centred approach where the child is placed at the centre of the learning process in a child-friendly environment. Momanyi and Rop (2020), Maina, (2023) opine this change necessitates a pedagogical change in the training of teachers to adequately prepare them for this type of task

Teachers, as implementers of curricula, play a key role in the success or failure of any given curriculum. This depend largely on teachers possessing relevant pedagogical competencies amongst other requirements. It is therefore, necessary to investigate if secondary school teachers possess the required pedagogical competencies to implement the Competency Based Curriculum.

Methodology

The research was carried out as a desk study. The literature review was as a descriptive study to provide information if secondary schools are ready for implementation of the Competency Based Curriculum in Kenya. The information in this study was sourced from various secondary sources as listed in the reference. It is worth to note that this report is not a comprehensive review of the available literature on the topic.

Results

As noted earlier, teachers play a critical role in implementation and assessment of the curriculum. The purpose of this study was to determine if secondary school teachers in Kenya possess the pedagogical competencies required for implementation of Competency Based Curriculum. Alicia (2023) observed that, most secondary school teachers were ill-prepared and under-trained to implement the Competency Based Curriculum. The main area of concern was assessment of certain competencies like handling and taking care of laboratory equipment amongst other competencies. Research indicates that some of the restrictions in smooth and effective implementation of Competency Based Curriculum include inadequate teacher training and lack of innovative classroom practices, which can only be achieved through capacity building of the instructors (Maina, 2023).

Maina (2023) states that like all other countries, Kenya's adoption of CBC could be moving to the right direction in training of manpower but the existing reality is that implementation is happening with no regard to available resources and understanding of what is being implemented, how it will be implemented and how to examine the competencies. Maina (2023) further notes that in Kenya, the entire curriculum development lies with the Kenya Institute of Curriculum Development (KICD). And that the main drivers of any curriculum are the trainers but unfortunately they are not brought on board by the curriculum's developers. Teacher training on implementation of Competency Based Curriculum should have been developed and rolled out first before the curriculum for learners.

Sarah and Ondieki (2023) in their research established that most of the teachers lacked knowledge of what Competency Based Curriculum was about. They opined that secondary school teachers are used to teaching their subjects distinctively and found integration of subjects ambiguous. Their study revealed that a one day training was not sufficient to make teachers competent to implement a weighty program like Competency Based Curriculum. It was further established that only a few teachers had been inducted to handle Competency Based Curriculum. The vast majority were yet to be in - serviced. This make the implementation of Competency Based Curriculum a challenge. The learning areas in which teachers were least equipped were: visual and creative arts and computer. Most of the teachers did not take computer science in college and therefore did not have basic computer knowledge and skills (Sarah and Ondieki, 2023).

Discussion

From the findings, it is evident that vast majority of secondary school teachers in Kenya lack the required pedagogical competencies to implement the Competency Based Curriculum. These findings concur with Muchiri et al., (2022) who opined that regardless the roll out of Competency Based Curriculum in the year 2018, most of the secondary school teachers were not conversant with the concept of Competency Based Curriculum, and hence lacked the pedagogical competencies to implement it.

The lack of the necessary pedagogical competencies by the secondary school teachers to implement the Competency Based Curriculum is a threat to successful realization of the vision of changing from the Content Based Curriculum to the Competency Based Curriculum, notwithstanding that a lot of resources have been used. Farrant (2006) notes that in Competency Based Curriculum, the teacher do not need to have outstanding ability in everything they have to do, but they do require a general competence to save them from embarrassing failure in the skills their learners must perform. This is consistent with the views of Maina (2023) who stated that teachers play a critical role in implementation and assessment of curriculum hence equipping them with appropriate pedagogical skills is critical.

Conclusion and Recommendations

From the findings of this study, it is clear that most secondary school teachers in Kenya lack pedagogical competencies necessary for effective implementation of Competency Based Curriculum. Most of them have undergone a one week in - service course popularly known as retooling. The study concludes that the training should be well structured with clear guidelines and not hurriedly done. The main focus of the training should be on all the major aspects of Competency Based Curriculum ranging from instruction practices to assessment. Also research should be conducted to assess how prepared different categories of secondary schools are prepared to implement the Competency Based Curriculum.

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